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Research-Based Strategies to IGNITE Student Learning

Insights from Neuroscience and the Classroom

Revised and Expanded Edition

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Introduction

The mind is not a vessel to be filled, but a fire to be kindled.

—Plutarch

Every class, assignment, memory, and experience shapes the brain. Understanding how the brain processes information into learning, what students' brains need in order to learn most effectively, and how and why your successful techniques work offers you keys to expanding your strategies and interventions for teaching and learning. Powerful tools of neuroscience can be applied to promote the goals of teaching and of education in general, making the classroom experience more joyful for both you and your students.

Advances in neuroimaging and mapping of pathways, connecting brain components working together, have further opened windows into the working brain. We can now see brain activity as information is being processed from the initial sensory intake to extended cross-brain conceptual networks. This ability provides us with a deeper understanding of neuro*logical* strategies that could promote students' learning, such as through personally immersive and emotionally engaging experiences. Brain scans cannot create lesson plans, but research in neuroscience has reinforced much classic educational theory and expanded our abilities to recognize the needs of individual students and provide increased opportunities for all students to develop their highest cognitive potentials.

It has been more than a decade since I wrote the first edition of *Research-Based Strategies to Ignite Student Learning*. Ongoing developments in neuroscience technology, the resulting research, and the correlations from these to classroom practices have further transformed the landscape for optimal teaching and learning. These profound research implications are the major focus of this new book. More than 80 percent of the material is new, including strategies, guided student instruction, and a planning template to further promote teaching in ways the brain learns best.

Coauthor Malana Willis is a vital presence in this book, contributing her experience and insights from the front lines of teaching and research application. And I've added new content rooted in my progression from neurologist, to 10 years as a classroom teacher in primary and secondary schools, to currently teaching educators internationally as a presenter and consultant. I continue to evaluate the most current neuroscience research and have now written more than 200 articles and 9 books connecting the science to teaching and learning practices.

As in the first edition, the major focus of this book is to help educators like you to acquire or hone strategies to guide students' brains to more effective focusing, sustained attentiveness, and active construction of understanding and memory so that they can store, connect, retrieve, and extend learning to new applications, problems, and innovations. Understanding the *why* and not just the *how to* of your most effective teaching strategies will inspire positive expectations and motivate you to use and expand these strategies and ignite these skill sets in others. By understanding the relevant aspects of brain development, attention, memory, executive functions, and development of conceptual understanding, you'll find your work becoming more effective and energizing as your students become more engaged and knowledgeable.

One foundation of the original book was the intense responsibility I felt as a neurologist, neuroscientist, and educator to increase other educators' awareness of and appreciation for the implications of *valid* neuroscience related to teaching and learning opportunities, in the face of so many "neuromyths" and "educa$h-in" products. It remains unacceptable that people without an academic background in neuroscience continue to make commercial products or become self-proclaimed pundits for personal profit, spewing forth books, presentations, or products with claims that are inadequately or not at all supported by neuroscience research.

Although educators are now much more aware of this problem, the pundits and profiteers continue to find and use invalid and self-serving interpretations of research—as well as commercially funded bad research—to promote their claims, books, and products. As a result, we need to be even more vigilant as myth busters. To that end, this book shares what I consider to be the most scientifically supported neuroscience research, background understanding, and resources you can use to distinguish illegitimate or exaggerated claims from valid conclusions. Equipped with the updated information and technology you'll learn about in this book, you'll increase your expertise at seeking the most authoritative studies and using the science to guide your own correlated strategies.

As you build your understanding, connecting the powerful discoveries of brain research to classrooms and curriculum, you'll find that you increasingly incorporate ways to help students learn more effectively and joyfully. With your increased knowledge, you'll be in the vanguard of educators better serving the needs of today's students and guiding fellow educators through inevitable transformations in how to prepare learners for the challenges and opportunities of the 21st century.

How This Book Is Organized

The sequence of chapters in this book follows the progress of sensory data through the brain as it is processed into long-term memory. In effect, the sequence charts the journey of how we process information—and thus of how we learn. Chapter 1 reviews the research, theories, and suggested strategies regarding factors that influence student attention and what triggers the brain's awareness. Chapter 2 explores how emotion affects learning and what it takes to get new information through the emotional filter. The journey continues in Chapter 3, with the construction of durable and applicable memory. Chapter 4 features the development of strong executive functions in this era of high demands on focus, self-management, goal-setting, prioritizing, organizing, judgment, reasoning, critical analysis, and innovation.

The chapters include some brief sections that supplement the primary content. Those titled Gray Matter provide scientific or technical information for readers who are interested in further exploring the topic or neuroscience that underscores the teaching strategies. Neuroscience Read-Aloud sections are practical guides for teaching students about the challenges in their developing—and still stress-reactive—

brains, and about how they can build the brain powers needed to achieve their goals with greater engagement and success. In addition, an online study guide is available for you to use as you progress through the book and for leading others in professional learning opportunities for further discussion.

Thank you for your efforts to be your very best so students can be their very best! Keep igniting!

—Judy Willis

1

How Red Wagons Capture Students' Attention

All thinking begins with wonder.

—Socrates

As I sat in the amphitheater in one of the older buildings on the Harvard University campus, attending the first day of my summer physics class, my mind was miles away from the lecture scheduled to begin momentarily. This was Physics 101–102, an intensive six-week summer alternative to the usual full-year course.

The students did not know one another, but most were taking the class for the same reason: it was a prerequisite for medical school. I sat there dreading the upcoming hours of listening, reading, and solving seemingly irrelevant problems. My thoughts shifted from these scientific endeavors to exploring the city of Cambridge after class, the cute boy in front of me wearing the tie-dyed Grateful Dead shirt, and my pile of dirty laundry that would soon walk away on its own.

Suddenly, the swinging door leading to the lecture area burst open, and a man who appeared to be in his late 50s propelled himself into the room, crouched on a little red wagon. He wore a wizard's hat and was aiming an activated fire extinguisher at the wall. This was my introduction to Professor Baez, demonstrating Newton's third law of motion—that for every action there is an equal and opposite reaction.

