Research Based Strategies to Increase Content Knowledge Understanding Through Inquiry and the Tools of Technology and Engineering

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As we go through the systems at work when your students brains learn most successfully, consider the following topic for your grade level and how to apply the brain-learning strategies we will explore to build your students' knowledge development of this sample topic from your standards:

What is the relationship of environment to species survival and how can your students use inquiry, technology, scientific knowledge and the engineering design cycle to acquire knowledge and develop understanding so the knowledge can be applied to other areas of their learning and lives.

Look up or down on the Learning Progressions chart and think about how the strategy would work with the content at the grade level you teach.

Use the spaces below to make your own notes about applying these strategies to important aspects of increasing content knowledge and understanding such as:

Activate Prior Knowledge

Stimulate Interest: Here-Me-Now

Build Observation Skills

Motivate by Connecting Meaningful Personal Goals to Learning Goals

Building Subject Specific Vocabulary in Science

Build Long-term Memory With Mental Manipulation (choice, categorizing, comparing, contrasting, deduction)

Strengthen Executive Functions (organization, examining multiple perspectives, reasoning, planning, judgment, analysis, prediction, goal-setting and achieving, and communicating ideas accurately to others)

RAD LEARNING = **R**eticular Activating System + **A**mygdala (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.

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.

How Can You Use Technology, Scientific Knowledge, and the Engineering Design Cycle to 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 *Here-Me-Now so* Students See Value of the Information:

- 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. Enthusiasm is generated when students 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, students will be pulled into the school lessons they bring home and they will be motivated to connect with the information in a meaningful way.

Strategies to Maintain Attention and Focus

- 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, graphic organizers as preview and overview of lesson.
- **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 (Reading Study):** 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.
- **Novelty and surprise** with music, costumes, speak in a different voice, hang a dollar bill, overhead optical illusions or bizarre factoids.
- **Suspenseful Pause**: just as a your speaking in a novel accent of different cadence of

speech grabs RAS attention, a significant pause before saying something important builds anticipation as the students wonder what you will say or do next.

- **Color for novelty and Differentiation**

  Marking key points in color results in increased recall. Write most important fact of the lesson in another color.

  Keep students' attention and ability to keep content organized by varying the color of the paper, font, spacing, content, presentation and graphic organization.

  Different color for different activities and new day's work helps you differentiate, because you are able to identify by color when students who work more quickly are working on homework, how much progress individual students are making (and at what level of difficulty) on a portion of the lesson, and who in the room needs your help.
- **Discordant Events:** "I'd rather have half of a quarter of a pizza than a quarter of a half piece. What would you prefer?"
- **Physical activity** every 15 minutes: Sing a song with associated movements, teach from a different part of the room so students turn their chairs.
- **Physically alter** the arrangement of your classroom. Make the classroom come alive- vary bulletin boards, plants, animals, and changes in seating arrangements. One teacher followed this suggestion and wrote,
- **High Interest Connections to Prime Interest**: high interest information about mathematicians or scientists, especially something they did – an interesting anecdote or a significant event in their lives when they were the same age as the students in the class.
- **Personalize for RAS**: by connecting topics with students' goals, talents, learning strengths, interest (interest survey at beginning of the year).
- **Kidwatching cards**: using their names in sample problems. Have made the problems purposefully ridiculous. Use student information in examples Joe threw a ball 12 feet, Mac threw it 5280 feet.

WRITE: How can you use some of the RAS strategies to stimulate interest and motivate you students' to select the information they need about the topic from all of the sensory information available to them. There are lots of things students can select for attentive focus. Which strategies can you use so their RAS is focused **on the goal of this lesson?**

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Amygdala

If students are stressed information won't pass through the ***affective filter*** in the ***amygdala.*** 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.

Avoid Boredom and Engagement with Differentiation Every 10 Minutes

Ongoing feedback helps students perceive their progress from an outside perspective or as compared to preset standards. Good feedback can help students see how they are progressing to their short and long-term goals.

Feedback During Lessons: Feedback is a valuable form of ongoing assessment. Ongoing assessment is necessary for keeping all students actively connected to the lessons. ----

-**Individual white boards**

-**Thumbs up or down**

Every ten minutes respond to individual needs for more explanation or challenge

Pair-Share: Initial note taking in class should not be for detail but rather for initial key ideas they think are important. After a period of instruction based on time or topic the students need time to add detail to their notes as they mentally manipulate the new information. These early notes can be in differentiated form e.g. graphic organizers (scaffolded) outline (scaffolded), note-taking/making (extended), key ideas or vocabulary, sketches, confusing parts. Then students can compare in small group or pairs to add to their notes and confirm on questions leaving questions that they cannot answer together for whole class questions.

