Published in *Edutopia* as Staff Blog October 2011
Part 3 of 6 part series about:

Brain-based Teaching Strategies to Build Executive Function in Students

By Judy Willis MD
10/5/11

For young brains to retain information, they need to apply it. Information learned by rote memorization will not enter the sturdy long-term neural networks in the pre-frontal cortex (PFC) unless students have the opportunity to actively recognize relationships to their prior knowledge and/or apply new learning to new situations.

Here are some teaching strategies to help build executive function in your students.

1) Provide Opportunities to Apply Learning

When you provide students with opportunities to apply learning -- especially through authentic, personally meaningful activities -- and then provide formative assessments and feedback throughout a unit, facts move from rote memory to become part of the memory bank.

These opportunities activate the isolated small neural networks of facts or procedures, which then undergo the cellular changes of neuroplasticity that link them into larger neural circuits of related information. These extensive neural circuits integrate new information when they are a) simultaneously activated and b) when they recognize patterns in common.

The expanding of related categories of information (Piaget's schema) through executive function activities will consolidate learning into networks. These networks can be activated when students are prompted to use new learning to solve problems or create new products. This is the transfer process that further promotes network activation with the resulting neuroplasticity to construct long-term memory. Without these opportunities for strengthening, any memories learned by rote are simply pruned away from disuse after the test.

2) Introduce Activities to Support Developing Executive Function

Students need to be explicitly taught and given opportunities to practice using executive functions such as how to learn, study, organize, prioritize, review, and actively participate in class. Activities that can support executive function network development include comparing and contrasting, giving new examples of a concept, spiraled curriculum, group collaboration, open-ended discussions. Additionally, executive function is developed when students summarize and symbolize new learning into new formats, such as through the arts or writing across the curriculum. (See The Brain-Based Benefits of Writing for Math and Science Learning.)

Authentic, student-centered activities, projects, and discussions will give students the opportunity to do the following:

- Make predictions
- Solve a variety of types of problems
- Pursue inquiries
- Analyze what information they need
- Consider how to acquire any skills or knowledge they lack to reach desirable goals

This type of student-prompted information and skill seeking strengthens students' attitude about the value of learning. When motivated to solve problems that are personally meaningful, students apply effort, collaborate successfully, ask questions, revise hypotheses, redo work, and seek the foundational knowledge you need them to learn. And they do this because they *want* to know what you *have* to teach.

When students acquire desired facts, skills, or procedures to achieve authentic, valued goals, the information has a template (neural circuit) to which it can link. Foundational knowledge is not isolated. Learning is consolidated into related patterns, connected in neural networks of long-term conceptual memory, and available for retrieval and transfer to solve future problems and investigate new ideas.

3) Model Higher Thinking Skills

In planning instruction, consider how and when you will model these higher thinking skills and provide opportunities for students to activate their developing executive function networks throughout the learning process.

Judgment

This executive function, when developed, promotes a student's ability to monitor the accuracy of his or her work, and to analyze the validity of information heard or read. Techniques such as estimation with feedback and adjustment, editing and revising one's own written work using rubric guidance, or evaluating websites using criteria to separate fact from opinion are examples of promoting the development of networks for judgment.

Prioritizing

This executive function helps students to separate low relevance details from the main ideas of a text or topic of study. Prioritizing is the executive function that guides students when they plan an essay, select information to include in notes, and evaluate word problems in math for the relevant data. Prioritizing also promotes one's ability to combine separate facts into a broader concept with recognition of degrees of relevance and relatedness.

Prioritizing networks will be activated as you guide students to organize, plan ahead, keep records of their most successful strategies, and use this information to make the most efficient use of their time.

Setting Goals, Providing Self-feedback and Monitoring Progress

Until students fully develop these pre-frontal cortex (PFC) executive functions, they are limited in their capacity to set and stick to realistic and manageable goals. As they develop these executive functions, they need guidance to recognize their incremental progress they make as they apply effort towards their larger goals. This is part of the "video game model" described in my previous blog, How to Plan Instruction Using the Video Game Model.

Prior Knowledge Activation and Transfer Opportunities

Plan activities where students can relate what they know from past experiences to their current learning and tie it to the larger concept. When you provide learning experiences by which students can apply new learning to multiple applications, you promote the neural construction of larger conceptual networks that make the new information a valued tool and part of long-term memory. An example would be the use of the rules of magnetism and geographic facts to discover how to use a compass.

Metacognition

Taking the time to plan learning contexts that are personally desirable 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 adequate activation of prior knowledge and mental manipulation. When you plan for and teach with mental manipulation for executive function in mind, your students will come to recognize their own changing attitudes and achievements. When students begin to experience and comment on these insights, consider sharing the processes you used to create the instruction that they respond to positively. Describe your mental manipulation, challenges, and the executive functions you used to create something new as you found the authentic active learning opportunities that activated the students' interest, perseverance, and higher levels of thinking.

