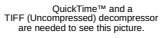
Research Based Strategies to Ignite Student Memory and Learning with RAD Teaching

Bismarck, ND
October 9, 2007

Judy Willis, MD, M.Ed
jwillisneuro@aol.com
www.RADteach.com

Goals for This Presentation

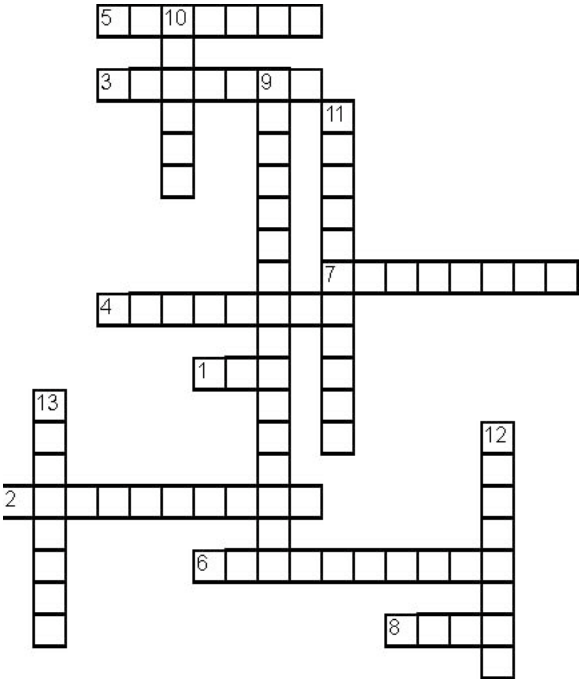
- Using advances in memory research to **IGNITE** student learning
- Turning on the brain's learning centers
- Maximizing and maintaining attention and focus
- Strategies to increase memory retrieval
- Creating Long-Term Memories by mental manipulation in the prefrontal cortex with executive function strategies



Research-Based Strategies to Ignite Student Learning and ***Brain Friendly Strategies for Inclusion Classrooms*** by Judy Willis, MD, M.Ed available on line at Amazon.com, BarnesandNobel.com, and ASCD.org. Check **website RADTeach.com** for publication dates for next two books, ***Brain-Friendly Strategies for Teaching Reading and Comprehension*** to be published 2008 by ASCD; **Brain Gifts Unwrapped:** ***Ignite the Brains of Gifted Middle School Students*** to be published 2008 Great Potentials Press

Brain Words

Brain Puzzle by Judy Willis: Complete the puzzle using the clues shown below.



ACROSS

1. Reticular activating system
2. Capacity of brain to change
3. Eliminates unused neurons
4. Emotional memory
5. Space between neurons
6. Coordination and memory
7. Mediates conscious activity
8. Extension of neuron

DOWN

9. Chemical info carrier
10. Brain cell body
11. Memory consolidation
12. Pleasure neurotransmitter
13. Integrates sensory input

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.
.

Select answers from these words:

Hippocampus, Amygdala, Neurotransmitter, Cerebellum, Thalamus, Axon, Neuron, Cerebrum, Dopamine, Pruning, Synapse, Plasticity, RAS

Discovery SCHOOL

Brain imaging has succeeded in correlating successful cognitive psychology theories with visible evidence of how the brain processes information - learning. Functional imaging (PET scans, fMRI) has been able to document the brain's metabolic and biochemical responses to strategies suggested by cognitive and educational researchers.

Types of Memory: awareness, working memory, episodic memory, rote (item or semantic memory), and relational.
Awareness: attention of the moment subconscious e.g. billboards seen while driving.
Rote Memory *(item or semantic memory)*

- Rote memory is the type of memory most frequently required in traditional classrooms and tested on most standardized tests.
- When we ask students to learn lists of unrelated facts, memorize grammar rules, historical dates, biologic genus and species, or other details of specific content with no great personal relevance, and to take most standardized tests, success is often dependent on rote memory.
- Unlike relational memory, rote memory is independent of context. When students remember information in rote memory, they do not remember the time, place, and events surrounding the learning of the information. They recall the information itself.

Working memory (procedural memory): memory of what you think you need now- the mind looks for patterns.
Fades in less than minute.
Limited capacity, approx 5-9 items so as new comes in, others go out
Chunking: Help students remember information more effectively because it is related into chunks. E.g. We chunk phone numbers and social security numbers into chunks of 3 or 4.

Working Memory to Relational Memory

Relational Memory: (milk and white paper demonstration) When new input connects with a previously stored memory the dendrites connect in new pattern sequences and the new relational memory is integrated into neuronal memory networks with previously stored memories. When either fact is later recalled or prompted, the patterned integration or association that was created will efficiently activate the related memory.

Strategies to Increase Memory Storage and Retrieval

- Memory retrieval increases with multiple and varied modes of instruction of the same material.
- Avoid one lesson fits all. Differentiated instruction: use different learning style focuses each time you teach review the material.
- Retrieval is better when students know how information is organized e.g. categories, and best when they create these categories or graphic organizers themselves
- Visual imagery: Students visualize the history event then note it using words or sketches.
- Produce a product, make models
- Role play, skits, pantomime
- Link item to be learned with positive emotional events: flash bulb memory. (We remember the song playing during our first kiss.)