It was a lesson I never forgot but sadly never emulated until 30 years later, when I left my neurology career and became a teacher, trying to capture the attention of my students. I recalled how powerfully that memorable lesson engaged my attention and wondered how teachers without red wagons and fire extinguishers could focus students' attention.

My subsequent investigations of the neuroscience research about attention led me to understand why that physics lesson worked. Further, it showed me that other uses of novelty and excitement through strategies of surprise, unexpected classroom events, dressing in costumes, playing music, showing dynamic videos, displaying comic strips or optical illusions on a screen, and even telling corny jokes could capture my students' attention and promote initial connections to the lesson. I learned that if I tapped into their natural curiosity and marshaled the power of predictions, I was more likely to sustain their attention throughout a lesson or unit. I also found that I could employ activities to develop students' executive functions of focused awareness and distraction inhibition. With these strategies in place, my students were better able to attend to and engage with lessons and more successfully engage in the process of constructing understanding and durable memories.

The Brain's Gatekeeper: The Reticular Activating System

All learning begins with sensory information, but not all the sensory information available from the senses and environment is accepted for admission. For sensory input from what you hear, see, feel, smell, and taste to become memory, it must first be admitted by the brain's attention intake filter, the *reticular activating system* (RAS), shown in Figure 1.1 at the top of the brainstem (in the lower brain). This operation turns out to be very competitive. Every second, millions of bits of sensory information from the eyes, ears, nose, taste buds, internal organs, skin, muscles, and other sensors bombard the brain. Notably, though, only a tiny fraction—about 1 percent—of all that information passes up through the attention filter (see Figure 1.2).

The RAS is an attention-entry filter for incoming sensory information. It is key to arousing or "turning on" the brain's heightened level of receptivity to input. Soon you will learn how it is programmed in favor of letting in sensory information that's important for survival. Then we'll explore the development of more top-down attention focus

FIGURE 1.1

Reticular Activating System

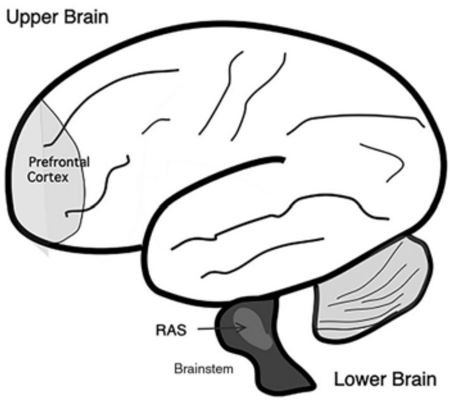
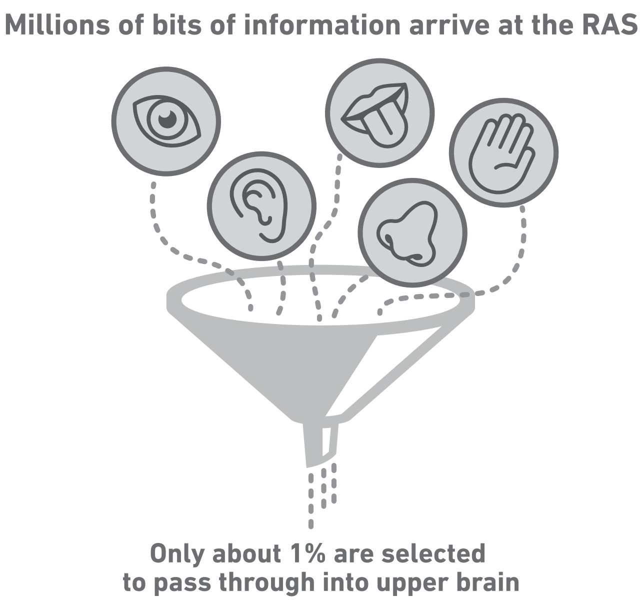


FIGURE 1.2

From Input to Output: The Selective Filter of the RAS



management as children grow. Top-down management of attention focus refers to the ability to direct attention to a particular stimulus or event in the environment (Katsuki & Constantinidis, 2014). These management circuits increase one's ability to actively dictate some of the sensory information to be accepted by the RAS.

The Priorities of the First Gatekeeper

The work of the RAS follows the survival-oriented programming of other mammals living in unpredictable, often harsh environments. Because the capacity for intake is so limited, the selection process for what gets in must be rapid and efficient. To support survival success, it makes sense that priority intake scrutinizes for potential threat or for survival resources (e.g., food, shelter, mates). This scrutiny is reflected, then, in priority going to sensory information concerning what is changed, unexpected, or different in the environment (Brudzynski, 2014).

With its programming as an alerting filter, it is understandable how the RAS responds instinctually to what is new in the environment (Garcia-Rill, D'Onofrio, & Mahaffey, 2016). Living things need to respond to changes in their environment to survive. A rapid response to novelty optimizes the chance of survival. Mammals need shelter from sudden storms, access to new sources of water when streams dry up, and places to escape to when danger is imminent, so priority attention to the unexpected or unusual is helpful in revealing new available resources for these potential future needs (Awh, Belopolsky, & Theeuwes, 2012).

What RAS Programming Means for Students

The strong reaction to novelty makes sense for this more primitive system in the human brain, but it presents a challenge when teaching information that may not evoke interest or effort. If the RAS does not select the information delivered in a lesson, little will be "learned," so we'll be looking at how to incorporate RAS intake boosters into instruction. Before describing the relationship of the RAS intake to learning in students, let's briefly consider why we adults are not as prone to paying attention only to what glitters, sparkles, moves, or pops. Simply put, adults' neural networks related to top-down attention focus are more mature. These circuits, in our highest cognitive centers located in the brain's prefrontal cortex (see Figure 1.1), develop into more efficient circuits that allow us to send messages down to the RAS to influence what information it takes in.