These are teachable moments to promote student metacognition, where they can recognize their abilities to extend their horizons and focus beyond simply getting by with satisfactory grades. Help them make the connection that they can build their executive function of long-term goal-directed behavior when they choose to review and revise their work, even when it has been completed, rather than to be satisfied with "getting it done." Your input helps students see the link between taking responsibility for class participation, proactive collaboration, and setting high self-standards for all classwork and homework such that they can say, "I did all I could to do my best."

Making the Case for Investing in Executive Functions

As the caretaker of your students' brains during the years of rapid prefrontal cortex development, you should consider how you can activate and guide the development of your students' greatest resources -- strong executive functions. The opportunities you provide for mental manipulations using these critical neural networks are precious gifts. These tools will empower them to achieve their highest potentials and greatest satisfaction as they inherit the challenges and opportunities of the 21st century.

Time Well Spent

Planning instruction and teaching units that activate executive function processing takes teacher and student time -- and it's time that's already severely taxed. However, that time is regained because the learning in these units is successfully retained in long-term memory and re-teaching time is vastly reduced.

The first ones to notice the brain changes of learning that is mentally manipulated through executive functions may be your students. Beyond the increased engagement they experience through active learning, they will find it takes less time to review for tests beyond the unit test, such as a final exam. You'll find that students, who previously didn't have the growth mindset needed to stay with challenging lessons when understanding was not instantaneous, now persevere. But the "payoff" will be especially powerful when their teachers ask you the next year, "What did you do?? The students from your class actually remember what they learned last year."

Now think what this means in terms of time. If you didn't have to re-teach "last year's material" you'd be getting all those weeks of time at the beginning of each unit. Thus the a school that promotes instruction for the activation that is needed for development of strong tracts of executive function and long-term memory will build better brains for its students. These brains will retain learning in sustained, transferable, and retrievable long-term memory. Instead of the re-teaching previously required before new instruction can start, there will be weeks of "found time."

Take Care of Yourself

In the professional learning communities I observe when I travel throughout the country I see dedicated professionals who chose to become educators because of their dedication to making a difference for all students. Teachers are drawn to their career choices for admirable reasons. (We know it is not for the big bucks or having the work day "end at 3.") Creativity, imagination, perseverance, and motivation endure in the educators I meet, even in these times of teacher blame and over-packed curriculum.

It is critical that we prepare today's students with the executive function skill sets they will need for success in the globalized, information explosive, and ever-expanding technologically progressive 21st century. Just as certain is the continued accountability by educators to teach the over-packed curriculum in the existing standards.

Please take care of yourselves. Take the time to acknowledge any progress toward your goals. What I'm advocating regarding more activation of students' executive function networks may not provide you with immediate evidence of the changes you are promoting in their brains -- although it is highly likely you'll find behavior "management" problems decrease as engagement increases. You'll have to use your executive function of resisting immediate gratification (such as eight hours of sleep or a weekend without prep work) to persevere on the long-term goal of setting in motion the birth of dendrites and synapses to give your students the best chance of achieving their highest potentials of professional, social, and emotional joy, and success in the years to come.

Thank you for what you do!

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Neuroscience Insights from Video Game Model for Motivation and Perseverance in the Classroom

The popularity of video games is not the enemy of children's successful and motivated learning, but rather a model for best strategies to apply to all learning. Games insert players at *their achievable challenge level* and reward player effort and practice with acknowledgement of *incremental goal progress*, not just final product. The same *brain processes and neurochemicals* that compel children to skip meals and sleep to play video games can be activated by parents and teachers to increase their brains' motivation to be attentive class participants, do homework with focus, and even reverse school negativity to reignite the joy of learning.

Dopamine-Pleasure Rewards Achievement

The fuel that compels computer game perseverance and can also motivate academic or other skill learning is the brain chemical, *dopamine*. Dopamine is a neurotransmitter that, when released in higher than usual amounts, goes beyond the synapse and flows to other regions of the brain producing a powerful pleasure response.

This is a deep satisfaction, such as quenching a long thirst. This increased release of dopamine is the brain's reward response to achievement of a challenge - *intrinsic reinforcement*. After making a prediction, choice, or action, and receiving feedback that it was correct, the reward from the release of dopamine prompts the brain want to repeat that action and receive more dopamine-pleasure.

During the play of computer games with progressing levels of challenge, the progressive achievement feedback, such as getting to a higher level of play, is the feedback to the brain that it succeeded in the challenge and made the correct response. These bursts of pleasure drive the brain to seek the next burst, so gamers upon reaching the next level want to continue on playing, even through increasing challenge and frequent failure. Actually if the new level of play doesn't pose new challenge, the gamer loses interest as the dopamine-reward response will not take place if there is no new task or skill to master.