- Personal involvement in learning experience - hands on and discovery learning, prediction, write on overhead projection paper to share with class, cooperative group work
- The person who does the work (thinks) LEARNS. Each time students participate in any endeavor the specific pathway of neurons is activated and neurons and their connections in this pathway are stimulated again. The more times they repeat the thought process or action, the more efficient, stronger, and less susceptible to *pruning* these brain pathways become. Eventually, only triggering the beginning of the sequence of an action or recalling first part of a set of data, will result in the remaining pieces following in sequence. Examples: Tying shoes, touch-typing.
- **Multisensory learning**: Stimulate multiple brain processing regions and cross-connections through multisensory lessons.
- When there are multiple pathways (cross-brain referencing) connecting to the learned material, there are several neuronal circuits connecting to the information so retrieval can occur from a variety of cues. The building of these multiple pathways by which students can access and recall the information is the reason multisensory learning and review (rehearsal) makes memories permanent and actions automatic.
- **Connect With Past Knowledge**: Help students relate the new information with data they have already acquired through personal experience or real world associations. The ***hippocampus*** takes sensory inputs and integrates them with relational or associational patterns. This binds the new information with already stored and patterned information and builds long-term relational memories.
- Students See Value of the Information: If students don't sense the information is important to them, it won't go through the *hippocampus*, become patterned into new synaptic connections ***(relational memories),*** and become long-term memory. Memories that are associated with emotional or personal meaning are most likely to become relational memories and be stored.
- Achieve maximal memory storage conditions with teaching strategies that connect with students as individual learners through their strengths and promote positive emotional states.

Prefrontal Lobe for Highest Cognition and Executive Function

- Teaching is not just the dispersing of facts. Students need to develop cognitive skills of thinking, learning, and reasoning because only then will they find personal or relevant meaning in what they are taught.
- Help students make higher-level frontal lobe connections to stimulate ***executive processing*** through metaphors (discovering relationships), graphic organizers, predictions, judgment, pair-share, and open-ended questions.
- **Open-ended, child-centered discussion strategies:** Ask questions related to the topic of study that connect the new information to things he or she is already interested in. These discussions start with questions you frame that have more than one answer and ask for opinions so there is little risk of being wrong. Give wait time before any response is permitted to build judgment and communication skills. Encourage more than one opinion (problem-solving skills, patience, creative problem solving) and ask for reasons to support the opinion.

Math: Ask how adding a row of numbers is like finding the total score using the runs scored in each baseball inning?

Grammar: Read a paragraph alone or together from which you have eliminated punctuation. Read it again with the punctuation marks in place. Discuss how the commas, periods, question marks, and exclamation points made it easier to read and understand.

Other open-ended discussion topics:

Any subject: Why might this information be useful to you someday? What people, doing what jobs might use this information? How could you use this information to build a better skateboard, advertise a product you invent, plan a party with a budget, write a book for a younger child about this topic. How might you explain this new information to a child from another country who has never seen a (fill in the lesson word here).

History: How does learning about history help people in the present?

Your example of an open-ended history question here:

_____

_____

Science: What is your favorite modern invention and how do you think it came to be invented – what did the inventor need to know or have on hand to create the final product?

Your example an open-ended science question here:

_____

_____

Literature: How are you like the character in the book? What would you do if you had his problem? Why do you think he did _____?

Your example an open-ended literature question here:

_____

_____

Mentally manipulate

- Organize – graphic organizers, *Inspiration* software
- Analogies for relational memory: White is to Snow as Blue is to Sky

  Your examples here:

  Capillaries are to arteries as _____are to _____.

  Past tense is to yesterday as _____is to _____.

- Similes: Photosynthesis for plants is like breathing and eating for people. Exercising my muscles makes me stronger like reading makes me smarter.
- Puzzlemaker.com
- Mnemonics: like HOMES for names of the Great Lakes (Huron, Ontario, Michigan, Erie, Superior) or ROYGBIV for the colors of the rainbow (red, orange, yellow, green, blue, indigo, violet).
- Mnemonic sentence for the first five US Presidents: Washington, Adams, Jefferson, Madison, Monroe. "**W**ill **a**ll **j**obs **m**ake **m**oney?"

Make up a mnemonic sentence for the five senses (see, hear, touch, smell, taste)