The RAS response to the sensory information received affects the speed, content, and type of information that gains access into the higher-thinking regions in the prefrontal cortex. These top-down attention control circuits continue to develop through the twenties. Your interventions to strengthen these circuits can boost students' influence on what information passes through their RAS filter. Further, they can learn and incorporate strategies to block intake through the RAS of input that is irrelevant to the goal or task at hand (Petersen & Posner, 2012).

By neuroscience criteria, students' brains are always "paying attention." The RAS continually filters which sensory information gets in. Often, however, what gets in will not be the information you are providing in your instruction or through students' reading and homework. Students are frequently criticized for not paying attention, but we now know that failure to focus on classroom instruction does not mean their brains are inattentive. The RAS is paying attention to (letting in) sensory input, but unfortunately it may not be related to what is being taught at the time.

Because students' environments are full of new and enticing information from the visual, auditory, and kinesthetic inputs continually surrounding them (sometimes plugged into their ears from their devices), teachers are challenged to guide students to select and focus on the intended information. It takes guidance and effort to build their abilities to resist some of the distracting input competing for attention through their intake filter systems.

Neuroscience Read-Aloud

What Gets Your Attention?

Your body has millions of nerve-cell endings that receive information from your senses—the sights, sounds, smells, tastes, touches, and movements around you and from within your own body. However, only about 1 percent of this information ever reaches your brain for further processing. Your brain can't process the millions of bits of data it receives every second, so it has a gateway, called the *attention filter,* to select what gets in. When you know the characteristics of what type of information gets through this filter and into your brain most easily, you can take control of your attention filter and decide what you want to pay attention to.

Your attention filter is programmed to give first priority to things that are new, unusual, or unexpected. That's why the focus of your attention shifts when something in your environment changes. For example, although you may start off focusing on a lecture, your attention will likely be pulled away when your senses admit something new, such as the sound of friends talking behind you, the flash of flickering lights, the breeze from the window, or smells from the cafeteria. The good news is that understanding what gets priority entry through your attention gateway will allow you to recognize the distractions and redirect your attention filter intake. You can build your skills to recognize that you have become distracted and choose to refocus your attention on whatever you choose.

Opening Attention Intake

We all come across lessons or units that don't inherently capture our students' interest. Although you've no doubt developed effective strategies to jump-start students' attention, understanding how *novelty, curiosity, surprise, the unexpected,* and *change* can influence the RAS can expand your toolkit.

There are many creative ways to infuse your subject matter or lesson with a bit of novelty and curiosity. Despite the glitter of some of the examples that follow, we're not suggesting that "edu-tainment" with bells and whistles is the simple and sole answer to holding students' attention. These examples can be altered to fit a wide range of topics and subject areas. Some require advance preparation, whereas others rely on materials that you probably have on hand or involve a simple shift in your presentation style. Here are some favorites for captivating the RAS.

Show video clips available on the internet about the upcoming topic. In college, one of Malana's professors launched his social psychology classes with a relevant clip from the television show *Seinfeld*. The human foibles portrayed on the show were an engaging way to bring social psychology principles to life while capturing the attention of students in a large lecture hall.

Play music related to the coming lesson. For example, some jazz before a discussion of *The Great Gatsby* or the theme music from the game show *Jeopardy!* before reviewing for a test would engage learners and set the tone for the activity to come.

Move in a different way. For example, if you walk backward during your normal activities while students are entering the classroom, the novelty can spark their interest as you reveal the day's topic of instruction—negative numbers, going back in history, past tense, flashbacks in literature, "backward" analysis, or hindsight about events leading up to discoveries.

Speak in a different voice or vary your cadence or volume as you read aloud, describe a scientific phenomenon, or recount a historical event.

Use suspenseful pauses before saying something important, because silence is novel.

Wear a hat or even a costume relevant to the topic. Malana and her classmates looked forward to their AP biology class because their creative teacher would frequently dress and accessorize to fit the theme. Her skeleton earrings and T-shirt accompanied her anatomy lessons, and all manner of flora and fauna were represented to pair with her lectures on botany and zoology. Despite the challenging content, her playful nod to the theme of the day captured her students' notice and lightened the mood.

Make alterations in the classroom, such as a new display on a bulletin board. A vase of flowers on the front table could draw attention to an art lesson on Georgia O'Keefe, a language arts lesson focusing on sensory details, or a discussion of pesticides or the globalization of agriculture.

Greet students at the door with a topical riddle along with a hello. For example, the following classic riddle could be written on a large sheet of poster paper next to the door for students to read as they enter the classroom: "I have streets but not pavement; I have cities but no buildings; I have forests yet no trees; I have rivers yet no water. What am I?" As students come into the classroom, they will find the answer: maps! This novel introduction can lead to a lesson on cartography, the features of maps, different types of maps, what information is included and excluded from maps, and even the creation of student maps.

Hand students note cards with a math problem (review) before they enter the room. Explain that calculating the answer will provide them with the number of the table at which they will sit that day.

Start with an unusual fact or offer a provocative quote. Invite students to consider who might have said it and why, and how it might connect to the day's theme. For example, you could post the following quote for students to ponder, initially without an attribution, before a chemistry discussion on entropy, a lesson on seasonal changes in ecosystems, or an analysis of relationships in a novel: "Nothing is absolute. Everything changes, everything moves, everything revolves, everything flies and goes away." You could pose questions such as, Who might have said this? What might this person have been referring to? How could the quote relate to the topic we are going to discuss today? Following the lesson, you could return to the quote and ask some follow-up questions: In what ways is this quote similar to what we learned today? How does it differ? What else could it connect to in chemistry, ecology, literature, and so on? This quote was said by artist Frida Kahlo. How does that information affect your reflections?

Use color to highlight something novel. We know that colored flyers in students' Friday folders tend to get more attention. Color and unusual color changes, such as a picture of a red river or a purple polka-dotted tree, do the same in class openings.