Dopamine & Cocaine Addiction

Compulsive computer game playing, gambling, and risk taking can result from excessive craving of the dopamine pleasure, especially when people are depressed or do not have other sources of pleasurable experiences in their lives.

The addiction of cocaine is the direct result of dopamine increase. Cocaine would have essentially no euphoric effect if it were not for dopamine. Cocaine use is associated with a "high" because it increases the brain's levels of its own dopamine. Because cocaine elevates dopamine to very high levels, the euphoria can be intense, but when the dopamine plunges to below normal as the effects of the drug wear off, the response of an addict is to seek relief from that low by using more cocaine. However, the dopamine takes time to be restored to the storage areas, so repeated use of the cocaine brings less and less of the desired response and to regain that initial high an addict will use the drug at more frequent intervals and/or greater amounts.

Dopamine and Survival

The survival benefit of the dopamine-reward system for mammals is rewarding a successful or beneficial behavior or response when it is chosen so it will be repeated the next time a similar choice or response is needed. For animal survival, the dopamine-release from good predictions promotes life or species-sustaining choices and behaviors, such as remembering that scent that was chosen from other "choices" that lead to a mate or a meal and choosing that scent the next time it presents.

Dopamine Motivates Learning Without the Video Game

The human brain, much like that of most mammals, has hardwired physiological responses that had survival value at some point in evolutionary progression. The dopamine-reward system is fueled by the brain's recognition of making a successful prediction, choice, or behavioral response.

The release of the dopamine surge is a reward because it is a response to choices or the outcome of a behavior or response when the person or animal is not already certain of success. It requires the uncertainty of making a prediction or choice that activates the dopamine-reward cycle release (nucleus accumbens) to respond to the result of that prediction. When there is no challenge of making an accurate choice, because the outcome or answer is already known, such as adding 1 + 1 when a child is certain that the answer is 2, there is no activation of the dopamine-reward release when that answer is given. This lack of challenge disengages children's interest when they are required to drill repeatedly when they have already fully mastered the learning.

In addition to the challenge required for the dopamine reward pleasure response, the brain must be *aware* that it correctly solved a problem, such as figuring out a correct response in the video game, correctly answering a challenging question, or achieving the sequence of movements needed to play a song on the piano or swing a baseball bat to hit a home run. This is why children are especially motivated to keep playing video games because they give *frequent feedback* about the accuracy of their choices – hitting targets, choosing the correct move in a maze, such as accumulating points and progression to higher game levels.

Awareness of Incremental Goal Progress

In a sequential, multilevel video game, feedback of progress is ongoing, such as accumulating points, visual tokens, or celebratory sound effects. The dopamine-pleasure reward is in response to the player achieving a challenge, solution, sequence, etc. that allows him to progress to the next and more challenging game task.

When the brain receives the feedback that this progress has been made, it reinforces the memory networks that were used to predict the success. Through a feedback system, that neuronal circuit becomes stronger and more durable. In other words, memory of the mental or physical response used to achieve the dopamine reward is reinforced.

It may seem counter-intuitive to think that children would consider harder work a reward for a predicting a correct response on a homework problem, test, or physical maneuver. Yet, that is just what the video game playing brain seeks after experiencing the pleasure of reaching a higher level in the game. A computer game doesn't hand out cash, toys, or even hugs. The motivation to persevere and pursue greater challenge at the next level is the brain seeking another surge of dopamine -- the fuel of *intrinsic reinforcement.*

Helping Motivate Children through Achievable Challenge

Imagine you are placed in the following scenarios:

- You are dropped off at the top of a ski resort's steepest run when you've only had experience on the beginner slopes.
- You have to spend your day on the bunny hill when you're an expert skier.
- You play a game of darts with the target two feet away.
- You play a game of darts with the target 200 feet away.
- You are a 3rd grade student trying to do a crossword puzzle designed for experts.
- You are an adult trying to do a crossword puzzle designed for children.

In each of these extremes, you would feel either frustrated or bored, depending on your level of achievable challenge. Reflecting on those personal feelings helps us understand what it feels like for children who do not have the background understanding to understand the new topics the class is learning or who have already mastered the current material and are bored by having to listen to lessons that don't introduce new information for them.

Video games that are designed for progression to appropriate levels based on player mastery all each player to participate at their individualized achievable challenge level. This a*chievable challenge* is key to motivating perseverance in academics, sports, musical instruments and other forms of learning that require effort and practice.

