# UNCOMMON SENSE TEACHING

## Practical Insights in Brain Science to Help Students Learn

From the creators of the popular online course Learning How to Learn

Barbara Oakley, PhD; Beth Rogowsky, EdD;
Terrence J. Sejnowski, PhD

Advance Praise for

# UNCOMMON SENSE TEACHING

"This book is an absolute must for anyone who cares about education. The brain is geared for learning and adaptation, and this is the definitive set of tools for helping students get the most out of learning. Learning is supposed to be fun—knowing how to do it in the way your brain is designed to learn is the most fun of all. What a delightful, brilliant book."

—Mayim Bialik, PhD, four-time Emmy nominee for *The Big Bang Theory* and *New York Times* bestselling author of *Girling Up* and *Boying Up*

"This accessible and engaging book will make it easier for teachers to teach and for students to learn. The authors provide the kind of information all prospective teachers should get during their training—but rarely do."

—Natalie Wexler, author of *The Knowledge Gap*

"Learning is about making changes in the brain. This book describes how that happens, why it can be difficult, and how to facilitate more learning in the classroom. Veteran teachers will find explanations for why some of their techniques work and ways to improve them. Newer teachers and parents supporting students at home will find countless practical suggestions to help learners succeed."

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"This is the first neuroscience-based book I've read that has provided me with a deeper understanding of how the brain functions while learning, and specific strategies that should be used while teaching. I recommend it most highly."

—Robert Marzano, PhD, cofounder of Marzano Resources and author of *The New Art and Science of Teaching*

“The authors bring to this highly practical, user-friendly book a deep understanding of teachers and classrooms, the implications of neuroscientific findings for successful teaching and learning, and the ability to write about complex ideas in an approachable way.”

—Carol Ann Tomlinson, EdD, author of *How to Differentiate Instruction in Academically Diverse Classrooms*

“I can’t wait to get this insightful book into the hands of teachers, home educators, and parents. Every kind of learner is honored and helped in this practical handbook on brain function and study habits. Highly recommended!”

—Julie Bogart, author of *The Brave Learner*

“A fantastic resource. The authors translate sophisticated brain research into practical insights anyone can apply immediately. A must-read book for educators and students alike.”

—Scott H. Young, author of *Ultralearning*

“Informed by neuroscience, leavened with humor, and written with verve and wisdom, *Uncommon Sense Teaching* is a brilliant new take on the ancient problem of pedagogy. I can’t wait to apply its insights to my own teaching—and my own learning.”

—Steven Strogatz, PhD, Jacob Gould Schurman Professor of Applied Mathematics at Cornell University and author of *Infinite Powers*

“The neuroscience-based tools in this book empower educators to make meaningful pivots in teaching practices to increase student success. Foundational reading for educators across the K-12 and higher education spaces.”

—Jacqueline El-Sayed, PhD, Chief Academic Officer, American Society for Engineering Education

"Every educator who reads this book, no matter how long they have been teaching, will take from it a better understanding of the brain and practical strategies to bolster student learning, performance, and well-being."

—James M. Lang, PhD, author of *Small Teaching*

"In *Uncommon Sense Teaching*, the authors do a marvelous job of bridging gaps between teaching, psychology, and neuroscience. As a cognitive scientist and a teacher myself, I found the book full of fascinating research from my field as well as practical strategies I can use in my classroom tomorrow. If you're looking for research-based teaching strategies, with evidence to back them up, *Uncommon Sense Teaching* is a must-read."

—Pooja K. Agarwal, PhD, coauthor of *Powerful Teaching*

"This book translates a wealth of knowledge about cognitive science into action, equipping teachers with a better understanding of the science of learning and offering practical strategies to help students learn."

—György Buzsáki, MD, PhD, author of *The Brain from Inside Out*

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Barbara Oakley, PhD,
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Terrence J. Sejnowski, PhD

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# Contents

# A Note to Our Teacher-Readers

*Uncommon Sense Teaching* may sound like a presumptuous title. After all, if you've already been teaching for a while, most insights about teaching seem like simple common sense.

Enter Barb Oakley and Terry Sejnowski. Their massive open online course (MOOC) "Learning How to Learn," with its brain-based approach to teaching and learning, has catapulted into being one of the most popular massive open online courses in the world, taken by millions. This popularity is a tribute to the value people place on fresh, practically useful insights. The course combined Terry's expertise as a computational neuroscientist and neural network pioneer at the Salk Institute and Barb's know-how as a professor of engineering, a linguist, and an adventurous world traveler to explain how brains learn. Much of the information in the course was so new it hadn't made its way into schools of pedagogy. But it is profoundly useful in helping people learn more effectively. And it also overturns some commonsense intuitions about how to approach teaching.[1]

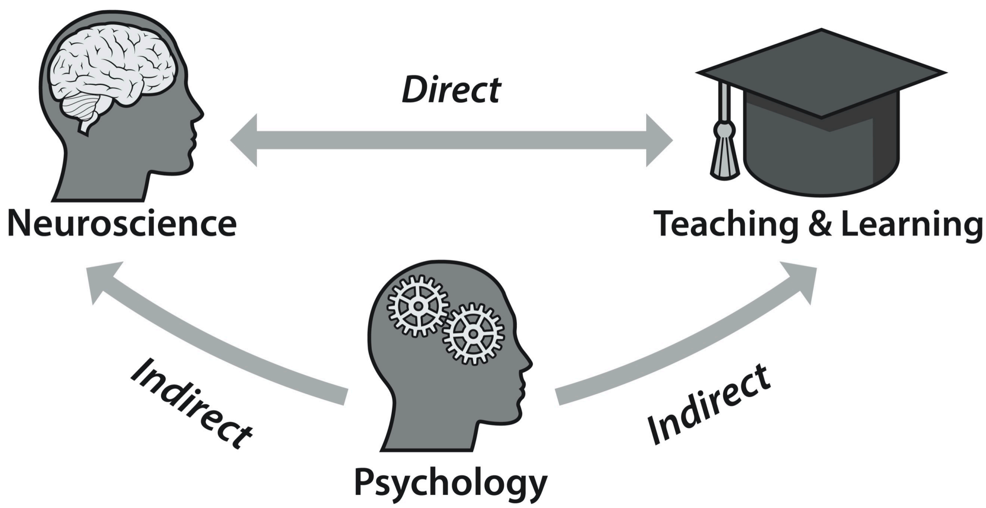
Let's step back a moment. For too long, teaching has been called an art, and yet the art of teaching remains elusive. New teachers enter the profession wanting to create masterpieces, but when they discover classrooms filled with diverse learners and are faced with overwhelming expectations for student success, they quickly move from budding Leonardos to starving artists. Most teachers want to be the best teacher that they can be. But they naturally fall into teaching the way they were taught. Unfortunately, the way they were taught, which was the way *their* teachers were taught, doesn't necessarily work for what students need to learn today.

Enter Beth Rogowsky. In the 1990s, when Beth first began her teaching career, she was eager to change the world, one student at a time. During her fourteen years of experience teaching middle schoolers in both urban and rural classrooms, she became revered as a teacher. But she began to realize that although her students were productive and having fun—a laudable goal—they often weren't learning at the level she wanted.

So she went further. Her doctoral dissertation on computer-based cognitive and language training brought her to the attention of leading neuroscientists. She would ultimately complete a three-year postdoctoral fellowship at the Center for Molecular and Behavioral Neuroscience at Rutgers University, where she worked with a network of prominent neuroscientists. Today, Beth is an education professor at Bloomsburg University of Pennsylvania, where she frequently observes K-12 classrooms as part of her professorial duties. What's striking is how often she sees the same ineffective practices she used in classrooms decades before—even though research has shown us new and better ways.