_____

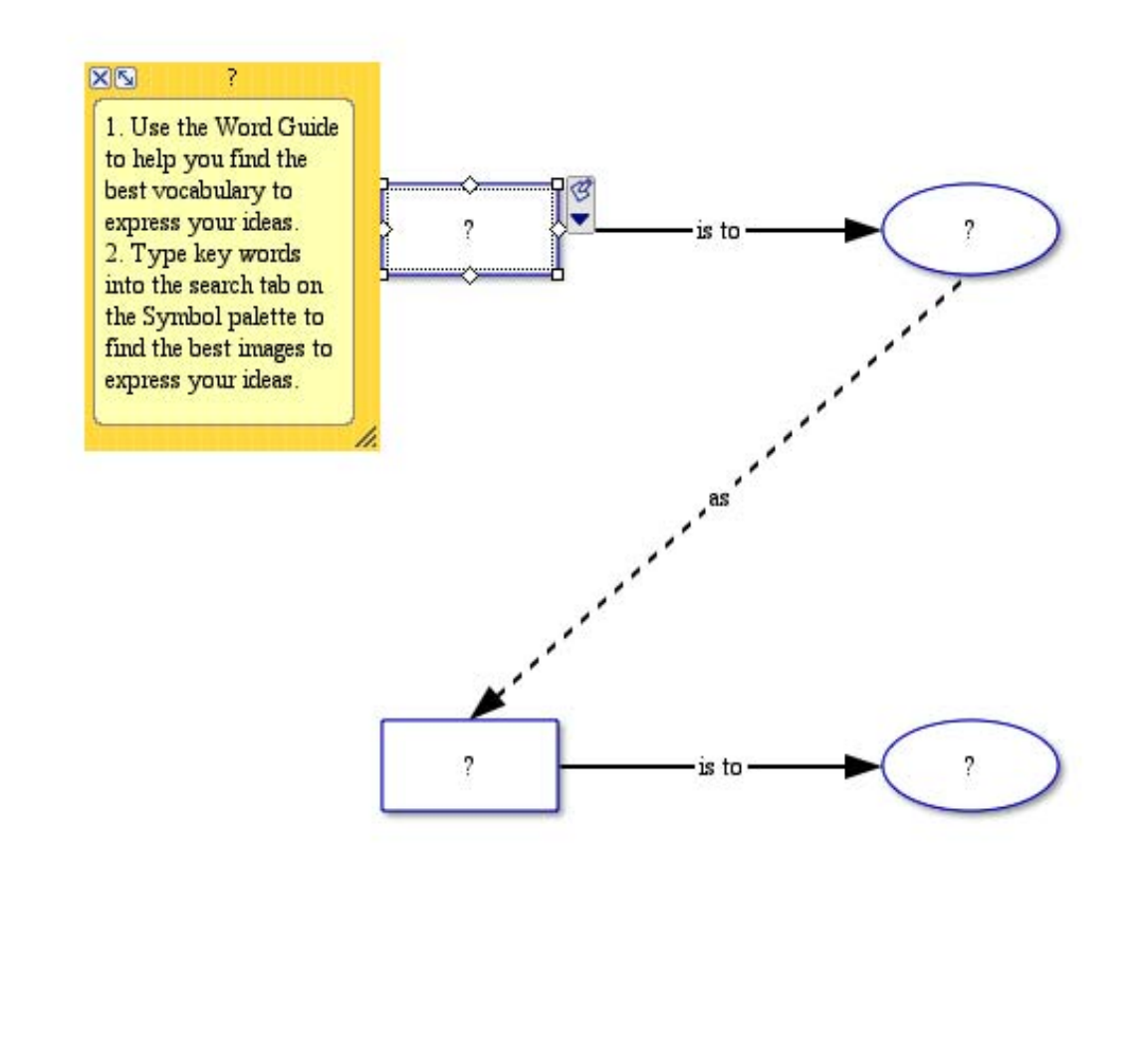
_____.

Strengthen Neuronal networks with Review Using Different Learning Strengths

Ideas from your small group or pair-share on how children with different sensory learning strengths might review vocabulary words:

Auditory (sounds)
Visual (seeing or visualizing)
Kinesthetic (movement)
Tactile (touch)
Interpersonal: such as dramatization, cooperative group activity

CREATE AN ANALOGY ABOUT LEARNING AND THE BRAIN



RAD LEARNING = **R**eticular Activating System + **A**mygdala's Affective Filter + **D**opamine

Reticular activating system: how to use changes in the environment, surprise, teachable moments, multisensory lessons to turn on the brain's attention via this filter that alerts the brain to changes and gets it primed to interact with new information and experiences.

Affective Filter in Amygdala: how to keep filter from blocking information entering the brain due to stress. How to use some stimulation such as building curiosity, positive emotional associations and prior experience to actually expedite passage through the amygdala's affective filter

Dopamine: this neurotransmitter's release is associated with pleasurable experiences and in expectation of pleasurable experiences. Its release also increases focus and executive function in the frontal lobes. Strategies to make lessons that coincide with the Dopamine-Reward Theory.

Reticular Activating System

Novelty alerts the brain to changes and gets it ready to pay attention. Examples of building novelty into learning new information: changes in voice, appearance, color, size, hat, changes in seating to standing, music, dance, picture, photo, radish!!!

Attention and Focus

- Students are criticized for not paying attention; they may just not paying attention to what their teachers think in important.
- **Emotional Charging of Memory Connections** - Conscious memory of personally meaningful and emotional experiences increases memory storage.
  Emotional Significance- Increased retention occurs when learning is linked to emotional experiences.

Strategies

- Help students remember important information by connecting the critical information to positive emotional experiences in the classroom.
- Start with global concept, prompt interest, invite engagement through prediction, KWL or KTWL
- Avoid Attention Divided: trying to listen and take notes can interfere with getting the big picture and making the connections that become memories. One brain activity at a time. If students need to take notes, stop and let them take notes. During the stop time you can answer questions.
- Focus: Students are most focused when they know they will have to do something with the information. (PET scan and reading study-the greatest brain activation when the students were told they would have to retell the story). Knowing a *think-pair-share* follows will increase active focus. Pairs write down and share one or two of their items with the whole class to validate.