For other learning tasks to have the same motivating effects ad the video game model, the opportunities for progression must be individualized for maximum benefit. The levels vary at different times for different children and no two children, even at the same age, will always progress at the same rate for all new learning. However, we've learned from seeing the powerful compulsion that pulls children to play video games, is good reason for parents and educators to do their best to individualize learning progression so there is always achievable challenge.

Video games with levels of play allow the player to progress quickly through levels when the gamer already has the skill needed and play at levels where the challenge is just right. When instruction and practice requirements for children in other learning experiences are as compelling as video games, children persevere when there is new information to be learned and practice that is at the child's "just right" level of challenge. It is only when the brain perceives a reasonable possibility of success for achieving a desirable goal that it invests the effort to work through a challenge.

This means the child has expectation of possible success without the off-putting boredom causes her to lose interest because she has already mastered the required skill or knowledge so there are no "predictions" made – and no chance of prediction-reward.

The task must also not be perceived as so difficult that a child believes she has no chance of success. fMRI and cognitive studies reveal that the brain "evaluates" the probability of effort resulting in success before expending the cognitive effort in solving mental problems. If the challenge seems too high, or children have developed a *fixed mindset* related past failures, the brain is not likely to expend the effort needed to achieve the challenge.

The Video Game Model Sustains Perseverance and Desire for Increasing Challenge in All Learning

The motivating video games place players at their individualized achievable challenge levels. When children have opportunities to participate in learning challenges at their individualized achievable challenge level, their brains invest more effort to the task and are more responsive to feedback and they reach levels of engagement much like the focus and perseverance we see when they play their video games.

This type of just right challenge found in video games keeps the brain engaged because the dopamine surge is perceived to be within reach if effort and practice are sustained. This means that children need to participate in learning at their individualized challenge levels and not at a set pace of whole class instruction that is perceived as unachievable or as too easy (the information is already known so there is none of the prediction that the brain needs to activate the dopamine reward system).

Frequent Feedback Sustains Goal Effort

Challenge is a powerful motivator when students take on tasks they find meaningful and, through their efforts and perseverance, succeed. As Mark Twain wrote, "The secret of getting started is breaking your complex overwhelming tasks into small manageable tasks, and then starting on the first one."

Good games give players opportunities for experiencing intrinsic reward at frequent intervals, when they apply the effort and practice the specific skills they need to get to the next level. The games do not require mastery of all tasks and the completion of the whole game before giving the brain the feedback for dopamine boosts of satisfaction. The dopamine release comes each time the game provides feedback that the player's actions or responses are correct. The player gains points or tokens for small incremental progress and ultimately the powerful feedback of the success of progressing to the next level. This is when players seek "harder work". To keep the pleasure of intrinsic satisfaction going, the brain needs a higher level of challenge, because staying at a level once mastery is achieved doesn't release the dopamine.

Gamers reportedly make errors 80% of the time, but the most compelling games give hints, cues, and other feedback so players' brains have enough expectation of dopamine reward to persevere. These programs provide frequent and immediate corrective and progress-acknowledging feedback that allow the players to recognize their incremental progress, as they build skills progressively.

The academic learning model can follow suit.

As one teacher wrote, " This information has definitely been an eye opener as to the ways children and even adults still continue to learn. I still play video games now and then and as you were describing how students feel when they see that affirmation that they are doing well I realized that I still continue to look for it too when I play. You discussed that each level is like a child's own personal challenge level and that they want to strive to be better and do better than what they have set before them so they begin to set goals. I believe that incorporating this kind of theory will really help kids to want to challenge themselves to want to learn more."

Bringing Incremental Progress Recognition to the Classroom... and Beyond

In the classroom, the video model can be achieved with timely, corrective feedback so students recognize incorrect foundational knowledge and then have opportunities to strengthen the correct new memory circuits through practice and application. However, individualized instruction, assignments, and feedback, that allow students to consistently work at their individualized achievable challenge levels, are time-consuming processes not possible for teachers to consistently provide all students.

What we can do is be aware of the reason the brain is so responsive to video game play and keep achievable challenge and incremental progress feedback in mind when planning units of instruction. One way to help each student sustain motivation and effort is to shift progress recognition to students themselves. This can be done by having students use a variety of methods of recording their own progress toward individualized goals. Through brief conferences, goals can be mutually agreed upon, such as number of pages read a week (with comprehension accountability), progression to the next level of the multiplication tables, or achievement of a higher level on a rubric for writing an essay. Free bar graphs downloaded from the Internet can be filled in by students as they record and see evidence of their incremental goal progress. In contrast to the system of recognition delayed until a final product is completed, graphing reveals the incremental progress evidence throughout the learning process. I've found that for students who have lost confidence to the point of not wanting to risk more failure, it is helpful to start the effort-to-progress record keeping and graphing with something they enjoy, such as shooting foul shots or computer keyboarding speed and accuracy.