Beth's experiences have given her an in-depth understanding of two very different worlds—day-to-day teaching and neuroscientific research. She's become convinced, along with her coauthors, Barb and Terry, that teachers can use practical insights from neuroscience to make dramatic improvements in their students' abilities to learn.

Differences in students' working memories, for example, demand differences in teaching techniques. Neuroscience gives us insights about structuring those differences while balancing on the tightrope of teaching live, in front of students. Ultimately, children can give up in their studies, not because they don't have a growth mindset[2] or they haven't been taught in their preferred learning style[3] but because they honestly don't understand how to learn the sometimes difficult topics they're learning. And teachers often don't know foundational research insights, such as those involving retrieval practice and the value of teaching through both declarative and procedural pathways. Breakthroughs in these areas show us how we can help students more rapidly settle ideas into long-term memory so they can think and work more creatively. Neuroscience is vital, because it can give us far more direct insight into the foundations of learning and education than any other discipline.[4]




Neuroscience supports an understanding of teaching and learning (and vice versa) both directly and via its connections to psychology.

This book isn't meant to make a dramatic overhaul of your teaching. Although you'll see new teaching strategies to enhance the approaches you are already using, you will also see tried-and-true techniques. Because you'll be learning *why* these strategies are so effective, you'll also begin to see how to make slight but powerful tweaks that will enhance *all* of your teaching.

We've tried to write this book not just for K-12 teachers but for teachers of all kinds, including university professors as well as parents and caregivers. We keep the jargon to a minimum, and when we use a specialized term, we define it. This is especially useful for those new to the profession. If you're a seasoned teacher, you may even enjoy a refresher on some definitions you've taken for granted for years. We've included a variety of practical exercises and teaching tips for use with students across a wide span of grade levels.

The three of us are writing this book together. We focus here on teaching techniques that are broadly effective based on converging scientific evidence from both cognitive science and brain science, as well as our own classroom experience.

The work you're doing as a teacher is vitally important, not only for students but for society as a whole. Ultimately, teaching is a learning profession—whatever you know, it helps to learn more. Join us, then, as we share our learning together in *Uncommon Sense Teaching*!

Barbara Oakley
Beth Rogowsky
Terrence Sejnowski

# 1

# Building Memory:

## How Students Fool Themselves into Thinking They're Learning

Katina begins to tear up as she looks at her score. You already know why she's ready to cry—she barely passed the exam. "I just don't know why I lose everything when it comes time to take the test," Katina maintains. "I understand it fine when I'm at home or in class. It's just that when I see the test, I freeze. I think I suffer from test anxiety. Or maybe it's just that I can't do math. My mom says I'm just like her—bad at math."

Katina, by all appearances, is a good student. Testing has ruled out obvious challenges such as reading or math disorders. And Katina does her best to focus on what's being taught. She finishes her homework, even if it's sometimes imperfect. She also creates great craft projects and has many friends. In other words, she's creative and the kind of person other students enjoy being around.

It's not just Katina's stress with math.[1] Ben has the same problem. And Federico struggles with writing, Jared with Spanish, and Alex with understanding the periodic table. In fact, perhaps a third of your class seems to have already boxed themselves in with an "I can't" mentality in one subject or another. You worry that when it comes to state standardized tests, Katina—and others like her in the class, will pull down the school's average. Downward goes the school's average and the school's morale. And downward goes *your* morale.

What's going on? Can you help Katina, Jared, and the others improve their ability to be successful learners in their seemingly weakest areas?

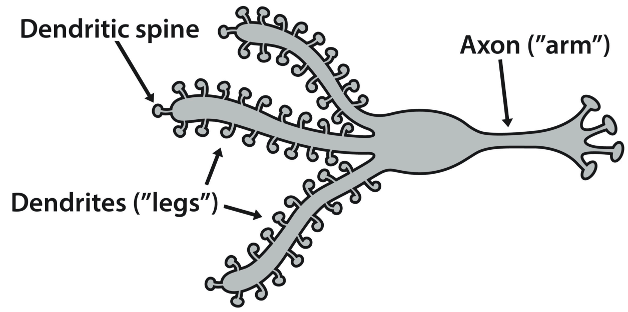
## Learning Creates Links in Long-Term Memory

To understand what's going on, it helps to take a step back and look at the fundamental building block of our brains—the biological cell called a *neuron.* Each person has about 86 billion neurons. There are plenty of neurons to go around—even your most challenging students have loads of them! Whenever you or your students learn a new fact, concept, or procedure, you are making new connections between small sets of neurons.

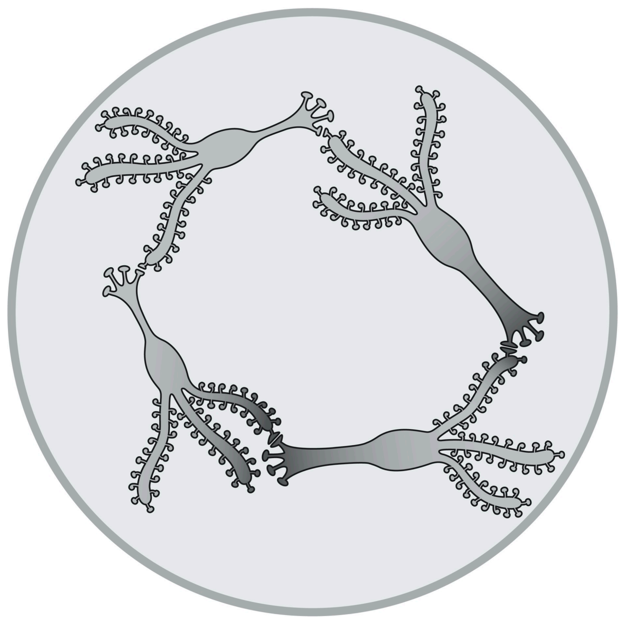
Neurons, if you look only at their main parts, are simple. They have legs, which are called *dendrites.* The legs have lots of *spines* on them, almost like a cactus (technically, these are called *dendritic spines*). And they have an arm, which is called an *axon*.

When students are actively focusing on their learning, they are *beginning* the process of making connections between neurons. These connections start forming whether students are sitting in front of you in class, reading a book at home, trying out their first lay-up in basketball, or deciphering the ins and outs of a new computer game. In other words, they are encouraging their axons (neural arms) to reach out and almost touch dendritic spines.

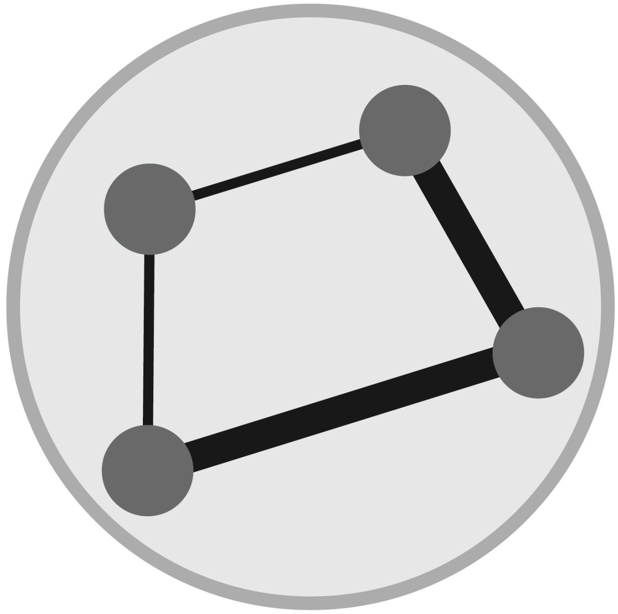
Once a neuron involved in the learning process comes close enough to a neighboring neuron, a signal jumps across the narrow gap (called a *synapse*) between the two neurons. That signal, as it passes from neuron to neuron, is what forms our thoughts—it's the foundation of our learning.




The main parts of neurons are easy to understand—they have spiny legs and an arm. We've dramatically enlarged certain features of the neuron in this drawing so that you can clearly see the axon, dendrites, and dendritic spines.