Strategies to Maintain Attention and Focus

1. Color: marking key points in color results in increased recall. Write most important fact of the lesson in another color.
2. Graphic organizers as preview and overview of each lesson.

3. Physical activity every 15 minutes: Sing a song with associated movements, teach from a different part of the room so students turn their chairs.
4. Make the classroom come alive-vary bulletin boards, plants, and animals.
5. Novelty and surprise with music, costumes, speak in a different voice, hang a dollar bill, overhead optical illusions or bizarre factoids.

How could you build novelty and therefore focus attention on a study or review session about action verbs or the science concept of friction?

_____

_____

Affective Filter in Amygdala

If students are stressed information won't pass through the ***affective filter*** in the ***amygdala*****. Stress and the Amygdala's Affective Filter**. Threat, fear, or high stress can activate excessive metabolic activity in the amygdala that interferes with information entering the brain's processing, patterning, and memory circuits.

Set the Emotional Climate: be the solid force that keeps students feeling safe and the classroom community strong.

Keep stress down to prevent blocking the flow of information into the thinking parts of the brain. Common stressors in the classroom: fear of being wrong, embarrassed about reading aloud, test-taking anxiety, physical differences, language limitations, negative peer relationships, cliques, unpredictability, frustration with difficult material, boredom from lack of interest.

What classroom community builders and/or confidence building activities can you use or have you used to reduce stress from one of these classroom stressors that interferes with learning?

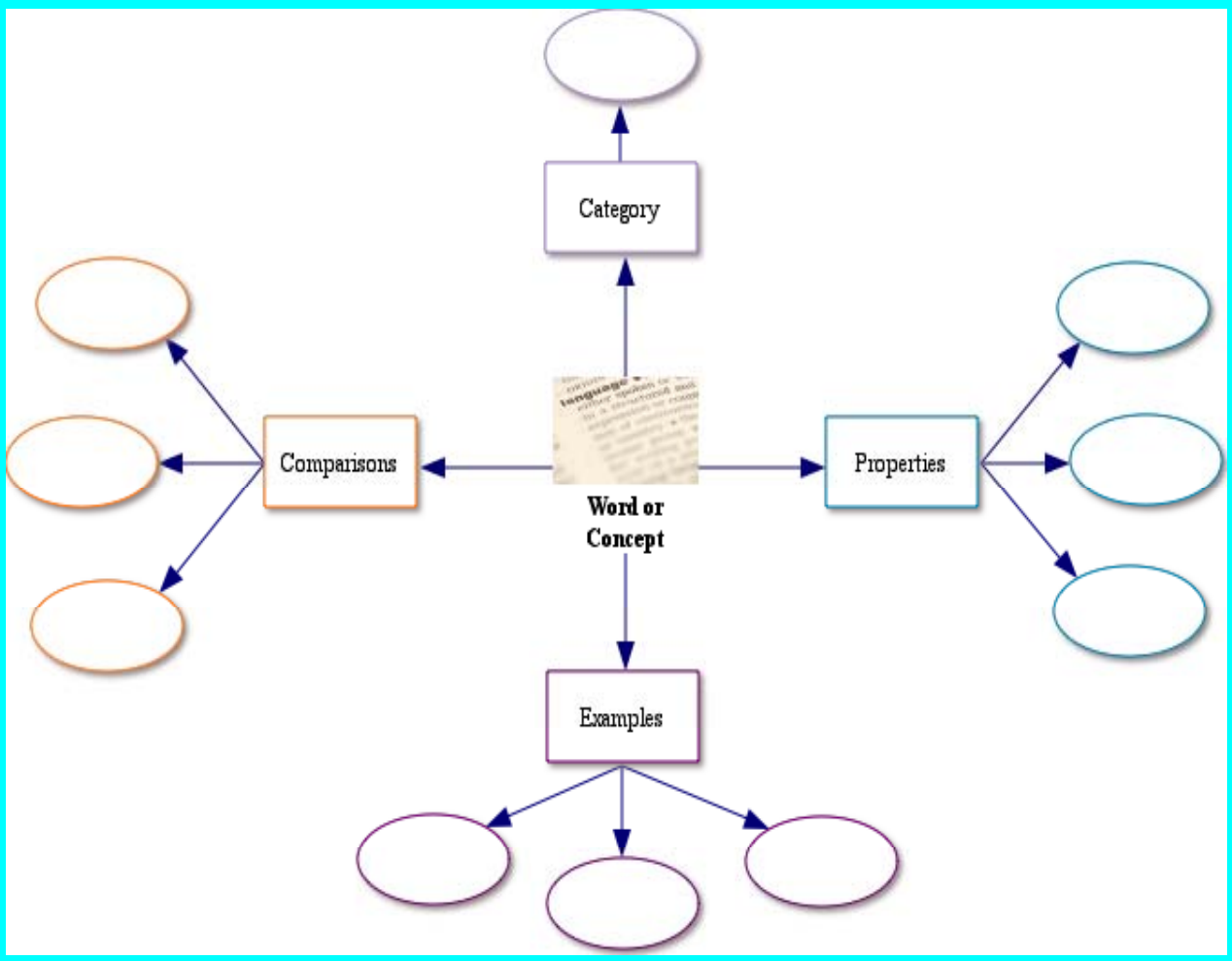
_____

_____

Teachers Set the Emotional Climate: The frontal lobes, where much of the ability to manage and control emotions is programmed, are the last part of the brain last to mature. This usually happens sometimes during adolescence, so teachers need to be the solid force that keeps students feeling safe and the classroom community strong.