Examples of Using Incremental Progress for Learning Motivation

The computer game model correlates to using achievable, incremental, challenge, with goal-progress recognition. To achieve the motivating goal-progress recognition of computer games, children can be guided based on current ability to incremental progress achievable goals on the way to greater goals, such as progressing from reading 10 to reading 15 pages a night.

If the class assignment is to read 20 pages a night, but that would be an unachievable challenge for a child, by mutual agreement, a more achievable goal can be set at 15, such that he is willing to apply effort because the goal seems in reach. He can keep a record of the pages read, and see on a bar graph or just from the increase in total pages read in a week, that he has reached his goal. Even though the 15 pages is still not enough to meet the class requirement or his ultimate goal will not mean getting an "A", he will have the intrinsic motivation of recognizing goal achievement. He's gotten to the next level of the video game. He may not be at level 10, but he's gone from level 3 to 4, and that will keep him "playing the game" and with perseverance as the continued feedback about incremental progress sends dopamine to sustain his effort.

Effort-Goal Graphs of Incremental Progress

Helping children keep records and make (or fill in bar graphs such as those you can get or make on websites such as **http://www.onlinecharttool.com**)of their ongoing progress can support them with a visual model similar to the video game feedback so they see that their efforts do lead to success and they have the power to build and build their achievement level. Creating progress graphs shows children their incremental goal progress in a concrete way to mimic the incremental progress feedback provided by getting to the next level on a computer game. The additional benefit is to show them that their effort toward their goal results in progress.

The brain's prefrontal cortex (PFC), where the brain develops the executive functions, such as the ability to recognize the effort to progress correlation and to resist immediate gratification to achieve long-term goals is the last part of the brain to mature, in a process that continues well into the 20s. What seems obvious to adults is not recognized as an effort to goal-progress correlation by young brains without explicit evidence.

Just as children can play video games for hours, even though gamers "fail" or make the incorrect response about 80% of the time, the same can occur with other learning when their incremental progress is recognized. As they eventually master the skill needed to reach the next level and get that pleasure-reward the dopamine system provides, they will enjoy the challenge of the academic work much like they do the challenge of the computer game......ah the building of resilience!

Teachers Recognize the Value of the Video Game Model to Encourage Children to Invest Effort

When I explain the video game model to teachers, they recognize the value of teaching that gives students opportunities to make predictions and receive frequent feedback as to their accuracy. Comments from teachers follow.

Said one teacher, "I have always believed that video games do no good to a child's development. I now have a better insight into the benefits of the video game *model* on children's self esteem. I never would have thought to compare the rewards children receive when playing a game, to how teachers should acknowledge students' progress along the way to larger goals. I now understand that the reward of frequent appraisal and feedback of progress is enough to encourage students to persevere in their learning efforts."

Another teacher had a similar response when she said, "I was surprised to learn about the information of how we can use the principles of the video game model as helpful in our classrooms. We can learn how to use video game model in the classroom to encourage students to put effort into their work if we plan instruction so they see their small steps of progress along the way."

"I now see that for kids the dopamine effect is a gratifying stimulus that should be transferred into the school setting, by providing the students with challenges without the fear of being judged. Video games do not discourage the player, but encourage the player perseverance and we can do that with other learning."

"Children spend hours playing video games not realizing they are actually working. If this could be applied to the classroom, students would have greater opportunities for success. It is really exciting to hear something positive about video games."

" It's great to find out why kids like video games so much and then come up with ways to apply that information to help kids in school. The idea that children will not only want more challenges, but also crave them is exhilarating. Children would learn so much more if they could take that motivation they have for video games and use it for school and learning."

"The achievable challenge level is a great point that I now believe every child goes through in the learning process; thus, the process of learning with a positive attitude can be made to be the same in classrooms as in video games."

"I never thought to compare learning to playing video games but it makes complete sense! If children understand the concept of starting at the easy level and working their way to the hard level, they can apply the same thinking to learning something new. This concept could be used with other activities like sports. When you begin to learn to play baseball you may not be that good at it. However, with more practice you can get better and eventually master the skill. Teachers and coaches and parents should make sure they give children opportunities unique to their learning experience so they can achieve individualized goals. They should provide effective feedback to keep them motivated and learn how to persevere through tough challenges in learning and life. We can't do that with worksheets!"

The Neurology of Learning Empowers Teachers and Students

By Judy Willis, M.D., M.Ed

Throughout my ten years of teaching, after a career as a neurologist, I have been most profoundly moved when I see students change from expecting failure to recognizing they hold the tools to their success. The empowerment they gain from knowing the science of learning changes their lives. With each strategy they choose and apply with focused, intentional effort, to achieve a positive outcome increases their perseverance to sustain effort through inevitable setbacks and progress on to higher and higher challenge.