WRITE: How can you apply Amygdala strategies for this science unit to decrease stress and increase academic risk-taking and participation? For example, *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?*

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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, optimism, and CHOICE.

Strategies to make learning release dopamine:

- Pantomime or draw sketches of math or science vocabulary words
- Word Gallery: **Vocabulary review for science terms** can incorporate movement, positive peer interactions, even music. If students have a list of vocabulary words they can walk around the room and write the number of the poster that has a verbal or pictorial representation of word. This can vary from actual definitions to the word used in sentences. Subsequently students can add their own sentences or drawings to the wall charts. Scaffold by allowing some students have a one-word definition or work with a partner as they boogie the vocabulary walls to music.

- 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.

WRITE: How can you use Dopamine release activities for this science lesson in my classroom?

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WRITE: How I will use RAD strategies from other teachers in my group or meet with other teachers in my school to share our ideas for our science challenge lesson? Keep a list of which strategies work for which parts of the unit.
R (reticular activating system)
A (Affective filter in Amygdala)
D (Dopamine-Pleasure Response)

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Research Brain-Compatible Memory Strategies

- Advances in memory research
- Strategies to increase memory retrieval
- Creating Long-Term Memories by mental manipulation and inquiry in the prefrontal cortex with executive function strategies

Working memory (short-term 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

Working Memory to Relational Memory

Relational Memory: 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.

Connect With Prior 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.

Strategies: Bulletin boards, play ball toss and students say what they recall about the subject, cross-curricular connections you find from your colleagues or other units you teach that can be related with this unit. KWL charts and discussions

WRITE: How will I activate prior knowledge my students can relate to this unit?

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PFC=Prefrontal Cortex

Patterning and PFC

Increasing prefrontal cortex executive practice can, through neuroplasticity strengthen prefrontal executive function. Math and science inquiry and problem solving help students build their information processing skills they may also be increasing the networks for emotional processing and decision-making skills. Inquiry and discussions that involve opinion development, analysis, judgment, and decision-making may strengthen information and emotional processing. Students learn how to rapidly process information and distinguish between what's reliable and what's not.

- **Patterning activity:** Students guess the pattern as you call up students with a similar characteristic such as blue shirts;
- **Patterning activity:** look for patterns in nature such as golden-triangle, Fibonacci sequences, patterns of gears in machines, cycles in nature that follow patterns,
- **Patterning activity**: You give examples and non-examples of a concept (such as prime numbers) and students make silent independent predictions as to what category or concept the items share.

  After you say "yes" or "no" about if the example you gave does or does not fit the concept (category) of which you are thinking, students write down the word you said on paper that already has a "Yes" and a "No" column.

  For the first few examples they would not know what the commonality is, but they gradually will by discovering which items are and are not in the category.

Students can use their notes. For further scaffolding, students who need the help can, be given the categories into which will be sorted, the first few already sorted, and they can have a list with the others to be sorted).

Ask students who want to make a prediction to first see if they can make the correct silent prediction for the next few examples before they make their verbal response. Let them know they will later be asked to defend the previous items that did fit into the category.

If their categorization is correct, connecting concept and they can offer another example rather than saying, "All the animals that fit your category are mammals because they have fur, bear young alive, and produce milk."

As each student correctly adds an item that "fits" they can form a small group where they then can add other items to the category or concept and write what the commonality or concept is. Whole class sharing follows where all **students can add to their notes**.

WRITE: How I can use this patterning/concept building activity for this science lesson in my classroom?

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"Dend-write" Notes for Memory Consolidation …and More

Build relational memories, connect with prior knowledge, stimulate interest, help students recognize new learning/progress, personalize, give choice with "Dend-writes"

In the last 5-10 minutes of a class or at completion of a lesson, students write "Dend-writes" (exit cards) 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 Dend-writes

- 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.

WRITE: Which dend-writes will work well for students' active summarizing, building memory, finding patterns, or feeling personally connected to this science unit?

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Neuroplasticity, Patterning, & Mental Manipulation –

The person who does the work (thinks) LEARNS.

Students experience a greater level of understanding of concepts and ideas when they talk, explain, and debate about them within a small group, instead of just passively listening to a lecture or reading a text.