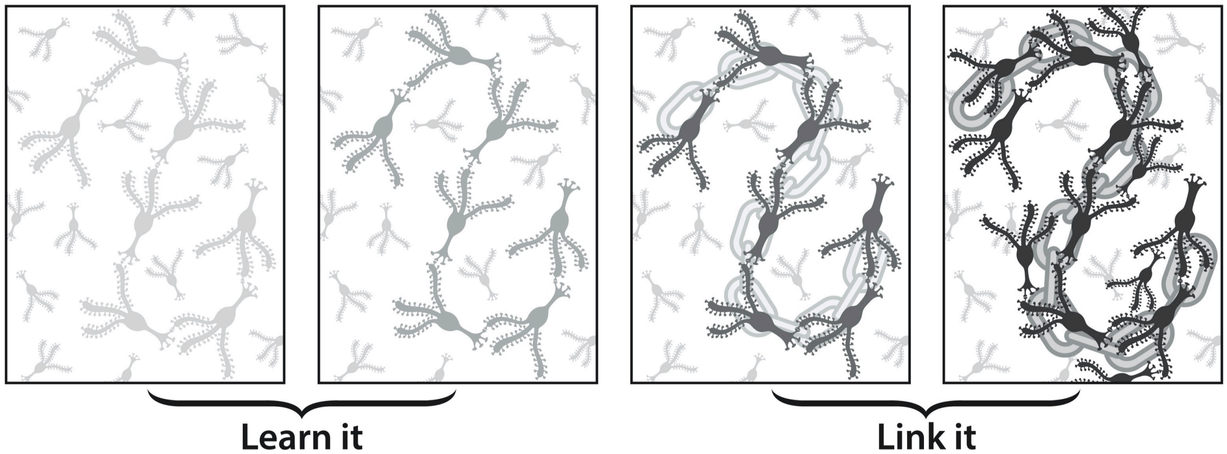
When students learn something, they form links between neurons. The spine of one neuron comes up against the axon of another neuron.



A set of connected neurons can be simplified as a connected set of dots. Stronger connections are shown with thick lines, and weaker connections with thin lines. A shaded circle is drawn around the set of links. This circle, with its "dot neurons" and links, represents a newly learned concept or idea.

## Learn It, Link It

**As students are learning, neurons are linking and strengthening. We refer to this process as *learn it, link it.*** This term has its origins in *Hebbian learning,* a process where neurons that fire together near simultaneously in time wire together.[2] (Donald Hebb, a Canadian psychologist, first described this process.) In other words, when a certain set of neurons begins to work together more often, they become like a well-practiced choir. "Singing together" is in fact how neurons form a sequence of links with one another, as shown in the above illustration.[3]




*Learn it, link it:* In the first *learn it* image on the left, you can get a sense of neurons beginning to find one another as a student is introduced to a new concept–for example, during a brief period of explanation by a teacher, or while reading a textbook or watching a video. Connections are made as a student follows along and practices the material (the second image). As a student works in active ways with the new idea, concept, or technique, links solidify in long-term memory and form the basis of proficiency (the third image). Still more practice in novel ways can extend the learning to new areas (the fourth image), which allows the neurons to tie in with other neurons that underpin related concepts.

To get a sense of how the neurons link together, look at the "Learn it, link it" panel of images above. When a student first starts to learn something, neurons begin to find one another and make connections, as you can see in the panel's first and second images. We refer to this as the *learn it* phase. (Actual neurons are laid out in a more complex structure in the *neocortex*—the evolutionarily new area of the brain that helps us do our heavy-duty thinking. But we'll keep things simple here with our neural layout.)

As a student solidifies her learning, she creates stronger links, as shown in the third image. Here, she reaches proficiency. As she practices the learning in novel and challenging contexts, she strengthens the foundational links and extends them even further, as shown in the fourth panel. We refer to this strengthening and extending of neurons as the *link it* phase. This broader neural entanglement is symbolized by the larger-sized links, with the richer set of neurons underlying these links.

People sometimes think they have only limited room in their long-term memories. This isn't true. The brain's information storage capacity appears to be around a quadrillion bytes. (A quadrillion is a 1 followed by 15 zeros—you can think of it as the number of dollars owned by a million billionaires.) This means that far more information can be stored in the brain than there are grains of sand on all the beaches and deserts of the world.

People's real problem with memory isn't how much they can store. It's getting the information into or out of memory. This is a little like having a music streaming subscription with a nearly infinite capacity for songs. In this situation, your real challenge is getting to the song you're looking for. There are around $10^9$ seconds in a lifetime and $10^{14}$ synapses in the brain, so we can afford to dedicate $10^5$ synapses per second as we experience the world.

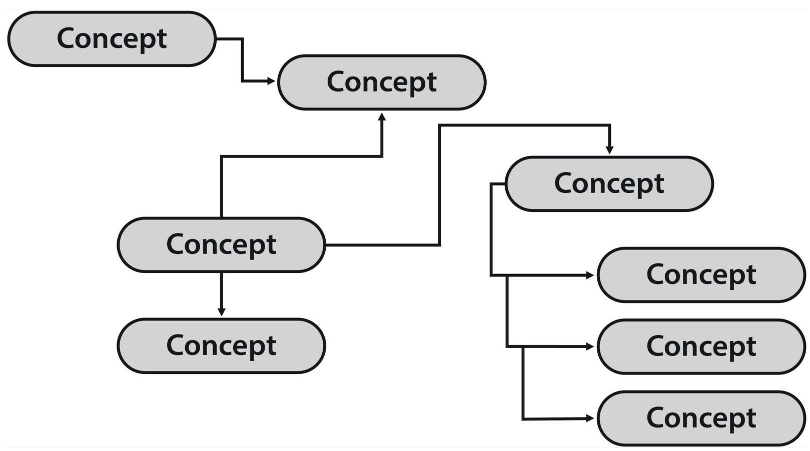
The kinds of neural connections we are talking about form in long-term memory. Getting these connections started can be hard work. Think about this. A student has to get a dendritic spine to pop out on one neuron, and the axon of another neuron somehow has to make a good connection with that spine.[4] And it's not like neurons have to connect in just one place. Altogether, clumps of neurons need to make dozens, hundreds of thousands, sometimes even millions of these kinds of connections, even when a student is learning something relatively simple—like how to say a word in a foreign language or how to solve an easy multiplication problem like 5 × 5.

But here's the challenge. Katina and Jared are *not* forming links in long-term memory when they study. Instead, they're placing the information in a different place altogether—a temporary storage shelf called *working memory.* You can think of working memory as a slightly slanted shelf that doesn't hold things very well. When you place balls (pieces of information) on it, they roll off as soon as you let go.

But before we dive deeper into memory, let's take a quick survey—a preassessment[*] of the material we're about to explore.

**Check one** of the following to indicate which technique has been shown by research to enable you to learn most efficiently.

- ☐ Reread
- ☐ Highlight or underline
- ☐ Recall (retrieval practice)
- ☐ Create a concept map such as the one shown here.