When parents and educators have background knowledge of the neurology of learning, they can apply more "brain-favorable" approaches to guiding children for academic and classroom success, increase attentive class participation, and motivate responsible, best quality homework. From playing games to actively focusing in class or when doing homework, children apply more effort when parents and educators teach them about neuroplasticity and how they can change their brains, intelligence, school, social, and emotional success by participation and practice because these are what cause them to grow stronger brain circuits and long-term memory.

I can think of no other scientific knowledge that is as life changing as children knowing what they can do to change their brains and reach never before believed potentials. When children understand how their most powerful tool operates, the wisdom brings a new sense of control and optimism for their futures.

Having taught my students a "Brain Owner's Manual" in elementary and middle school, I observed students with negativity and disconnection from school become more confident and apply more effort because they understood they could change their brains. When children know that practice makes permanent when it comes to memory circuits in their brain, the enjoy renewed optimism and regain the joy of learning they once had when they were younger. Encourage children to and draw new dendrites and synapses on their brain "self-portraits" to represent the way they changed their brains by participating and listening in class, doing homework, practicing an instrument, or memorizing a poem. These resilient children are the ones who will become lifelong learners with the adaptability, motivation, and desire to apply the necessary effort, to solve the problems they will inherit and more importantly, to recognize and follow through with the phenomenal opportunities that will be available to them in the 21st century.

Children Who Learn Their Brain Owner's Reverse Expectations of Failure

Children who have lost confidence in their abilities because experienced repeated failures stop applying effort – whether to sports, musical instruments or studying. Understanding how their brains store and retrieves memory, the influence of sleep and diet on their brain chemicals that power their memory, and finding out practice is what makes school information or the best way to kick a soccer ball stick in their brains is life changing for all children.

Children empowered by understanding the basics of how the brain learns and remembers, have the most powerful keys to success in school, careers, relationships, and every aspect of life. With this special knowledge comes the ability and desire to use the strategies most consistent with the neuroscience of learning and memory. That is why I wrote articles for parents and teachers to access for free to help them explain the brain to children. The children to whom I taught my Brain Owner's Manuals loved learning about their brains and their renewed motivation was evident in the increased effort they applied to study and review because they knew that each time the used a memory circuit it became stronger and more permanent. How could the resist doing a bit more review now so they would never again have to relearn the dreaded least common denominator rules!

Genius is more than Genes

Through my background in neuroscience research about the brain changes that accompany learning, and my duel careers as both classroom teacher and adult and child neurologist, I've known for almost 20 years about the power of the brain to change itself after injury through neuroplasticity.

Neuroplasticity, we now know, does more than create new pathways around damaged brain tissue where healthy cells take on the jobs once carried out by their neighbors. Every experience, thought, and emotion is the result of brain cells communicating with new neighbors or through existing circuits that grow stronger each time they communicate. The electrical activation that carries the communications is the stimulus for the brain to make these networks stronger by growing new connections (dendrites and synapses) and putting down more layers of insulation (myelin) around message carrying axons.

When you explain this to children you don't need to use complex textbooks or spend hundreds of dollars on commercial products. All it takes reading the four or five pages that put this neuroscience of learning into child-friendly words and examples, such as "You already know that your muscles become stronger and larger when you exercise, but did you know that exercising your brain makes it grow also." You can then go to free websites such as http://faculty.washington.edu/chudler/introb.html or the BBC Science & Nature website with interactive brain illustrations at http://www.bbc.co.uk/science/humanbody/body/factfiles/brain/brain.shtml

Once your child or student starts exploring these sites, they become as enthralled as they do playing video games because they see a tool they actually own as it processes information and grows more powerful with use!

This is when children who believed that they had limits on their intelligence because of their genetics and could never be great at a sport because they were not born "natural athletes" realize these are myths. What you can teach them in an hour or so is that when they practice and review physically or mentally they take control of their intelligence or skills.

Older children who believe that the genes they inherit before birth set the limits of their abilities or intelligence, develop a new mindset and motivation when they learn that even IQ is not under the dominant control of genetics. We now know that parts of genes (alleles) are turned on or off based on environmental influences, many of which are within the brain owner's control.

Knowing how their brains work gives them the scientific understanding. When children then see the actual brain scans change and grow denser as more and stronger connections grow in the parts of the brain subjects use to practice new skills such as juggling, playing piano, or studying street maps, they are ready to take charge of their own brains.