If taking attendance, have students say a response word instead of the usual "present" or "here." Your prompt can be "What was the color of your first bicycle?" Not only will color activate attention, but classmates' curiosity about their friends' bicycles may reduce the class disruption that can occur during the boring process of taking roll.

Use extremes. For example, because mammals survive in unpredictable environments, it would be reasonable for priority sensory selection to alert them to things that are more extreme than the rest of the environment, such as a huge wolf or a swarm of bees. You could use extreme numbers to add a surprising or dramatic element to a math word problem related to teaching the metric system, such as "The 3-month-old girl threw the ball 3,000 meters farther than the pitching machine did. Calculate the distance in feet that she threw it." You could also use outrageous statistics to prompt discussions at the outset of a topic. Books such as *Guinness World Records* have many real-life examples of extremes.

Start your presentations with a joke. The following pun would be a playful intro to any number of science or math activities. Q: Why didn't the sun go to college? A: It already had 27 million degrees!

Dazzle with surprising visuals. Often when students came into my math class, I had optical illusions projected, provoking their interest and conveying the message that they should always look beyond the obvious.

Start a lesson by mentioning relevant community or school events of high interest that can tie back to the lecture topic of the day. For example, if the local city council voted to build a parking lot instead of a skateboard park on available land, students could debate the pros and cons of the decision and consider the economic and political forces that led to the final vote.

Recall a personal anecdote from your own life that connects to the subject. For example, Malana's middle school Spanish teacher introduced lessons with stories about her time spent studying abroad in Spain and volunteering for the Peace Corps in Costa Rica. The tales were brief but rich with descriptive details and humor, and they helped the students focus and find meaning within the vocabulary or grammar lessons that followed.

Facilitate students' movement by speaking from different parts of the room. As they move their heads and eyes to see you, their visual sensory input changes with the shifting background.

Take students to an unexpected location to jump-start your lesson. A quick walk outside to a green space to lie down and "listen to the earth" ties in beautifully to the first chapter of the novel *Esperanza Rising,* in which the protagonist does the same. If an outdoor space is not available, a brief visit to another area on campus might work to provide novelty. Even having students sit in a different part of the classroom, switch seats, or stand up during the introduction of a lesson will alert their brains to pay attention.

Ask a question about something that students would be curious about related to the coming lesson. For example, "Why do you think monarch butterflies navigate their way about 3,000 miles (4,800 kilometers) each fall from Canada to Mexico? Each butterfly makes this journey only once in their lifetime, so how is it possible that they don't lose their way?"

Keeping Attention After the Red Wagon

Even better than using momentary novelty or change to open the RAS filter is *prompting more sustained curiosity* (Gruber, Gelman, & Ranganath, 2014). Curiosity is an intense and basic impulse critical to survival. From infancy, young brains need to make sense of the world in order to survive. Infants possess a sense of wonder, which merits preservation during school years to enhance both the memory and joyful learning. If you boost students' curiosity before or during a learning experience, the information becomes more desirable and memorable. When students are curious about something, the brain favors intake of sensory information to explain the unusual and unexpected. This curiosity motivates them to persevere in seeking information to fill the gap. Ultimately, the curiosity that triggered the initial attention becomes a source for sustained interest as the unit continues.

Advertising at the Beginning of a Lesson

Movie trailers are designed to gain the attention, curiosity, and interest of an audience. These "coming attractions" are advertisements that inspire the viewer to want more. They are usually edited to be dramatic, creating suspense by hinting at what the film is about but leaving out most of the details. The viewer, now enticed, wants to watch the entire movie to see how all the teasers resolve. Even movie posters showing a few key characters or an exciting scene spark interest.

You can advertise upcoming lessons in a similar way, using a variety of high- and low-tech tools to provoke curiosity about what's to come. You could use a poster from an existing film to spark curiosity. For example, an image from *Fantastic Beasts and Where to Find Them* could advertise a unit on the taxonomy of the animal kingdom or ecosystems and habitats. You could also create your own posters using photographs from past or present classes, or images that you create or find online. Posters could depict what people were able to do, find, or create because they had the knowledge you will be presenting.

You can tap into open-source videos and photos that come with certain computer programs. One such program is Animoto (https://animoto.com/education/classroom), which offers teachers a free Animoto Plus account to create their own promotional videos to engage curiosity and attention. Use the video at the beginning of a unit to entice your students with relevant images, video clips, music, and text. Use the following URLs to view some of the advertisements made by participants in my workshops:

- Funky Fraction Trailer at http://animoto.com/play/hJIiMYgkAHKHf7CLVhf3Kw
- Fractions: Yes We Can! at http://animoto.com/play/RZzA6MAHaGdcvsAv9FLcLA

Animoto can be a powerful tool when students use it to create videos to symbolize their new learning. This activity helps to build concept understanding and memory.

Building Curiosity Before a Lesson

Just as providing an enticing preview in the form of a poster or an Animoto video can spark interest at the start of a lesson, advertising several days *in advance of* a unit builds curiosity. For example, you can hang a series of engaging posters related to what students are about to study. Build interest by adding hints and new posters over a few days. This technique can be particularly helpful when a dull but critical and required section of curriculum is approaching.

An example was my use of *Star Wars* movie poster ads. I added a new one daily for four days, with the last one proclaiming, "24 HOURS UNTIL THE FORCE ARRIVES." The next day, the students came early and eager. I was swinging a paper cup on a string. When they were all attentive, I stopped, and a marble rolled out of the cup as I explained centrifugal force. Students' enhanced curiosity set their intake systems with a state of positive anticipation that harnessed attention. Similar "forces" for the same posters could include forceful verbs, exclamation points, forces of nature, forces that changed history, magnetic force—and no doubt others you can think of.

Another way to build curiosity is in the form of a wall puzzle. Take or make an engaging poster or picture related to the next week's unit. Cut it into five pieces, and each day add one more piece to the growing puzzle. Students will show more and more interest in what the puzzle might represent and be inspired to make predictions about what they'll soon get to learn.