(Check the footnote for the answer.*)

## Long-Term Memory Versus Working Memory

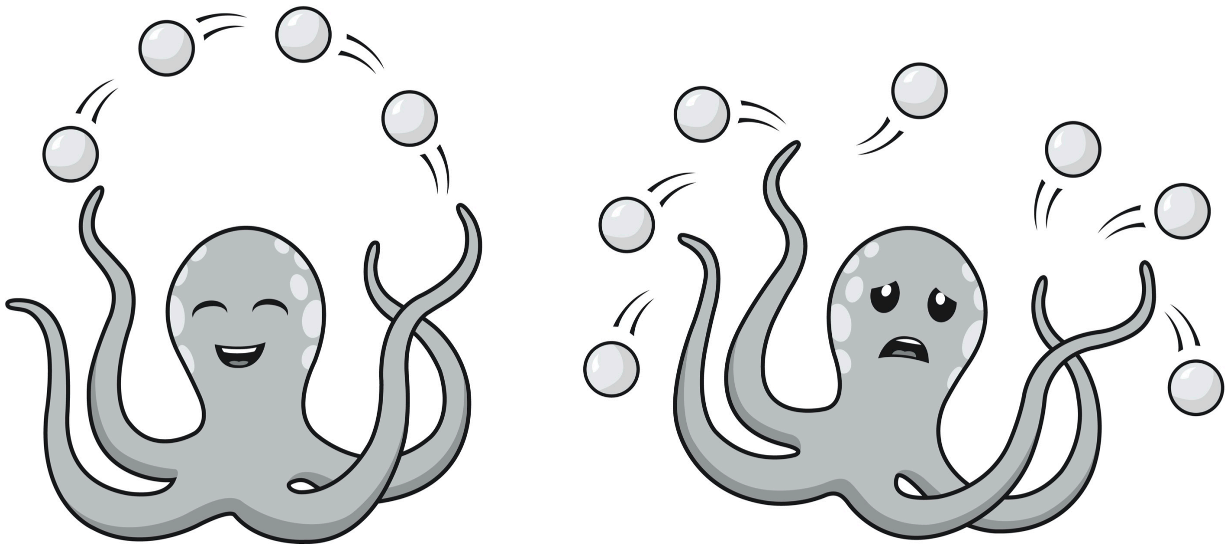
The "rolling away of balls" we alluded to in the last section leads us to do a deeper exploration of the difference between long-term memory and working memory.*

*Long-term memory* is what it sounds like—it holds the information we're able to store and bring back to mind from weeks, months, or even years before.[5] As we've seen, you can think of long-term memory as sets of neural links that students have developed when they've learned the material well. As we also mentioned previously, these neural links congregate in the neocortex—the thin sheet of neural tissue that rides over the ridges and deep grooves of the brain's surface.[6] If we reinforce the links of long-term learning through varied practice, our learning is generally in good shape.[7] (By *varied* practice, we mean not just practicing with the same material. For example, you don't want to just sit around testing yourself on lists of new foreign language vocabulary words. You also want to use those new words in a variety of different sentences and contexts.)

But *working memory*—that temporary holding pattern for thoughts—is different from long-term memory. Rather than sets of links that reside happily in the neocortex, working memory is more like an octopus tossing a set of balls. These balls represent thoughts that bounce over and over again from the front to the back of your brain, as long as you are holding the ideas in working memory.[8] An average working memory can hold up to four "balls" before ideas begin slipping from the mind, as you can see in the "quadropus" on this page. (Incidentally, students can't grow more arms on their octopuses. But the more students practice with the material, the bigger the balls of information can become. More on this soon.)

For now, you should know a quirky thing about working memory. Whenever the octopus gets distracted from throwing and catching balls, the balls can vanish. This leads to one of the fascinating aspects of working memory—its cunning ability to fool students into thinking *surely* they've put something in long-term memory. A student can, for example, stare at a list of ten new vocabulary words and think, *I've got them!* The student *does* have the words in mind—that is, as long as she is staring at the list.

Similar problems arise when a student glances at the solution to a complex math problem. *No need to waste time working this out on my own,* she might think. *I've got it in mind already.* And she *does* have it at least partly in mind—but only temporarily. Students discover the vanishing act when they take a test. ("I suffer from test anxiety" is in fact sometimes code for "I feel panic when I reach into long-term memory and nothing's there.")

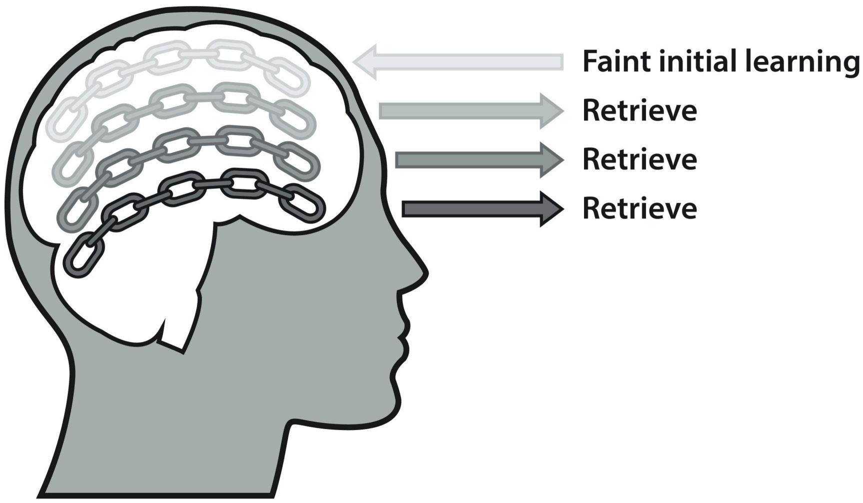


Most people can hold a maximum of about four pieces of information in working memory at once. But if they get distracted or they try to keep too many balls in mind at once, the thoughts can all fall out!

This “false friend” nature of working memory is why students naturally tend toward rereading and underlining. What could be more comfortable and more helpful than running your eyes past the information one more time, highlighting to add emphasis?[9]

But getting the information into long-term memory can be difficult. We’ll be exploring this vital topic in more detail in chapter 3. The key idea, however, is that *retrieval practice* is one of the best techniques for strengthening new information in long-term memory.[10] Retrieval practice means drawing ideas you’re starting to learn from your own mind rather than simply looking at the answer. Good examples of retrieval practice include using flash cards or merely looking away from a page to see if you can retrieve the key idea or ideas on the page.

As we’ll see, retrieval practice is far from some simple mindless memorization technique—it also builds conceptual understanding. But students often need to be taught to use retrieval practice. It’s hard for them to figure out on their own that this seemingly tough technique is beneficial.[11]




**Retrieval practice** is one of the best ways to strengthen neural links in long-term memory.

## Working Memory: Master Trickster

All of this leads to our single crucial point: Despite the very different processes involved, students often can't tell whether they have something in working memory or in long-term memory. Katina can look at an explanation in a book open right in front of her, and think, *I've got it!* But she's got it only in working memory—not long-term memory.

Why are Katina, and others like her, not able to do well on tests? You may have guessed the answer already. Katina's been using her working memory to help her learn the material. (This is a great way to *start* learning.) But come test-taking time, there's very little information in Katina's long-term memory for her to draw on. She panics.

But how could that be, especially if Katina is putting both time and effort into her studies?

Let's look at how Katina studies her math and how Jared studies his Spanish. Each is trying to do well. But both struggle when it comes to test-taking.

When Katina is looking at you in class as you teach concepts of, say, algebra, she is absorbing the information and following your logic with her *working memory*.

Later, when Katina sits down at home to study her algebra, she first quickly looks through the chapter. The example problems seem clear. So she skips right to the homework, looking for problems that are similar to what she's just read and what you've done in class. She does those problems right away, her finger following the example while she writes the solution to the homework problem. If a homework problem doesn't look like an example, she takes her best guess at trying to put it into the form of one of the example problems.

Notice that the example problems are *not* the issue here. Work done by educational psychologist John Sweller and his colleagues has shown that being exposed to and working with sample problems can be invaluable in allowing students to *begin* to form mental templates that allow them to understand and solve a wide variety of problems.[12]

The problem is this: Nowhere in her study process is Katina actively and independently working problems by herself, without looking at the solution. *She is only using her working memory to solve the problems*. Although she rereads the notes she took in class multiple times the night before the test, when it comes to test-taking time, no surprise, Katina does badly.

When Jared is working on his Spanish, he looks at the list of vocabulary in front of him and thinks he knows it. Why shouldn't he know it—*it's right there in front of him!* When it comes to completing the exercises in his homework, he fills in the blanks by looking back at the examples. Done? Great! Time to knock off!