- **Personalize** the information by relating it to their lives, current events, their interests, talents, or learning styles. "What does our town's debates over the building of a skateboard park have in common with the causes of the American Revolution?" e.g. Regulation (taxation) without representation.
- **Open-ended discussion strategies:** Ask a question of interest related to the topic of study that has more than one answer. Give wait time before any responses are permitted so all students have a chance to think. Invite multiple students to voice opinions without indicating if their opinions are right or wrong. It is fine to ask them for reasons to support their opinions.

CREATE A GRAPHIC ORGANIZER ABOUT THE AMYGDALA



1. In center write Amygdala
2. For Comparisons: What can you compare to the amygdala (can be an analogy)?
3. For Properties: What does the amygdala do?
4. For Examples: What can you do in your lessons to help promote information through the amygdala's affective filter?

Dopamine

This neurotransmitter's release is associated with pleasurable experiences. Dopamine release also increases focus and executive function in the frontal lobes.

Things known to increase brain levels of dopamine: movement, being read to, specific positive feedback or intrinsic satisfaction such as achievement of meaningful goals, humor, laughing, interpersonal activities

Strategies to make learning release dopamine:

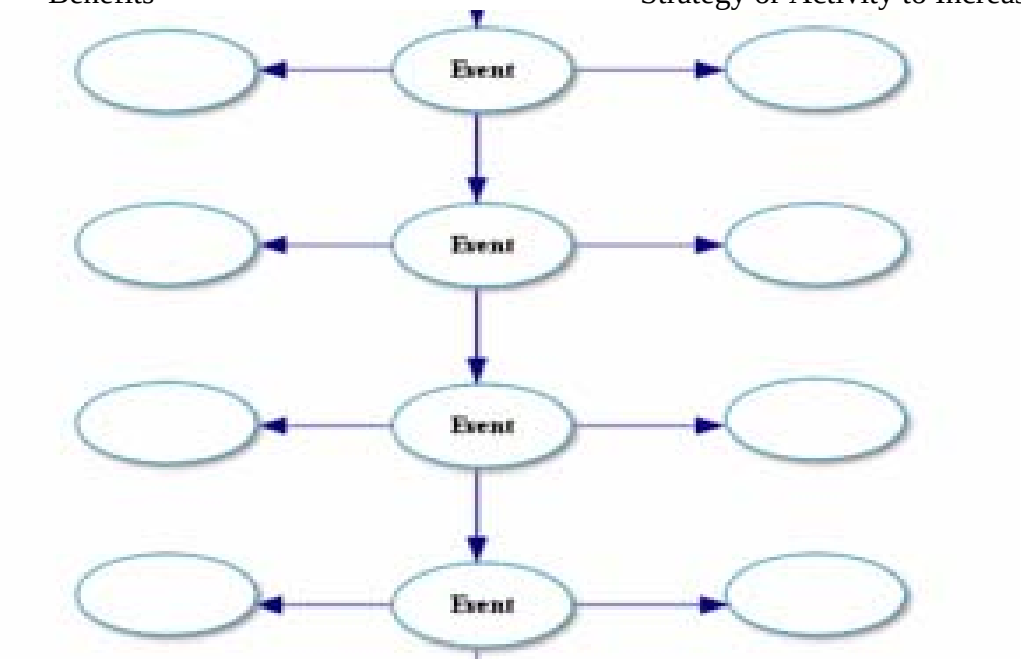
- Pantomime vocabulary words
- Put post it notes with the parts of a flowering plant on similar parts of the body e.g. head is flower, feet are roots, arms are leaves
- Ball-toss to review high points of a lesson (only if hands are turned up and eye contact is made)
- **Avoid Brain Burnout** with ***Syn-naps*** (brain breaks) needed to avoid depletion of neurotransmitters in the synapses. In this "burnout" state focus can't be maintained and new memories can't be created. Identify these overload times BEFORE they occur and have a break before that point.

Create a Graphic Organizer About Dopamine

1. In middle column write something that causes the release of dopamine
2. In the oval pointed to by the arrow, on your left next to that event, write an activity you could do using that type of event as dopamine-reward strategy
3. When possible add a comment in the oval to the left of what the potential benefit could be

DOPAMINE

Benefits Strategy or Activity to Increase Dopamine



Exit Cards are Dendrite Food for Memory Consolidation …and More

Build relational memories with "Dendrite Food"

Personalization

Connection to prior knowledge

Mental manipulation through executive function

In the last 5-10 minutes of a class or at completion of a lesson students write exit cards or write "Dendrite Food" in their notebooks in response to one or more of these prompts. (choice=dopamine, amygdala)

- Draw a picture, diagram, or graphic organizer of what you learned
- Create an analogy, write what it reminded you of, or how it fits with what you already know
- A reaction or a reflection of how something you learned relates to something in your life
- Something that made you wonder or surprised you; a new insight or discovery
- What do you predict will come next?
- How could you (or someone in a profession) use this knowledge?
- Something you are confused about or found difficult
- What you understood today that you haven't understood before
- The part of lesson that was most difficult for you and the part you enjoyed the most
- What strategy did you use to solve a problem today?
- The *"So What"* or the one thing you'll remember about today's lesson

More Uses of Exit Cards

- Feedback - how accurately the lesson was understood
- Next class, correct any misperceptions you discover
- Check one or two responses on the best cards
- Students with checks share those insights with the class as review or to promote discussion *(Lower affective filter – increased participation because confident about what they will say to the class)*
- Students listen and can add to their own notes based on their classmates' card reading
- Cards (notebook writing) become study aides
- Post on bulletin board cards that cover important information for students who were absent or for all to review.