When you download the "Brain Owner's Manual" I wrote for parents and teachers, and follow the links to the free websites with the interactive illustrations, you give children a gift that costs you nothing but becomes their magic genie. It is not quite as effortless for them as making a wish to make it so, but they do see that practice stimulates neurons to build stronger communication systems (*neurons that wire together wire together* and *practice makes permanent*). Their wishes are indeed the commands the issue their brains. Their part of the deal is to get the electricity flowing in their brain circuits by practicing whatever it is they want to build up in their own brains.

For Children Who Need a Booster Engine to Start Construction, You Can Promote an Emotional Tune-Up

Application of brain research to learning reveals that superior learning takes place when learning experiences are enjoyable and relevant to children's' lives, interests, and experiences. We've seen through brain neuroimaging, such as PET scans and fMRI scans, the influence of one's emotional state upon learning, judgment, memory storage, and information retrieval and transfer.

Memory construction is impacted negatively when learning takes place during emotional states of fear, anxiety, high stress, or depression. There is a switching station in the emotional brain (the amygdala in the limbic system) that determines if information coming into the brain is sent up to the highest thinking, *reflective*, prefrontal cortex or down to the *reactive,* involuntary lower brain where conceptual, retrievable memories are not constructed and the behavioral responses of fight/flight/freeze are the involuntary reactions.

Being embarrassed, confused, or feeling that all the others understand things that a confuse them, ambushes new information from even entering the long-term memory networks of the higher brain. Today's overly packed curriculum demands work against successful learning. When children are stressed, bored, frustrated, or feel helpless or confused by classroom instruction or reading, the input is sent down to their reactive lower brains active learning stops.

Understanding the influence of emotion on successful brain processing empowers children with the knowledge that past failures are not predictions of their future potential. Children who have background knowledge about their brains realize what external factors limited their success in the past. When you explain that their emotional state before and during learning influences successful memory they are receptive to suggestions supported by neuroscience about healthy diets, exercise, and sleep.

A very helpful way to help children believe in their abilities to change their brains and intelligence is by helping them recognize their *incremental progress* toward their goal. You can link to the website that lets you or the child keep track of time spent on a measurable learning or performance task results in more and more success. I've had my students start with graphing time spent practicing basketball free throws or learning to keyboard and help them learn how to record time spent relative to accurate throws or keyboarding speed/accuracy. What seems so obvious to adults is a revelation to children and teens. They haven't yet developed the prefrontal cortex "executive function" networks such as analysis, goal setting, or even the concept that effort toward a goal equates with progress. These networks are still maturing well into the 20s. But seeing their own effort to progress on a simple bar or line graph makes them recognize the real value of practice. You may have been telling students or your children these things for years, but until they see for themselves how effort and practice really make them better on the graph they make, that is when they make the transition from basketball shots to practicing math tables or reviewing vocabulary words becomes neuro-***logical*** and worthy of the effort they will now apply. All because they know what will happen in their brains and the success that is in their power to achieve.

could not scale related to their effort, reverses negativity and renews motivation. This results in a transformation from a *fixed* to a *growth mindset*. Using additional strategies to promote growth mindsets, such as metacognition (reflection about what strategies they used for success), brain-empowered students know how to make conditions personally favorable for learning and test taking. These students retake the drivers' seats to reach their goals and develop the adaptive skills they need for their brains to work at maximal efficiency on tests, on the job, or when making social and emotional choices.

Building a Better Brain is Within Every Student's Power

Rejuvenation of optimism continues as students learn about their brains' essentially unlimited potential to grow in memory and intelligence (neuroplasticity). Brain wise students know that seeking and constructing patterns in new information matches the way the brain most successfully stores information.

The brain turns data from the senses into learned information by encoding it into already existing patterns (actual networks of connected brain cells each holding bits of information that interrelate based on an underlying similarity – a unifying pattern or concept). When students understand their brains' pattern construction and recognition system, they can use strategies such as activating prior knowledge, making real world and personal connections, and other pattern stimulating strategies to achieve the most effective information intake, memory construction, and information retrieval pathways of brain connections.

The system of storing information in related patterns is an evolutionary development that increases prediction accuracy to promotes survival in animals and is the basis of intelligence in humans. Neuroimaging evidence supports that the brains of animals and humans make decisions (responses to changes in their environments) based on activation of neural networks constructed over time based on the stored outcomes of previous behavioral responses (predictions). The stored memories of prediction results become the basis of more successful future predictions (from choices of emotional responses to answers on a test). These prediction networks enable the brain to recognize relationships of new situations to prior knowledge stored in networks of related information (concepts).

This research confirmed what was already recognized from cognitive psychology about the benefit of patterning tools such as concept maps and comparisons of similarities and differences. Further studies gave evidence that the retrieval of information is most effective when students know how the information is organized, especially when they choose their most successful ways of structuring new information into patterns that are most logical and memorable to them.