Keep in mind—in all probability, no one has ever taught Katina or Jared anything about effective studying. These two students are doing as well as they can, given what little they know about how their brains work.

In the next chapters, we'll pull these ideas about creating links and different types of memory together to see how to best help Katina, Jared, and the many other students who find themselves lost come test-taking time. We'll also look at students who get things quickly. As you'll see, just because a student is fast *doesn't* necessarily mean that the student is successful.[13]

## NOW YOU TRY!

### INTRODUCING RECALL

**Students generally** have no idea about the differences between working memory and long-term memory. This is part of why they can be so easily fooled about whether they've truly learned the material. The perfect way to address this is to do an active exercise with your students that teaches them the valuable learning technique of *recall*. (This is a form of what psychologists call *retrieval practice*.[14])

1. First, explain to your students the difference between working memory and long-term memory. (You can use the illustrations from this book, found in the DOWNLOADS tab at barbaraoakley.com.) Tell them that working memory is like an octopus that has to constantly juggle the information to keep it in mind. An octopus can usually keep at most four pieces of information in mind—and that information can easily fall out. Long-term memory, on the other hand, is like a set of links in their brain that they can easily draw on—easily, that is, if they've made sure those links are solid and well connected. (If you can associate pictures, like the octopus and the sets of links, with the ideas of working memory and long-term memory, respectively, these concepts will stick better in students' minds.[15])
2. Next, ask the students to pair up and explain to each other what you have just taught them about the difference between working memory and long-term memory.
3. After students finish, explain that they have just used the *recall technique*. That is, they've just checked whether they have understood and can remember the key idea. In this case, they've performed the check by trying to explain the concept to their partner.
4. Explain to students that they can use the recall technique even when they are alone. To use this technique when they are by themselves, all they do is look away from what they've just learned and see if they can *recall* the key idea. Or they can test themselves to see whether they can remember a word or work a problem from scratch. In their excellent book *Powerful Teaching*,[16] Pooja Agarwal and Patrice Bain refer to this kind of recall as "no-stakes" testing—it's an easy way to see whether the material is lodging in long-term memory, where it should be.

Perhaps surprisingly, the recall technique has been shown to build an understanding of the material far better than any other approach tested, including rereading, underlining or highlighting, and concept mapping.[17] (We'll show you why in chapter 2.)

### BUILDING EVEN FURTHER: PRACTICING JOT RECALL

Recall can be easily added into your teaching routine by using the *Jot Recall* technique. Use an upbeat tone to remind students about checking to see whether they've moved the material from working into long-term memory.

- *Jot Notes:* As you are covering essential sections in your lesson, pause and ask your students to take a fresh piece of paper or sticky note and briefly, without looking at their notes, jot down the most important ideas you have covered. Move around in the class while you are doing this. Your quick sweep provides a check for you about whether the students are following along and getting the key ideas you are trying to convey. If time permits, when most students are finished, ask students to get together in groups of three or four to compare and discuss what they found to be the key ideas.
- *Jot Sketches:* Along with their notes, have students create drawings that represent their understanding of the material being taught. Allowing students to get creative can increase their interest as it deepens their understanding. Drawing pictures in place of words is also effective with emergent learners who are developing their writing skills.
- *Jot Reading Materials:* If you are having the students do quiet reading of materials in class, ask them to pause as they finish each page. As they pause, they should look away and see if they can recall the key idea of that page without looking back at the material. Have them jot that key idea down. (Remind students that this is also an exercise they can do at home.) Again, if time permits, when most students are finished, ask them to pair up and compare and discuss what they found to be the key ideas.
- *Jot Previous Materials:* Ask students to jot recall materials they learned the day before, or in the previous week or month. (This is an example of *spaced repetition*—when there is a time interval between the content being taught and the student being asked to recall the information.)

## Key Ideas of This Chapter

- Learning involves connecting, strengthening, and extending sets of neural links in long-term memory in the neocortex. We refer to this process as *learn it, link it.*
- The strengthening of connections between links as a student practices is known as *Hebbian learning.*
- There are many types of memory with different purposes. Two of the most important types of memory for classroom learning are *working memory* and *long-term memory.* Information in working memory can fade away within seconds. Information in long-term memory is more persistent, sometimes lasting (with subtle and occasionally not-so-subtle shifts) for a lifetime.
- An average working memory can hold up to four "balls" of information before ideas begin slipping from the mind.
- Students will often place information in working memory and mistakenly believe it has made its way into long-term memory. Later, they can perform poorly on tests because they have no information to draw from long-term memory.
- *Retrieval practice* encourages and strengthens the connections between neurons in long-term memory and prevents students' working memory from tricking them.

# 2

# Teaching Inclusively:

## The Importance of Working Memory Capacity

Barb used to teach undergraduate and graduate level electromagnetics. This difficult material uses advanced calculus to quantify the interwoven dance of magnetic and electric fields. Semester after semester, she watched as students struggled.

But almost invariably, each semester, there would be one or two "star" students for whom electromagnetics was straightforward—even easy. A complex question would barely be out of Barb's mouth when one such student—say, Farid—would whip his hand in the air with the answer. Quickly wrapping his mind around the idea and giving the answer, Farid would then go on to pose a deeper question.* The other students in the class would exchange furtive, embarrassed glances. Few of them could think fast enough to answer questions like that.

It was clear that Farid or Désirée or Mark—whoever the fast thinkers were that semester—had something like race-car brains. They could get to the finish line—the answer—very quickly. Other students in the class had more like hiker brains. They could get to the finish line, but more slowly.

Most learners are race cars on some topics and hikers on others. Or midway between fast and slow in their learning. Whether you are teaching college undergraduates or kindergartners, different types of learners are present in every classroom and make twenty-first-century teaching a challenge. To teach inclusively, today's teachers have to figure out how best to differentiate instruction to assist *all* the learners in their class.

The challenge is, some students do indeed have something akin to race-car brains: they can think very quickly, and in class, they are often the first ones with their hands up. But as we'll see, *speed is* not *necessarily an advantage.* Think about it this way. The race-car driver gets to the finish line quickly—but everything goes by in a blur. The hiker, on the other hand, is much slower. But the hiker can reach out and touch the leaves on the trees, smell the pine in the air, see the little rabbit trails, and hear the birds. It's an entirely different experience from that of the race-car driver—and in some ways, much richer and deeper. Nobel Prize–winning economist Friedrich Hayek, for example, observed that unlike his swift-learning colleagues, his innovative breakthroughs came from his slow, muddling struggle to grasp the material. Being forced to find his own way of expressing accepted ideas allowed him to see gaps and unjustified assumptions that others missed.[1] We will see in the upcoming chapters that two different neural pathways to learning—*declarative* and *procedural*—may relate to the race-car and hiker approaches to learning.

To get a better sense of the advantages of slower learning, we'll take a look at a Spaniard named Santiago Ramón y Cajal. Cajal was a prototypical hiker student—learning came hard and slow.[2] He had a poor working memory, which made it difficult for him to put new information into long-term memory. He also had behavior problems—his antics resulted in his being kicked out of several schools. Cajal wanted to be an artist, but his father wanted him to be a doctor. (This was back in the 1860s. Some things never change.) Ultimately, his father washed his hands of him.

But surprisingly, Cajal would eventually go on to get his doctorate in medicine. As if that weren't enough, he became so esteemed for his breakthrough research findings in neuroanatomy that he eventually won the

Nobel Prize. And as if *that* weren't enough, Santiago Ramón y Cajal is now considered the father of modern neuroscience.