Neurons that fire together, wire together: ***Neuroplasticity***

Greater brain region stimulation promotes the growth more connections between synapses and dendrites and more myelination there is value in **multisensory learning and repeated stimulation** of neural networks containing useful learned information through neuroplasticity. In multisensory learning more areas of the brain are stimulated as information is presented through *multiple* senses. These pathways interconnect and the stimulation of one appears to activate related ones as a part of the brain's patterning system. Multisensory presentations of the information stimulate the growth of more brain connections.

Use it or Lose It: Pruning

Brain regions not activated by neural stimulation receive less oxygen and glucose. The result can be a release of neuron-destructive chemicals that breakdown the unused neurons. This can be a useful phenomenon to increase brain efficiency when truly unneeded neurons and connections are eliminated. For example, once students can automatically tie their shoes without going through the memory prompt about a bunny running around the tree and into a hole, the brain network with that memory device can be pruned away so the shoe-tying neural network is smaller and faster when the activity is needed. The efficiency of pruning has also been demonstrated in accomplished pianists as practice leads to more automatic playing so less of the brain's motor cortex needs to be used to modulate the activity of moving the fingers on the keys.

Each time students participate in any mental or physical endeavor the specific pathway of neurons is activated and their connections strengthened.

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.

MENTAL MANIPULATION IN THE PFC

Teaching is not just the dispersing of facts. Students need to develop cognitive skills of thinking, learning, and reasoning as they enhance content knowledge and concept development through the science standards.

Help them find personal or relevant meaning in what they are taught and use mental manipulation through open-ended discussions, creative problem solving, deduction, and extensions of topics, and using their individualized interests and learning strengths to pull students into the unit. Doing so will increase electrical activity of these memory and higher thinking brain networks and make the information they learn become constructed networks of knowledge they can build and use.

Similarities and Differences: just as survival depends on recognizing the changes in an animal's expected environment (RAS of fox), people are also responsive to remembering information by identifying similarities and differences. Marzano compared studies research result for identifying similarities and differences and found a 12-46 percentile gain, greater than for any other relational memory strategy.

> **Find similarities from concrete to abstract or by generalizing:**
> **Relate New Knowledge to Personal Interest for Stronger Memory Links**
> **Syn-naps Activities during relational memory building:**
> Ask students to do a walk-about to connect the concept or new knowledge to something of personal interest and exchange these with three different partners. After the allotted time, write a list on the board.
> Students will learn of each other's interests (as will you) and find more ways the topic relates to their own interests.

Compare and contrast: i.e. Compare *basic features of plants and animals with the graphic organizers that are best for the task and for the way you enjoy learning best.*

Categorize: *i.e. Group animals by habitat and explain the relationship between the animal and the characteristics of the environment that supports its needs.*

With these progression through the new standards, your students' brain networks they will do the best possible learning – they will see connections between new and prior knowledge and each year as they investigate the

standards through deeper exploration of the topics, they will grow in thinking skills as well as scientific knowledge!

WRITE: How I can use comparison, categorizing, graphic organizers, or other mental manipulations so students see the "big picture" and build larger and stronger concepts, categories, and patterns in their brains?
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Graphic Organizers to mentally manipulate: Graphic organizers with visual, diagrammatic, pictorial, or graphical ways to organize information and ideas for understanding, remembering, or before writing a paper. For the most part, the information on a graphic organizer could be written as a list or outline, but graphic organizers give students another way to see and mentally, as well as visually and kinesthetically, manipulate the information.

Graphic organizers allow students to create visual pictures of information in which their brains discover patterns and relationships. When the brain can find and interpret information as a pattern, such as in a graphic organizer it receives the information as meaningful input for memory storage.

Samples of graphic organizers can be found at these websites:
Inspiration.com
http://www.ncrel.org/sdrs/areas/issues/students/learning/lr1grorg.htmand
http://www.teach-nology.com/web_tools/graphic_org/
http://www.inspiration.com/freetrial/index.cfm
http://www.ncrel.org/sdrs/areas/issues/students/learning/lr1grorg.htm

- **Analogies** for relational memory: White is to Snow as Blue is to Sky

Scaffold analogies, use ones students made last year) and leave out one, or two, of the four components of A is to B as C is to D. Then they can add the characteristic or relationship that ties the two sets together.

They can also make analogies to something about themselves.
___ is to ___ As I am to my puppy.
Multiplication is to addition as ____________is to _______________.
Your example here related to this science unit:
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- **Similes**: Exercising my muscles makes me stronger like science inquiry makes me smarter.
- **Puzzlemaker.com** useful website for science vocabulary practice students can create for themselves or classmates.