Space to create your RAD Lesson Plan

Topic-Title

Grade Level

Concept/Topic to Teach

Standards Addressed

General Goal (s)

Specific Objectives

Required Materials

Anticipatory Set (Lead-In)

Lesson Procedures step-by-step

Learning Style Adaptations and Extensions (LD, ELL, Gifted Students, Behavior Management considerations and accommodations)

Cross-curricular Connections

Plan for Independent Practice

Closure-Reflection

Assessment based on Lesson Objectives

How I will incorporate RAD:
R (reticular activating system)

A (Affective filter in Amygdala)

D (Dopamine-Pleasure Response)

Assessment

Metacognition Post Lesson

Did You Know?

Topics for discussion with your colleagues

Through neuroimaging studies (of the amygdala, hippocampus, and the rest of the limbic system and through measurement of dopamine and other brain chemical transmitters) we now have visible evidence that there is a profound increase in long-term memory and higher order cognition when students have trust and positive feelings for teachers, and supportive classroom and school communities.

The more dopamine students have released by positive emotional experiences (in school and out) the less likely they are to seek dopamine/pleasure surges from high risk behavior of drugs, alcohol, promiscuity, risky fast driving, overeating. More sports, music, dramatics, and enjoyable learning = less high-risk behavior and suicide in teens. This brain research demonstrates that superior learning takes place when classroom experiences are enjoyable and relevant to students' lives, interests, and experiences.

Learning connected with positive emotional significance that leads to the new information being stored in long-term memory. Learning associated with strong positive emotion is retained longer, and stress/anxiety interfere with learning, so those lessons do not sustain for end of the year testing, even if students pass unit tests.

Syn-***naps***: Any pleasurable activity (singing, walk about the room and chat with friends, listening to music, having a few pages of a class book read aloud to them, or sharing jokes) used even as a brief break can give the amygdala a chance to "cool down" and the neurotransmitters time to rebuild as the students are refreshed.

Dopamine release (and the pleasure associated with it) has been found highest in school children when they are moving, laughing, interacting, being read to, feel a sense of accomplishment, and when they have choice.

Discovery Learning: Interest and discovery drive achievement. Students are more likely to remember and really understand what they learn if they find it compelling or have some part in figuring it out or discovering some part of it for themselves.

The last part of the brain to mature (through plasticity and pruning is the prefrontal lobes. Children and many teenagers do not have fully developed delayed gratification skills during their school years. The prefrontal regions are major participants in the executive function networks of judgment, prioritizing, and delayed gratification processing. This is one reason students from kindergarten through high school continue to need support and encouragement from their teachers to keep their efforts directed on long-term goal achievement.

A longitudinal study of middle schoolers noted that teachers who emphasize competitive comparisons of student ability discourage students from asking for help.

For children with attention focusing difficulties, each time they focus their attention they are activating the brain's alerting and focusing pathways. This repeated stimulation of these pathways makes the neural circuits stronger and increases their ability to actively direct their attention where it is needed.

Enthusiasm is generated when children are presented with novelty and find creative ways to explore or connect with the new material and are inspired by it. Whenever you can generate this awe and sense of wonder, your children will be pulled into the school lessons they bring home and they will be motivated to connect with the information in a meaningful way.

Students experience a greater level of understanding of concepts and ideas when they talked, explained, and argued about them with their group, instead of just passively listening to a lecture or reading a text.

Use more senses: The experiential education motto is that you learn 40% of what you hear, 60% of what you hear and see, and 80% of what you hear, see, and do.

Useful Definitions

Acetylcholine: A neurotransmitter that stimulates multiple brain centers including the hippocampus, brainstem, and forebrain where new learning takes place. Associated with attention and focus.

Affective filter: Steven Krashen, in his studies of linguistics developed a theory of language acquisition and development that included the hypothesis of an affective filter. He described higher success rate of second language acquisition in learners with low stress and slower language acquisition when stress was high. He postulated that anxiety and low self-image created a mental blockade that filtered or blocked out new learning. The term is now generalized to refer to an emotional state of stress in students during which they are not responsive to processing, learning, and storing new information. This affective filter is represented by objective physical evidence on neuroimaging of the amygdala, which becomes metabolically hyperactive during periods of high stress. In this hyperstimulated state, new information does not pass through the amygdala to reach the information processing centers of the brain.