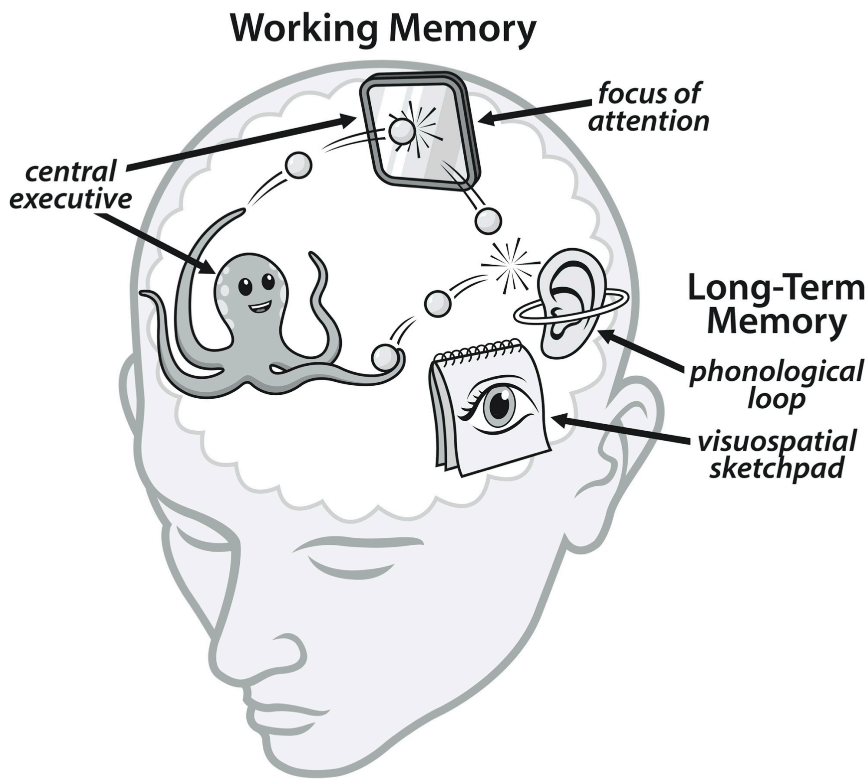
What are perhaps equally astonishing are Cajal's thoughts about how and why he was able to achieve so much.[3] His conclusion? That his success arose in part from the fact that he *wasn't* a genius. His scientific breakthroughs came precisely *because of* his slower, more flexible, way of thinking. When Cajal was wrong, he could change his mind. The geniuses he worked with, on the other hand, were used to being right and had little practice in acknowledging and correcting errors. So these race-car brains tended to jump to conclusions with speedy answers, and when they were wrong, they were unable to correct their mistakes. Instead, they'd use their intelligence to find ways to rationalize why they must have been right after all.

Having a powerful working memory clearly isn't the only way to be a successful learner. Let's take a more in-depth look at this fascinating area.

## Where Is Working Memory in the Brain?

In the last chapter, we said that working memory was akin to a system of balls (thoughts) that your mind kept alive by juggling—the balls reach across several regions of the brain. We can get a more definite sense of this process by imagining the working memory octopus (the *central executive*) as being at the front of your brain. It keeps a ball (the information) in mind by throwing that ball toward the back of your brain. The ball bangs against a reflecting surface (the *focus of attention*), bounces against the hearing and seeing networks, and then winds up back up at the front again.[4]

This focus of attention involves the parietal lobe,[*] possibly as a central hub of a *focus-of-attention network*. All this juggling is done through sets of neural links. As long as the information is lobbing back and forth between the front and back of the brain, it stays alive in working memory. This volleying is why you might keep silently repeating the names of the two new teachers you've just met, or the numerical code you're trying to transfer from your cell phone to a computer website.




Working memory is like an octopus (or quadropus!) in the front of your brain that keeps tossing the thoughts toward the back of the brain. Those thoughts reverberate back around again to the front of the brain as you focus your attention on them. That's what keeps the thoughts alive in working memory.*

But don't worry about the specifics. The key idea here is that the balls of information are kept alive in working memory by bouncing around the brain. The roundabout movement of the information as it's being tossed back and forth in working memory is why students can hold only so much information in their minds at once. It's a lot like a juggler who has a shorter and shorter amount of time to grab and toss each ball, the more balls she is trying to throw. Too many balls at once and, poof, everything falls away!

Experienced teachers know that depending on the complexity of the task, they may need to give one instruction, wait for students to complete it, then give the next instruction. Or they might write instructions on the whiteboard, so even if the information falls from students' working memory, the list is there anyway.

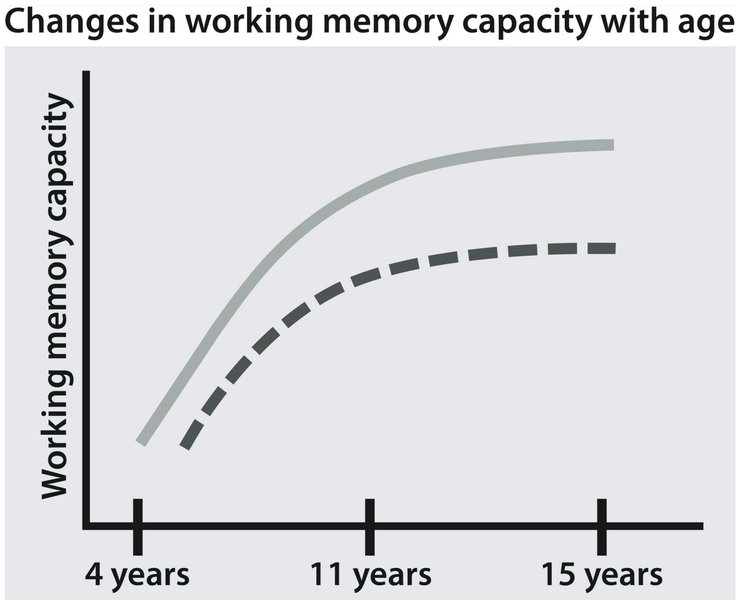
The types of neurons involved in working memory are different from those involved in long-term memory. (Sort of like how all of your students are students, but your students don't all act and look alike.) Working memory's neurons can't hold the information very long, while long-term memory's neurons can hold the information a long time.

> Key Point: Teachers sometimes believe they shouldn't write directions down for students because they think students need to "pay better attention to following directions." But it's not about paying better attention—it's about limited working memory capacity.

Fortunately, if you've learned information and stored it in long-term memory, that information can link into and boost your working memory. Long-term memory is a little like people resting in deck chairs who just *have* to get up and join the mental conga line when working memory starts singing their song.[5]

## How Differences in Working Memory Impact Your Classroom

One of the great charms (and frustrations!) of young children is their limited working memory. Tell them something, and within seconds, the information has somehow flittered away. As children mature, their working memory increases. By the time they're fourteen, they have, on average, an adult-sized working memory, which is more than twice what they had as four-year-olds. You can see this in the growth curve below, which shows average and lesser-capacity working memory for children of varying ages.