A colleague described a technique used by his professor to promote medical students' curiosity before seeing the hospital patients to be evaluated the next day. The students were primed with the names of five disease processes, three of which would be revealed in the next day's patients. Their curiosity prompted them to read about all five possibilities and to really want to know which ones they could correctly identify after their reading. (This is an example of giving an authentic purpose for students' reading.)

Using Predictions to Sustain Attention and Engagement

Humans are naturally curious and want to know more about new experiences, things, or events they don't understand. This characteristic dovetails into a natural extension of the RAS priority to alert to changes in pattern, the novel, and the unexpected. After curiosity provokes RAS intake, students' receptiveness is sustained when they can make predictions about the stimulus that evoked their curiosity—the sight, sound, object, statement, picture, question, and so on—envisioning what it does, how it works, and what it has to do with the lesson.

Prediction prompts even further interest by activating the brain's instinctual need to know the *result* of our choices, decisions, actions, or answers (more on this related to dopamine in Chapter 2). When you provide opportunities for students to make predictions, such as how the curious sensory input or other novelty connects with the coming lesson, they remain more attentive to sensory input (through your instruction and their discovery) to support their ideas. Attention is sustained further as their brains seek to find out if their predictions are correct (Hunter, Abraham, Hunter, Goldberg, & Eastwood, 2016).

The following examples demonstrate ways in which you can include opportunities for making predictions into your lessons.

Discrepant events. These happenings are unexpected and puzzle the observer. Something that does not appear or turn out the way the brain expects promotes enhanced attention intake as the brain seeks an explanation (Griffiths, 2015).

Gray Matter

Patterns and Predictions

The system of storing information in related patterns (explored in Chapter 3) is a positive survival system that enhances the accuracy of prediction (and future memory) in animals. The brain makes predictions (responses to changes or choices in the environment) based on activation of memory networks constructed over time in response to the outcomes of choices or predictions made. As experiential data accumulate, these stored memories become the basis of more successful future predictions, interpretations, or responses (Peng, Zheng, Zou, & Liu, 2015).

You can capture students' attention because they want to know how to make sense of something unexpected. Place a white carnation in a vase containing blue food coloring; after a few days, it will show blue coloration in its petals. At that point, place the carnation in a clear vase with clear water, present it to your students, and invite them to figure out what happened. Or, out of students' sight, rub a balloon on a wall or your shirt. As you hold it over students' heads and their hair stands up, ask them to predict why this might be happening. In both examples, students will likely be curious to learn if their predictions accurately explained these mysterious phenomena and will sustain focus as you reveal the science behind transpiration and cohesion in plants or static electricity.

A mid-lesson discrepant event using curiosity and prediction is a great RAS rebooter. Set an orange previously dipped in liquid nitrogen on a table or counter in front of the room and "inadvertently" knock it off the surface. In its liquid nitrogen–induced frozen molecular state, the orange, which appears normal, will startlingly shatter into dozens of pieces when dropped. Ask students to predict how the surprising event might connect to the topic to come. After making their predictions, students will readily sustain their attention for topics from physics, to the breaking up of the Austro-Hungarian Empire or the polar ice caps, to the breaking down of complex problems into smaller ones, or to a famous breakup in literature (ah, poor Romeo and Juliet!).

Mystery envelopes. Creating a bit of suspense and cognitive dissonance can be as low-tech as a manila envelope! This example comes from a 4th grade social studies unit Malana taught about the California gold rush.

After the students had learned about the activities of the forty-niners who had rushed to the state to search for gold, Malana wanted them to consider the impact the miners and gold seekers had on the indigenous tribes of that region. Although they had studied Native Californians throughout the year, they had not yet considered them in the context of the gold rush.

At the start of the lesson, she held up several manila envelopes with large question marks on them and said, "Inside these envelopes are pictures of tools that people in California used in 1849. What do you predict might be in these envelopes?" Students eagerly called out tools used by gold seekers at the time: pans, picks, shovels, sluice boxes, dynamite, and so on. After their predictions, she passed out the envelopes to small groups of students and asked them to explore and discuss the contents. Inside, students found images of arrowheads, grinding stones, reed baskets, canoes, and other tools used by Native Americans.

The images caught the students by surprise and prompted them to consider anew the people already established in California before the wave of newcomers rushed into the wilderness seeking their fortune. This unexpected shift in perspective captured her students' attention and encouraged them to consider how this clash of cultures affected the well-being and way of life of the indigenous people of California.

Previewing. Before teaching a new topic, invite or assign students to preview the text (in class or at home the night before) and predict what they'll learn and what they might especially enjoy in the coming unit. Without the stress of having to "learn," students can engage simply to build curiosity.

Previewing is especially useful for things that will jump out to the RAS; students' RAS filters will be drawn to bold prints, pictures (especially of faces and animals), big empty spaces, and similar images. After a few minutes of previewing, ask students to share what they noticed. These collective observations and predictions will arouse their attention circuits as the reading and unit continue.

Unexpected objects, or the power of a radish. Like many children, you once may have objected to radishes as a garnish on your plate. Imagine students walking into your classroom and finding a radish on every desk. Instead of prompting disdainful looks, these radishes can become sources of novelty and delight.

When I first used a radish on each desk as a prediction stimulator, students were—happily—more enthusiastic than I had expected. Some even asked if they could keep theirs and eat them when we were finished. The radish was not an unfamiliar object, but having one on their school desks was a curious situation and certainly a change in the usual pattern. I told them that the radish would be linked to their upcoming unit and encouraged them to keep an open mind as to what that connection might be. Now their attention was activated to admit "clues" to the puzzle of a novel object on their desks as they remained engaged and motivated to discover explanations and make predictions.