Amygdala: Part of limbic system in the temporal lobe. It was first believed to function as a brain center for responding only to anxiety and fear. When the amygdala senses threat, it becomes overactivated (high metabolic activity as seen by greatly increased radioactive glucose and oxygen use in the amygdala region on PET and fMRI scans). In students, these neuroimaging findings are seen when they feel helpless and anxious. When the amygdala is in this state of stress, fear, or anxiety-induced overactivation, new information coming through the sensory intake areas of the brain cannot pass through the amygdala's affective filter to gain access to the memory circuits.

Axon: The single fiber that extends from a neuron and transmits messages to the dendrites of other neurons (or to body tissues).

Brain Mapping: Using electrographic (EEG) response over time brain-mapping measures electrical activity representing brain activation along neural pathways. This technique allows scientists to track what parts of the brain are active when a person is processing information at various stages of information intake, patterning, storing, and retrieval. The levels of activation in particular brain regions are associated with the intensity of information processing.

Brain Stem: The brain region between the spinal cord and the rest of the brain. This is also where nerve centers essential for basic survival, such as heart rate, breathing, digestion, and sleep, are located.

Cerebellum: The lower posterior region of the brain that supervises coordinated movement, posture, and balance and adjusts actions in response to external cues, such as where your foot is in relation to the step. The greatest numbers of connecting neurons to and from the frontal lobe are in the cerebellum such that this region appears to influence higher cognitive processes such as reasoning.

Cerebral Cortex: This outer layer of the brain where most neurons are located is also called gray matter due to the coloration of the neurons. The cerebral cortex is associated with the highest cognitive processes, also referred to as executive functions, including planning, decision-making, reasoning, and analysis.

Computerized Tomography (CT Scan, CAT scan): This scan uses a narrow beam of x-rays to create brain images displayed as a series of brain slices. A computer program estimates how much x-ray is absorbed in small areas within cross sections of the brain to produce the image.

Dendrite: Branched protoplasmic extensions that sprout from the arms (axons) or the cell bodies of neurons. Dendrites conduct electrical impulses toward the neighboring neurons. A single nerve may possess many dendrites. Dendrites increase in size and number in response to learned skills, experience, and information storage. New dendrites grow as branches from frequently activated neurons. Proteins called *neurotrophins*, such as nerve growth factor, stimulate this dendrite growth.

Dopamine: A neurotransmitter most associated with attention, decision-making, executive function, and reward-stimulated learning. Dopamine release on neuroimaging has been found to increase in response to rewards and positive experiences. Scans reveal greater dopamine release while subjects are playing, laughing, exercising, and receiving acknowledgement (e.g. praise) for achievement.

EEG (Electroencephalogram): EEG measures the electrical activity occurring from transmissions between neurons in the cerebral cortex.

Executive Function: Cognitive processing of information that takes place in areas in the left frontal lobe and prefrontal cortex that exercise conscious control over one's emotions and thoughts. This control allows for patterned information to be used for organizing, analyzing, sorting, connecting, planning, prioritizing, sequencing, self-monitoring, self-correcting, assessment, abstractions, problem solving, attention focusing, and linking information to appropriate actions.

Frontal Lobes: With respect to learning, the frontal lobes contain the centers of executive function that organize and arrange information and coordinate the production of language and the focusing of attention.

Functional Brain Imaging (Neuroimaging): The use of techniques to directly or indirectly demonstrate the structure, function, or biochemical status of the brain. *Structural* imaging reveals the overall structure of the brain and *functional* neuroimaging provides visualization of the processing of sensory information coming to the brain and of commands going from the brain to the body. This processing is visualized directly as areas of the brain "lit up" by increased metabolism, blood flow, oxygen use, or glucose uptake. Functional brain imaging reveals neural activity in particular brain regions as the brain performs discrete cognitive tasks.

Functional Magnetic Resonance Imaging (fMRI): This type of functional brain imaging uses the paramagnetic properties of oxygen-carrying hemoglobin in the blood to demonstrate which

brain structures are activated and to what degree during various performance and cognitive activities. Most fMRI scan learning research has subjects scanned while they are exposed to visual, auditory, or tactile stimuli and then reveals the brain structures that are activated by these experiences (exposures).

Graphic organizers: Diagrams that are designed to coincide with the brain's style of patterning. For sensory information to be encoded (the initial processing of the information entering from the senses), consolidated, and stored the information must be patterned into a brain-compatible form. Graphic organizers can promote this more patterning if they guide students' brains when they participate in this creating of relevant connections to their existing memory circuitry.

Hippocampus: A ridge in the floor of each lateral ventricle of the brain that consists mainly of gray matter that has a major role in memory processes. The hippocampus takes sensory inputs and integrates them with relational or associational patterns thereby binding the separate aspects of the experience into storable patterns of relational memories.

Limbic System A group of interconnected deep brain structures involved in olfaction (smell), emotion, motivation, behavior, and various autonomic functions. Included in the limbic system are the thalamus, amygdala, hippocampus, and portions of the frontal and temporal lobes. If the limbic system becomes overstimulated by stress-provoking emotion (seen as very high metabolic activity lighting up those brain areas) the information taught at that time will be poorly transmitted or stored in the long-term memory centers.

Metacognition: Knowledge about one's own information processing and strategies that influence one's learning that can optimize future learning. After a lesson or assessment, when students are prompted to recognize the successful learning strategies that they used, that reflection can reinforce the effective strategies.