- **Mnemonics:** like ROYGBIV for the colors of the rainbow (red, orange, yellow, green, blue, indigo, violet).

Make up a mnemonic sentence for the five senses (see, hear, touch, smell, taste) students could use this to start investigating how an animal species evolved a modified sensory system to adapt to its changing environment. Create a sample mnemonic for your unit here: ____
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More Mental Manipulation 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 a science concept in action, such as the water cycle, then note it using words or sketches.
- Produce a product, make models
- Role play, skits, pantomime
- Personal involvement in learning experience - hands on and discovery learning, prediction, manipulatives, students in groups write their ideas/results on overhead projection paper to share with class, cooperative group work.

Memory Cement

- ***Here-Me-Now so* 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.
- **Real World Connections and Teachable Moments**
  When would this knowledge be useful to you?
  Meaningful comparisons: Comparing the amount of weight or the size of a car and gas mileage.
- **Extend working to relational memory** by asking students to construct verbal and written summaries, represent the content as pictures, symbols, graphic organizers, physical models, and create mental images. LATER revise their notes, pictures, graphic organizers, homework,
- Achieve maximal memory storage conditions with teaching strategies that connect with students as individual learners through their strengths and promote positive emotional states.

<u>Prefrontal Cortex for Highest Cognition and Executive Function</u>

Through prefrontal lobe activation, students can be more successful in remembering and applying past emotions and experiences to new situations, decision-making, analysis, and judgment. When we **strengthen prefrontal executive functions in students we build their**

information and emotional processing and their decision-making skills. Discussions about multiple perspectives or approaches to a math or scientific problem or real life problem that involves math and science.

- 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.
  - **Prioritize:** Practice separating low relevance details from the main ideas as in word story problems. This represents the executive function of prioritizing skills to help students practice the cognitive strategy that will help them make the most efficient use of study time.
  - **Setting goals, providing feedback, monitoring progress:** Humans are the only creatures with the ability to analyze their thoughts and behaviors and then act in accordance with expectations for goal attainment Setting specific learning goals at beginning of unit and asking students to add or rephrase in their own learning goals. Provide feedback on learning goals throughout the unit, asking students to keep track of their progress on learning goals, provide summative feedback at end of a unit, ask students to assess themselves at end of unit.
  - **Judgment:** This executive function includes self-checking strategies such as estimating or checking math accuracy, time planning, looking for clues for questions in subsequent questions, and checking in with themselves to monitor their focus.
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- **Open-ended, student-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. (Low threat prompts such as, "What I understand you as saying is that… Am I correct in that?" Why do you think that is true?"

Open-ended discussion topics:

Observations: After observing this fossil what do you predict about the animal that once existed that left this evidence of its time on earth?

Personal Relevance: Why might this information be useful to you someday? What people, doing what jobs might use this information to prevent extinction of an endangered animal? How could you use this information to make a better habitat for a pet you own if you needed to leave him alone for several days?

USE the knowledge for desirable goals: Write a book to teach a younger child about this topic. Write an opinion piece to the newspaper supporting your suggestions or concerns with evidence.

Your example of an open-ended question related to this science unit here:

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- **Hypothesize-Predict** Example: Relationship of environment to species survival.

What has caused some animals to become extinct? How can you find and use clues, such as fossils, to predict what the extinct animal was like?

What animal species is now or may soon become endangered? What evidence supports your hypothesis?

What might happen to that species if conditions stay the same? What evidence supports your hypothesis?

Predict what can be done to change conditions that threaten the species survival. What evidence supports your prediction?

Students respond to modeling. How will you model the use of your executive functions? Think of a way you can demonstrate to students how you can use information you know to make a prediction about something that will happen at school, but is not yet confirmed, such as the outcome of an upcoming football game?

What prediction and/or hypothesis building activities can you build into this science unit to engage your student's highest thinking brains – their prefrontal cortex executive functions?

WRITE: How I can use comparison, categorizing, graphic organizers, or other mental manipulations so students see the "big picture" and build larger and stronger concepts, categories, and patterns in their brains?

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WRITE: What three things I enjoyed learning today will I incorporate as I help my students use brain research-based strategies to construct learning into wisdom through the science learning standard progressions in my classroom?

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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 students when they are moving, laughing, interacting, being read to, feel a sense of accomplishment, and when they have choice.

The last part of the brain to mature (through plasticity and pruning is the prefrontal lobes. Students 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 students 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 students 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, students 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. Students 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.