This novelty triggered an enthusiastic and far-ranging discussion. For example, for a unit on westward expansion, I posed questions related to the radish as they progressed. One question that was carried throughout the unit was "How could your radish relate to the experiences of people during westward expansion?" Their written responses showed much more depth of understanding and compassion than those of students in previous years. Here are two examples:

- Tribes that farmed needed good soil and rain but were given the worst land when they were forced onto reservations. Their poor harvests made them bitter like radishes.
- The colonists kept the best land for their own farming and grew green, leafy crops like the radish leaves.

Making Concrete Predictions

After their curiosity has been provoked and initial predictions encouraged, students sustain greatest attention if they all make predictions, have multiple opportunities to revise or add to these predictions, and independently write them down (or otherwise respond, as with clickers). Providing multiple opportunities for conjecture creates a learning environment in which students remain focused and interested because they now want to know what you have to teach. The reason it is important that all students participate is that brains that are displaying curiosity and making predictions will be far more invested in the information that follows.

Imagine being with a group of friends who make a wager about the number of attendees at a sporting event. They are likely to be more observant to their surroundings and alert to the announcer's comments than a group member who does not get in on the wager.

For prediction to entice the brain to stay connected with information, the brain owners must remain invested in their predictions. For students to really consider the information and make enthusiastic predictions, they need sufficient time to analyze the question (or source of curiosity). When a teacher routinely asks questions and calls only on students who raise their hands, many of their classmates stop actively making their own predictions, especially when the student called on gives a correct response before the others have had time to consider their own. The brain finds no pleasure in trying to make a prediction when it expects that someone else will give away the answer. Having all students think about and write down or click in their predictions, without calling on any individual, gives everyone a chance to be an active participant. Here are some ways to do that.

Whiteboards or response cards. You can ask students to predict what a curious item might have to do with the day's class or to answer a simple question such as "Is a lizard a mammal or a reptile?" They can write their predictions on individual whiteboards or use response cards. Response cards could be preprinted with words or phrases such as yes/no, true/false, or I agree/I disagree, and students can point to their answer. Instructing them to hold their predictions close to their chest when they show you their answers relieves them of the fear of making mistakes because others won't see their responses. You also can tell if students need more time when a number of students haven't yet held up their responses. Making this observation eliminates the question that students are often too embarrassed to answer: "Who needs more time?"

Clicker systems. The digital exchange of communication in "wired" classrooms provides another way for all students to make predictions and respond to teachers' questions. This system can be expanded to show them an ongoing tabulation of class responses so they can further evaluate their predictions. Studies of undergraduates using clickers with feedback-system links have reported improved learning outcomes (Anderson, Healy, Kole, & Bourne, 2013; Deslauriers, Schelew, & Wieman, 2011). In such a clicker system, much like individual response cards or whiteboards, the teacher can ask a question, and students respond with their individual yes/no, numerical, or multiple-choice letter answers. However, with clickers, the teacher can see each individual student's response, as well as the class responses as a whole. This feedback provides immediate guidance, so teachers know if they need to revise instruction on something missed by a number of students, or if they should avoid tedious repetition of information already mastered.

Without formal clickers for tabulation, a low-tech version of getting feedback from students uses simple preset response cards with the letters *A, B, C,* and *D* in each corner. Before doing an experiment, for example, you could ask, "What will happen to the balloon's volume as it rises into space?" Students put their heads down on their desks and hold up their response card pointing to their chosen letter (or simply hold up the number of fingers that represent their responses from multiple choices listed as 1 to 4). After the various possible responses are counted and the tabulation written on the board, students lift their heads and follow up with partner or group discussions or further investigations before voting again.

Open-ended questions. Questions that do not have a single correct answer and that are student centered (connected to students' interests or experiences) can maintain interest and curiosity—and keep predictions coming—especially when students have a variety of ways and times to respond and revise. For a whole-class discussion, allow enough thinking time before calling on any respondent. Another option is to allow individual thinking time and then divide students into pairs or small groups, where it's much less stressful to make predictions and even mistakes. These opportunities promote brains engaged in the curiosity, prediction, and feedback reward experience that keeps students on track.

Embracing Teachable Moments to Sustain Interest

A migratory duck once flew through an open window in my 5th grade classroom and flapped around in a panic, bumping into walls, until I opened an outside door and it escaped. Although the event certainly triggered a huge and exciting disruption, it became a teachable moment when I was able to set aside the day's lesson plan and let students share their questions, concerns, and suggestions. From that random duck, they expanded into a student-directed discussion and inquiry about the loss of natural rest stops for migrating birds due to human encroachment on the land.

Although curiosity remains a driving force in attention and learning, we often see children gradually construe school as a job where they must follow someone else's agenda and not their own curiosity. You can recapture that curiosity and passion for learning when you take advantage of experiences they (or you) didn't expect that take place at school, triggering their attention as a powerful tool to connect with learning and wisdom in the moment and beyond.

You have probably observed students' passionate reactions to unexpected or unplanned events that ignite their emotions—perhaps after an assembly with an inspirational speaker or the announcement of a momentous news event. Teachable moments might come when you announce that a class member has unexpectedly moved away or when a butterfly flies in through the classroom window. Sometimes you don't have enough time to follow up with these potential teachable moments, but when you can, take advantage of your students' heightened state of attention and awareness.

To help the teachable moment become a focus rather than a distraction, consider the following options to sustain students' engagement and connect it to learning goals.

Prompting conversation. Older students in particular may be reluctant to open up about their personal responses or interpretations of an experience. Student-centered questions can facilitate their personalizing of the experience. Have the students discuss as a whole class, with small groups, or with partners the things that surprised, interested, or disturbed them. You can also ask what more they want to know or what they would like to do about what they just saw, experienced, or heard.

You've no doubt shared powerful assemblies with your students during which they heard speakers provide firsthand accounts of compelling personal stories, perhaps sharing the struggles of living with physical challenges, years of captivity in a POW camp, or the traumas seen as a first responder. These speakers can naturally ignite teachable moments and discussions. Sometimes your teachable extensions in the classroom will be facilitated by your previewing the topic. With your background knowledge, you'll be able to develop ways to sustain the effect of these speakers.