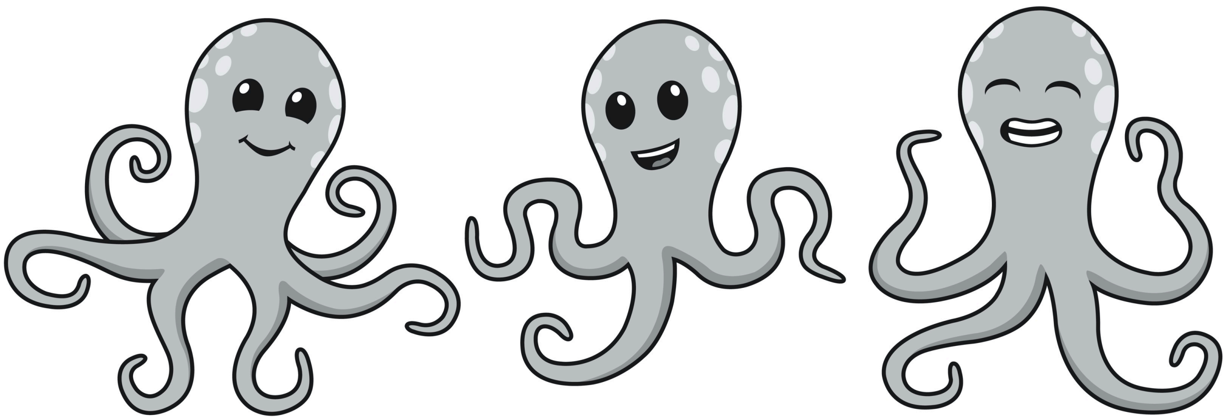

**Working memory growth curve:** The changes in working memory capacity with age for an average child are shown by the solid line. Scores of a child with lesser-capacity working memory are represented by the broken line.[6]

Students' varying working memory capacities have an impact on you as a teacher in the classroom. As working memory experts Susan Gathercole and Tracy Alloway explain:

> *Differences in working memory capacity between different children of the same age can be very large indeed. For example, in a typical class of 30 children aged seven to eight years, we would expect at least three of them to have the working memory capacities of the average four-year-old child and three others to have the capacities of the average eleven-year-old child, which is quite close to adult levels.*[7]

You can think of students' differing working memory capacities as being like our familiar octopus but with differing numbers of arms. The average working memory of an older teenager or adult is four arms—meaning they can simultaneously hold a maximum of four pieces of information. But this is just an average. Some students have larger-capacity working memories—

they can hold six or more pieces of information at once. Others have less working memory capacity—they can hold perhaps three items at once. All these students can learn well—they just need different approaches to enable them to be successful. (We'll be giving you a supply of these different approaches!)



Students can vary substantially in their working memory capacity. Although the average is four "arms" on their attentional octopuses (that is, four pieces of information they can hold in mind), some students may have only three arms, while still others can have six or more arms.

Sooner or later, you will probably teach students with a working memory capacity that is far less than average. In these cases, it's not as if a student is actively fidgeting in a way that might raise a red flag, as with attention deficit hyperactivity disorder. Instead, a busy, sometimes overwhelmed teacher can conclude that a student is just something of a bumbler, especially when the other students seem to be able to follow instructions just fine. Students with working memory deficits often struggle as tasks get more demanding. They also lose track when it comes to more complex activities. For instance, when writing a sentence, a student with working memory deficits may leave words out or repeat the same word.

At younger ages, students with a working memory capacity that is less than average can also quite honestly forget even a simple assignment or request. A set of directions such as "Put your sheets on the green table, put your arrow cards in the packet, put your pencil away, and come and sit on the carpet" can be overwhelming.[8] Testing the working memory of students who have difficulty holding a number of ideas in mind can go a long way toward capturing a potential learning challenge early on.[9]

## STRATEGIES TO HELP STUDENTS WITH LESSER-CAPACITY WORKING MEMORY

By accommodating students in your class with lesser-capacity working memory, you can often assist all students. Here are some ways to help your students.[10]

- **Be brief and as linguistically simple as possible with your directions.** Lengthy instructions will likely be forgotten.
- **Make sure your students are looking at you when you are giving directions.** "Please turn so you can see me" can be surprisingly helpful.[*]
- **Give instructions one at a time, including "step checks" to make sure everyone is with you.** (A typical step check might be to ask students to turn to their desk partners and gently tap their paper with their pencil, saying, "Well done!" if the step is completed. If the partner isn't quite done, the teacher offers assistance.)
- **Provide instructions on the board or as a checklist on students' desks** for them to refer to while completing the assignment.
- **Use mnemonics** (memory tricks) to enable students to more easily recall larger pieces of information.
- **Supply spellings of unfamiliar and challenging words** to students as they respond to a writing prompt. (Having to stop and think about spellings of new and challenging vocabulary slows students down and can make writing both tricky and clunky.)

## Strengthen Working Memory by Building Long-Term Memory

The terms *working memory* and *intelligence* describe related underlying processes.[11] And sure enough, those with lesser-capacity working memory can struggle more with their learning. But remember, long-term memory can ultimately become a part of working memory, especially with retrieval practice. This is good news. It means that *if the person with a lesser-capacity working memory creates and strengthens neural links in long-term memory, those links can extend their working memory on that topic.*[12] Another way of saying this is that the more assistance working memory gets from the prior knowledge stored in long-term memory, the easier it is for students, especially students with less capacity in their working memory, to learn new material.

Background practice is critical in ways that can at first be difficult to grasp. For example, let's take the sentence "The green penguin is eating an apple." It would be easy for you to write each letter of the sentence down a minute later. Now let's take another sentence: "Зеленый пингвин ест яблоко." Unless you're a Russian speaker, it's going to be pretty difficult for you to hold all the letters in mind and write them down a minute later, even though the Russian green penguin is similarly eating an apple. Our working memory capacity appears to be much greater, depending on whether our long-term memories have had English or Russian implanted. Your background training matters—*a lot.* It increases the size of the "balls" of information (sometimes referred to by neuroscientists as *chunks*) that your working memory can hold. So even though the number of arms on your attentional octopus can't increase, more background training on that topic means you can hold more information in working memory. The balls of information your octopus can hold are bigger.[*]

As researcher John Sweller, perhaps best known for his theories related to cognitive load, has pointed out, the intricate relationship between working memory and long-term memory is easily the most critical factor in human cognition. It goes a long way toward understanding how our mind works.[13] But long-term memory is like a wedding crasher—it sneaks into any attempt to measure working memory. This is because the contents of long-term memory massively transform the capacity of working memory.

Sadly, there's no good evidence from research that general working memory capacity can be increased through training—although something that looks like working memory increase occurs within specific areas of practice.[14] (This relates to the idea that the attentional octopus can juggle larger balls of information with the same number of arms—if, that is, the information has been well-practiced to strongly secure it in long-term memory.) In other words, practice with geometry can increase a student's apparent working memory capacity with geometry. Practice with a language—say, French—can increase apparent working memory capacity with French. Practice with the piano can increase apparent working memory capacity with piano, and so forth.

Of course, no one wants to create and strengthen links via poorly designed "drill and kill" approaches. But as we shall see in chapter 6, drill is not all bad—in fact, when drill is done properly, the expression might better be put as "drill and skill." Given additional time and well-designed practice, people with lesser-capacity working memories can become as good as those with larger-capacity working memories in their areas of expertise—or even better.[15]

The transformative effect of education is *not* that it changes students' working memory capacity.* Education instead changes the amount of knowledge held in long-term memory. The more knowledge held in long-term memory, the easier it is to add more. (This is the *expertise reversal effect*, where the more knowledgeable students are about a topic, the less guidance they need. Too much guidance in these situations can impede learning.[16]) With the right kind of information implanted in long-term memory, people can effortlessly process enormous amounts of information—even if their working memories aren't that capacious. This is why building students' prior knowledge in a given subject area is critical. (More on this when we get to schemas in chapter 6.)

Keep in mind, though, that there are several ways to get information into long-term memory. One way—the declarative pathway—uses working memory. We'll describe this in more detail in the next chapter. But there's an even more astonishing way—the procedural pathway—that we'll explore in chapter 6.

**TEACHING TIP:**

Gauging a Student's Working Memory Capacity

It can sometimes be difficult to deduce a student's working memory capacity. (Remember, the average is four balls of information.) Here are some rules of thumb that can help, at least for students who are old enough to transcribe and synthesize notes:[17]

- If students can understand your more complex classroom explanations and simultaneously take notes, they probably have excellent working memory capacity.
- Students who can take notes during your explanations but sometimes lose track of what your explanations mean, especially when you are covering more challenging material, probably have average working memory capacity.
- Students who struggle to both take notes and simultaneously understand what you are saying, even with relatively simple material, probably have lesser-capacity working memory.