There is no right or wrong way to construct information into a pattern and later connect patterns into concepts. However, we do know that when information passes through the amygdala into the hippocampus (for pattern matching) when it is in a positive emotional state, the memory that subsequently forms undergoes cellular changes that make it more durable.

The benefits of patterning are undeniable and the habit is accelerated when students are encouraged to actively relate new information to positive past experiences, personal interest, and opportunities to experience the use of the new information in the context of meaningful applications. Once again linking the use of useful strategies, such as pattern matching and manipulating, are further reinforced when students have guidance to help them recognize the *incremental progress* they achieve through application of strategies, rather than defining their success or intelligence by a test or report card grade of rote memory that is far from a valid assessment of what they have learned.

Learning that Transfers to Life Success

The goal of education should be learning how to be successful beyond the classroom. With the force-feeding of overstuffed curriculum there is little classroom focus on application of new learning to new situations beyond those in which the facts are taught in a classroom. Students need to acquire the valuable life skill of *conceptual transfer*, which does not come from IQ or memorization, but rather from emotional and personal relationships to learning that transform isolated facts into conceptual knowledge.

Wiggins and McTighe often use sports analogies in their book, *The Understanding by Design Guide to Creating High-Quality Units* (in press, ASCD) to demonstrate the value of conceptual transfer by giving students opportunities to apply new learning to authentic situations. One such analogy, to demonstrate the value of the learner seeing the "big picture" and the authentic purpose for learning specific skills and knowledge, is soccer. They describe the interplay between discrete skill learning and practice (sideline drills) with opportunities to actually *use* the skills in relevant and authentic situations (playing the game). Instead of waiting until learners master all of the individual skills before letting them on the field, children have opportunities from the beginning to play the "real" game, and *then* work to refine needed skills. That same interweaving of real application opportunities to skill development makes for meaningful, effective and motivated learning occurs -- on the athletic field or in the classroom.

Students who understand the brain's system of storing information in relational patterns can use strategies of meaning making to connect new information to previously stored categories of knowledge and relate facts and skills they must memorize to goals they value – *so the brain wants to know what it has to learn.*

Using strategies that promote successful pattern recognition and matching, new information is linked into cell-to-cell networks holding "big ideas" so learning becomes conceptual instead of isolated. The integration of facts into concepts, which results from the practices of pattern building and review, promotes the neuroplasticity that connects information into usable categories (networks of connected neurons).

Students who use strategies to store information in the related patterns of concepts and repeatedly stimulate these neural networks by review and application, are the ones who take advantages of the brain's ability to expand its intelligence. Storing memories of experiences, especially the memories of how predictions turned out, is an evolutionary development that promoted survival in animals. This potential for lifelong intelligence growth is the result of the brain's ability to construct and expand memory networks based on the outcomes of each prediction (choice/behavior) it makes and to use these outcomes to modify or strengthen the neural networks used to make the prediction. Thus with each prediction, intelligence increases as seen in better and better responses to subsequent similar situations. (As a fox has more and more experiences finding dinner, its brain stores the result of each prediction to improve the success of future predictions. Ultimately the fox has the highly honed ability to predict which disturbance in the brush is likely to be a tasty bunny for dinner.)

The culmination of understanding the brain and using brain-research compatible strategies gives students greater ability and motivation to add new learning - to construct more and more accurate networks of related information (concepts) that guide better and better predictions. These are the students who will be best prepared to achieve the life goals they choose. They will they have the accumulation of learning *stored efficiently in concept networks* to make more and more accurate choices, hypotheses, and analysis. They will use their expanded intelligence far beyond animals' use of better prediction for better survival.

At the beginning, students who learn about brain-research compatible strategies will develop confidence and restore motivation as they learn to recognize their incremental progress in a challenging subject. Confidence will grow, through further successes, to the realization that their social, emotional, and academic intelligence is within their control, and their potentials are virtually limitless.

The students who build their better brains strategically now will have the powerful concept networks for more accurate, faster, and more confident predictions. Far beyond using these for survival, their human brains will expand as they construct their greater and greater intelligence. Their increasing prediction powers will start with selecting the correct answers on tests. These same brain networks will grow and ultimately guide these individuals to make the wisest choices in work and social situations, and create the most successful solutions to future problems. Society will improve and progress because these students worked to develop the knowledge, confidence, interpersonal skills, and vision to be tomorrows' revered, creative innovators.

Links to "Brain Owner's Manual" articles published in *Educational Leadership. The actual titles of the articles are noted below and the links are without charge or membership requirements*

How to Teach Students About the Brain by Judy Willis, M.D., M.Ed
http://www.radteach.com/page1/page8/page44/page44.html

What You Should Know About Your Brain by Judy Willis, M.D., M.Ed
http://www.radteach.com/page1/page8/page45/page45.html