Journaling or written reactions. After a bit of class discussion, you can encourage reluctant participants to connect with their heightened interest and emotions through writing. This approach certainly can help all students to focus more clearly on both their feelings and the content of the information and to make connections. These writings can be mostly private, but you might invite students to share a phrase or sentence with the class. Later, their writing can serve as prompts for more formal essays or editorials about the subject. You can compile these into a class compendium posted on the bulletin board or sent home to parents, submitted to a local or school newspaper, and even forwarded to the motivational speaker who prompted the reactions.

Extending teachable moments. When teachable moments stem from highly emotional class responses, the shared compassion can strengthen the class community. A communal emotional experience, with students giving and receiving comfort and understanding from each other, builds bonds that can be recalled during times of conflict. In such times, a class community can again express the caring feelings they shared earlier. Once, when a series of arguments about handball-court rules at recess seemed to be disrupting class harmony, I said, "Remember how we were able to comfort each other after our hamster died? Can we use those caring feelings now as we work out our handball-court problems?"

Questions students raise about the events that inspired a teachable moment have future value; they are filled with the emotional importance of that powerful shared experience. You can collect a list of the questions raised by these moments and place them on a wall chart for future consideration. If the emotional moment was a terrorist act, for example, students might raise both philosophical and historical questions that could be applicable to future lessons in history, literature, or even science: Should terrorists who are arrested receive the same rights as other people accused of crimes? Was terrorism ever part of the American struggle for independence or minority rights? How are buildings designed so they implode (fall inward) instead of exploding outward when powerful detonations occur?

Referring to the questions on this list can enhance the personal significance of future lessons about related topics. The questions, originally written in response to the emotional surge of the attention-grabbing event, will rekindle some of that emotional energy, and students will respond with the heightened engagement and personal connections that propel a memorable lesson.

Powerful opportunities arise when we support students' responses to the effect of teachable moments. These opportunities can help them develop their skills of critical thinking and open-mindedness. After all, aren't those the skills we hope they will use in response to emotionally charged issues when they are adults and future leaders?

Elevating Attention Skills in Executive Function Networks

Effortful control of attention develops gradually throughout childhood and young adulthood, with a maturing and strengthening of the executive function communication networks. You can promote this development by providing opportunities for students to build top-down influence on their attention filters. Focusing and concentrating for long periods can be challenging for students—as it is for all of us. You can help them improve their abilities to stay on track longer by developing classroom opportunities that exercise those executive function networks that direct and sustain attention. Chapter 4 provides detailed discussions of the whole topic of boosting executive function; here, the focus is on some strategies for building the skill sets that promote attention focus.

Building Attention Skills Through Practiced Observation

You can help students build attention skills with guided experiences for sustained focus and observation. After considering opportunities to build their focus and observational skills, we'll look at strategies that promote students' self-awareness of their attention control capabilities.

Opportunities for younger students. With younger students, games and physical activities can be incorporated into learning to provide powerful opportunities to help build focus and extend self-regulation (Rueda, Posner, & Rothbart, 2005). The following games can be played at any time or incorporated into instruction.

- Encourage slow (but curious) observations, like following clouds moving in the wind, jet contrails spreading across the sky, or a snail slowly moving in the yard. Observations can be recorded in science journals or used to inspire artwork or creative writing.
- Toss slow-moving balloons instead of balls. While reviewing vocabulary words, students could toss balloons back and forth. A student could say a word and its definition as the balloon slowly arcs through the air or name all of the synonyms for a particular word that she can recall before the balloon is caught by another student.
- Draw a winding chalk trail with two lines students can walk between, using focused attention. The lines could follow the plot of a story, a historical time line, or geometric shapes.
- Play Follow the Leader using subtle or precise movements mixed in with broader ones. The movements could mimic those of characters in a book, behaviors of animals, or scientific principles such as the life cycle of a frog.
- Play games that require children to think or wait before acting on their first response (e.g., Simon Says or Red Light, Green Light) to build their skills of delaying immediate responses.
- Build concentration and focus by letting children find Waldo or subtle differences between two otherwise identical pictures. Students could compare and find the differences in similar maps, graphs, animal markings (patterns on the fur, feathers, scales, or skin), habitats, works of art, or photographs of natural phenomena such as sunsets, ocean waves, and waterfalls.
- Practice mindful awareness by having children intentionally use all their senses while experiencing an activity. For example, a classic introduction to mindfulness is to have students thoughtfully explore eating a single raisin as they draw their attention to all of its sensory details. This activity could carry over into a writing assignment invoking sensory details, an art lesson on textures

and shading, or a science lesson on dehydration and the evolution from grape to raisin. (Mindfulness practices in general can be a powerful way to enhance focus and attention in people of all ages. We discuss mindfulness in more depth in Chapter 2.)

An opportunity for older students. You may have heard about an experiment done in some police academies during the first few weeks of the program. A confederate of the teacher runs into the class, steals the teacher's briefcase, and runs out. The students are then asked to write down all the details they can recall describing the intruder and the intruder's actions. After they have written their reports, they are told that it was a setup, and the scene is reenacted. Predictably, they are astonished and embarrassed by how inaccurate their own eyewitness accounts were.

The experience just described dodges a high-stress individual reaction because participants see how many details were missed by *all* classmates. As such, they are receptive to the lesson to be learned: paying careful, studied attention is quite different from passively watching and listening.

You can produce a similar situation in the classroom; however, make sure that the classroom visitor's actions will not alarm students. For example, you can invite a colleague unknown to the students to come in with a basket of rose petals. (In advance, coordinate positions in the room so you cannot see her.) Have her walk to the back of the room, silently sprinkling the flower petals, and leave before you turn around. Prompt students to write a brief description of the visitor and her actions, including as many details as possible, such as hair color, clothes, and height. Did she make eye contact? Keep her eyes down? Shift them from side to side? More extended questions could invite conjecture about why the person came to the classroom. Did she seem nervous or confident? Where did she go upon leaving? Encourage students to give reasons for their interpretations. After the discussion, have the visitor return and do a reenactment so that students can notice the discrepancies between the event and their recall.