Neuronal Circuits: Neurons communicate with each other by sending coded messages along electro-chemical connections. When there is repeated stimulation of specific patterns of a group of neurons, their connecting circuit becomes more developed and more accessible to efficient stimulation and response. This is where practice (repeated stimulation of grouped neuronal connections in neuronal circuits) results in more successful recall.

Neuron: Specialized cells in the brain and throughout the nervous system that conduct electrical impulses to, from, and within the brain. Neurons are composed of a main cell body, a single axon for outgoing electrical signals, and a varying number of dendrites for incoming signals in electrical form. There are more than 100 billion neurons in an average adult brain.

Neurotransmitters: Brain proteins that are released by the electrical impulses on one side of the synapse, to then float across the synaptic gap carrying the information with them to stimulate the next nerve ending in the pathway. Once the neurotransmitter is taken up by next nerve ending, the electric impulse is reactivated to travel along to the next nerve. Neurotransmitters in the brain include serotonin, tryptophan, acetylcholine, dopamine, and others that transport information across synapses. When neurotransmitters are depleted, by too much information traveling through a nerve circuit without a break, the speed of transmission along the nerve slows down to a less efficient level.

Occipital Lobes (visual memory areas): These posterior lobes of the brain processes optical input among other functions.

Parietal Lobes: Parietal lobes on each side of the brain process sensory data, among other functions

Plasticity: Dendrite formation and dendrite and neuron destruction (pruning) allows the brain to reshape and reorganize the networks of dendrite-neuron connections in response to increased or decreased use of these pathways. Plasticity refers to the ability of synapses, neurons, or regions of the brain to change their properties in response to usage (stimulation).

Positron Emission Tomography (PET scans): Radioactive isotopes are injected into the blood attached to molecules of glucose. As a part of the brain is more active, its glucose and oxygen demands increase. The isotopes attached to the glucose give off measurable emissions used to produce maps of areas of brain activity. The higher the radioactivity count, the greater the activity taking place in that portion of the brain. PET scanning can show blood flow and oxygen and glucose metabolism in the tissues of the working brain that reflect the amount of brain activity in these regions while the brain is processing information or sensory input. The biggest drawback of PET scanning is that because the radioactivity decays rapidly, it is limited to monitoring short tasks. Newer fMRI technology does not have this same time limitation and has become the preferred functional imaging technique in learning research.

Prefrontal Cortex (front part of the frontal lobe): The prefrontal cortex responds to event and memory processing and makes conscious decisions. It is the region of the frontal lobe where the brain directs the planning of the movements to do a task

Quantitative Encephalography (qEEG; brain mapping): This brain wave monitoring provides brain-mapping data based on the very precise localization of brain wave patterns coming from the parts of the brain actively engaged in the processing of information. Quantitative EEG uses digital technology to record electrical patterns at the surface of the scalp that represents cortical electrical activity or brainwaves. "Functional" qEEG testing adds recording to evaluate the brain's responses to reading, listening, math, or other demands and provide visual summaries in topographic maps.

Reinforcement Learning Theories: Theories (such as *Dopamine Reward Learning*) based on the assumption that the brain finds some states of stimulation to be more desirable than others and makes associations between specific cues and these desirable states or goals.

Relational Memory: Learning consists of reinforcing the connections between neurons when students learn something that adds to what they have already mastered that expand on neuronal networks already present in the brain.

Reticular Activating System (RAS): This lower part of the posterior brain filters all incoming stimuli and making the “decision” as to what people attend or ignore. The Reticular Activating System alerts the brain to sensory input that sense receptors in the body send up the spinal cord.

The main categories that focus the attention of the RAS and therefore the student include physical need, choice, and novelty.

Scaffolding: This is instruction based on the concept that learning always proceeds from the known to the new. Children construct their new learning on the foundations of what they already know with the help of teachers, parents, or a more knowledgeable other who support them with instruction to help them build upon the abilities and knowledge they have to reach a higher level.

Somatosensory Cortex Areas: One in each parietal brain lobe where input from each individual sense (hearing, touch, taste, vision, smell) is ultimately processed.

Survival Level of Attention: Ideally students are beyond a basic survival mode and can direct attention to more than just avoiding danger. However, too much stress can push them into this survival mode. This can occur when students feel confused and overwhelmed by a classroom experience such that they cannot connect with, focus on, and create patterns and meaning from lesson's sensory input data.

Synapse: These gaps between nerve endings are where neurotransmitters like dopamine carry information across the space separating the axon extensions of one neuron from the dendrite that leads to the next neuron in the pathway. Before and after crossing the synapse as a chemical message, information is carried in an electrical state when it travels down the nerve. It is through synaptic transmission that cells in the central nervous system communicate when an axon sends a neurotransmitter across the synaptic cleft to activate the receptor on the adjacent dendrite.

Temporal Lobes: These lobes on the sides of the brain process auditory and verbal input, language and phonetic discrimination, mood stability through projection fibers leading to limbic system, and learning.

Venn Diagram: A type of graphic organizer used to compare and contrast. The outer areas are for differences and the similarities are listed in the middle area.

Working Memory (Short-term memory): This memory can hold and manipulate information for use in the immediate future. Information is only held in working memory for about a minute. The memory working span of young adults is approximately seven for digits, six for letters, and five for words.