While their curiosity sustains their interest, you can explain that the observational experience reveals that their brains' attention intake is not always accurate and frequently overlooks much sensory information (e.g., descriptive details). The explanation will help them appreciate the value of attention-control focus, especially in emotionally charged situations when clear thinking is most challenged. You can certainly motivate some students' interest further by letting them know that professional detectives or investigators in science, medicine, crime labs, and archaeology have been trained and work actively to develop their observation and focused-attention skills so they can be successful in their jobs.

Transfer the insights from their observation of the unexpected classroom visitor to other experiences incorporated in your instruction. Let the students know they'll be developing those same observational skills as they observe a scenario, listen to a passage you read from a book, or watch a short video. After the experience, have them repeat the "stranger in the room" process of first writing what they recall unprompted, then adding to their observations in response to questions, and finally making interpretations that they support with evidence. They may also choose to reread or review the image, passage, or video to identify further details. Through repeated practice, they will incorporate the observation-prompting questions as part of their own independent observations, thereby increasing the quality and quantity of sensory input they can accurately perceive.

Elevating Attention Skills Through Metacognition

Attention is not just a simple process of information getting through the attention filter. Attention is a combination of self-awareness—recognizing the pulls on attention (both externally, in the environment; and internally, influenced by thoughts or worries)—and prioritizing the array of sensory information to accept the most important and block the distracting (Vossel, Geng, & Fink, 2014).

Becoming aware of the impact of distractions (distraction awareness) and learning how to avoid or minimize that impact (attention keeping) are two interventions that can strengthen students' developing executive functions of attention, concentration, and distraction-blocking control.

Distraction awareness. You can guide students' recognition of when they are less efficient at understanding or focusing on learning as a result of distractions and help them build skills and habits to inhibit the influence of distractions (Marshall, Bergmann, & Jensen, 2015). Explain to students that the ability to self-regulate what does and does not get their attention is still developing in their brains and can be strengthened by practice, similar to exercising a muscle. Plan for ways for them to recognize their progress as their attention-focus skills build. (See Chapter 2 for more about feedback on progress.)

Students will come to better understand the effect of distractions with a demonstration of how their focus and learning are reduced by distractions that you produce. For example, after explaining what you are about to do, you can provide similar types of lessons under a variety of distracting conditions (e.g., turn on a radio, repeatedly drop books, have a colleague come in several times and interrupt your lesson). Following these lessons with noncredit, self-corrected quizzes enables students to gain more insights about the impact of distractions on their learning. Class discussions after these experiences will be enlightening and provide an opening to discuss strategies.

After you moderate a class discussion about distractions and students have a chance to share strategies they use or could use to combat them, they'll be ready for the next step: advance preparation. Help students keep notes of what situations, subjects, class activities, or learning environments are most likely to stymie their attention control (e.g., an assembly, a class speaker, student presentations, recess when other students can be heard playing outside). Give them time to prepare before these situations: "We're about to go to the computer lab. If you recognize one of your attention-control thieves, which strategy will you be ready to use to keep control?"

Teaching students about their attention-keeping powers. A skilled teacher at Wichita Collegiate School in Kansas prepared a class list of attention robbers and attention-keeping strategies, some of which are presented here.

Attention Robbers

- Side talking
- People trying to be silly in class
- People making sounds at desks—clicking pens, humming, moving chairs
- Outside noises
- Too many decorations

- Teacher talking too much
- Not enough sleep
- Being hungry
- Being upset about something in your personal life

Attention Keepers

- Tell your teacher if you are having a bad attention day.
- Stand at the desk
- Sit for success (move to a seat farther away from distractions or temptations)
- Employ noise-canceling headphones
- Bring a water bottle
- Get sleep and eat breakfast
- Use a cardboard privacy "office" when doing desk work or taking tests
- Prepare your mind to focus in advance when you know it will need to

When teaching students about strategies that build brainpower, their recognition of what they can get from their efforts can be motivating. Here are some examples from class discussions about what students thought they could get from building their powers of attention over distraction:

- Remembering the content of classes so I can do homework more efficiently, accurately, and in less time
- Knowing the question or topic when I'm called on in school
- Keeping track of my assignments and what materials I need when and where (e.g., things I need to bring from home for school)
- Reading a book and keeping my mind on it
- Staying focused (even during boring classes) so I remember what is taught and don't have to spend time relearning it for homework and tests
- Following all parts of directions
- Being alert to trick questions and finding my mistakes on tests
- Not being thought of or criticized as "scattered," "inconsiderate," or "irresponsible"

- Being aware of what pulls my attention off task so I can stay on task and take control of my time

Surprise students today and help them build attention-focusing skills, and you will be rewarded by their successful memory retrieval months from now. Your interventions for attention focus will empower them with the attention-intake boost they need early on. Similarly, your ongoing interventions will encourage them to build and use executive functions and higher-order thinking to sift through information, form connections and relationships, and achieve the ultimate goal of instilling new knowledge solidly into their memory storage centers.

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About the Authors

Judy Willis, MD, MEd, is a board-certified neurologist who combined her 15 years as a practicing neurologist with 10 subsequent years as a classroom teacher to become a leading authority in the neuroscience of learning. With her unique background in both neuroscience and education, she has written 9 books and more than 200 articles about applying neuroscience research to classroom teaching strategies.

After graduating Phi Beta Kappa as one of the first seven women to graduate from Williams College, Willis attended UCLA School of Medicine, where she was awarded her medical degree. She remained at UCLA and completed a medical residency and neurology residency, including chief residency. She practiced neurology for 15 years before returning to university to obtain her teaching credential and master's degree in education from the University of California, Santa Barbara. She then taught in elementary and middle school for 10 years.

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