Keep in mind that students' circumstances–for example, a keen interest in a topic (say, computers), or, on the other hand, a stressful home environment–can increase or decrease their apparent working memory capacity.[18]

## Inclusivity and Differentiation

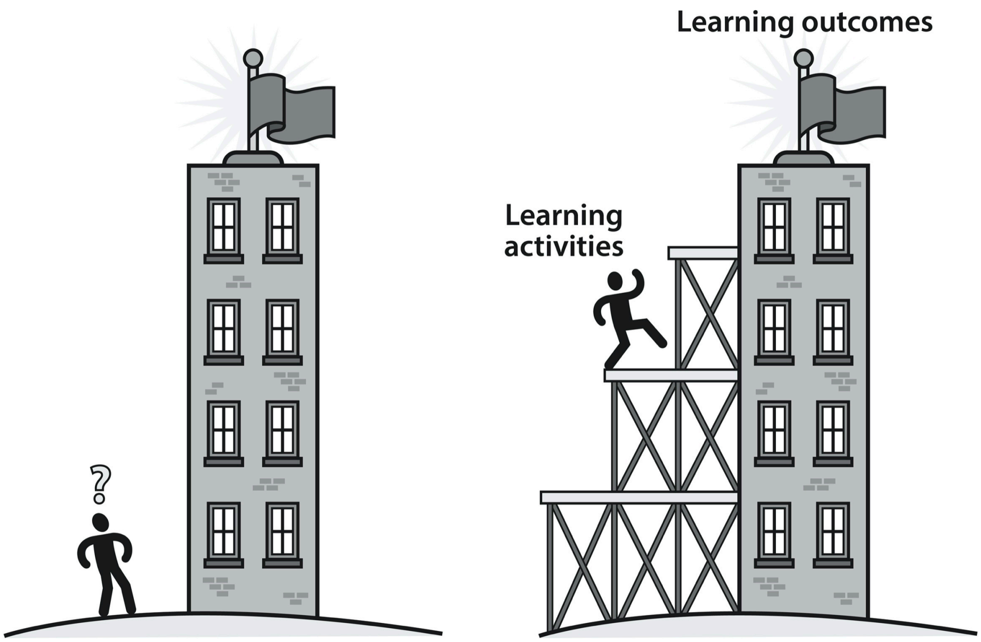
In general use, the term *inclusivity* means reaching out to include those who are commonly marginalized or excluded. But in U.S.-based education, an *inclusive classroom* has a more specific meaning. It describes teaching students who receive special education services[19] and general education students in the same classroom.

In an inclusive classroom, general education teachers,[*] special education teachers, and other specialists work collaboratively with overlapping roles to teach students with and without disabilities. One common model in U.S. schools is for one teacher to be responsible for whole-class instruction while a co-teacher monitors students' work and provides bursts of additional instructional support.[20] The general educator often takes the lead as far as content and instruction but capitalizes on the expertise of special educators, who adapt materials and methods to make learning accessible to special education students. This co-teaching model ideally benefits all students.[21]

Learning is not the same for everyone, and a one-size-fits-all approach rarely works for *every* brain. Because working memory capacities and background knowledge can vary dramatically from student to student, the instruction we teachers provide shouldn't look the same for everyone.

Enter differentiation. *Differentiation* means teaching the same content knowledge and skills to *all* students but using different approaches to meet individual needs.[22] Differentiation is not just for an inclusive classroom—it is intended for *all* students. When we think of differentiation, we think of offering "different approaches to what students learn, how they learn, and how they demonstrate what they've learned."[23] Sometimes adjustments to your instruction can be as simple as incorporating students' interests. A strong interest in a topic—for example, sports—can increase a student's apparent working memory capacity. A hiker can turn into a race car as soon as the statistics from a favorite sports team enter the discussion.

But often, differentiation includes adjustments in instruction, materials, and assignments. Here is where scaffolding to support a student's readiness comes into play. As Professor Carol Tomlinson, author of the classic *How to Differentiate Instruction in Academically Diverse Classrooms*, notes: "Scaffolding is at the core of differentiation."[24] Just as scaffolding temporarily supports workers on a skyscraper, scaffolded instruction is the temporary support teachers use to assist students with lesser-capacity working memory and other learning challenges.*




Scaffolded instruction allows students to gradually climb to heights that might at first seem insurmountable.

Here's what scaffolding can look like for hiker-type learners:

- **Meeting with individual students or in small groups to reteach a concept or skill.** Students may feel safer asking you what they perceive to be "stupid questions" individually or within the small group. Your one-on-one or one-on-a-few discussion will allow them the opportunity to talk through their understanding of the concept or the task they are supposed to complete.
- **Allowing more time** for a student to complete a task or practice solidifying the skill.
- **Breaking down the steps** of a problem by providing examples for each step along the way toward completion.
- **Using criteria that match *and then* extend individual students' skill levels.** For example, being prepared with a variety of questions at different levels of difficulty.

At the same time, how can you best scaffold instruction for race-car learners?

- **Go beyond simple factual questions** with answers that are "right there" by asking more in-depth questions and exploring how concepts connect.
- **Allow race-car learners the opportunity to work with one another**—to bounce ideas off of and challenge one another with multiple perspectives.
- **Don't just give race-car learners more of the *same* types of problems to do.** They may take it as a punishment. Instead, create more complex, multilayered problems and assignments—or ask them to devise their own problems.
- **Allow students to choose among meaningful "sponge activities" to soak up extra class time.** These sponge activities could be reading authentic* texts on the current topic. Or such an activity could be an extension project the student develops and the teacher monitors.
- **Accelerate learning** by allowing race cars to use video-game-like computer software that individualizes instruction based on their responses.

Differentiating instruction to meet the diverse working memory capacities of your students may seem daunting. Often there is only one of you and upward of thirty students who represent a continuum of race-car- and hiker-type learners. But differentiation can be as simple as lending an encouraging word to a student who needs attention or explaining the meaning of a word to an English language learner. (If you know writing might be difficult for certain learners, you may want to offer a paragraph frame* to get them started.)[25]

Keep in mind that students enter a topic with different amounts of prior knowledge and working memory capacities, and these differences mean that students work at varying speeds. Instructional strategies that support differentiation can include learning stations (different spots in the classroom where students work individually or in small groups on various tasks simultaneously), agendas (a personalized list of tasks that a student must complete in a specified time), and orbital studies (independent investigations that "orbit" around an aspect of the curriculum). The goal is to make it to the finish line, not to make it to the finish line quickly. We are fans of Carol Ann Tomlinson's "teaching up" approach—aiming high and then building the scaffolding for all students to reach the top level.[26]

To be successful in their studies, students can make up for lesser-capacity working memories by creating strong and varied sets of links in their long-term memories. These links extend and reinforce the capabilities of their working memories. Having students downsize their notes from class onto flash cards strengthens the links. Frequently quizzing themselves and one another at the start of class then solidifies the learning. Retrieval practice in all its myriad possibilities is invaluable.

Although it takes work to get information safely planted in long-term memory, this well-seated information provides a special advantage for those with lesser-capacity working memory. Why? The long-term links they form simplify and crystallize concepts.[27] Ultimately, this means that an industrious lesser-capacity type of student can make elegant simplifications that those with larger capacities have difficulty seeing. (In a related vein, being tired, which lessens working memory capacity, seems to heighten people's ability to solve problems that need creative insight.[28])

## Working Memory: Implications for Students

Students often question how to study. Take listening to music, for example, which students are often told to avoid. The problem is that some successful students happily listen to music while studying. Why should Sven avoid music when he knows darn well that Jolina listens to it and still gets great grades?

The latest research findings solve the puzzle. Music's effect on studies varies with—you guessed it—working memory capacity.[29] Those with a lesser capacity seem to be better off avoiding music altogether in their studies. Those with larger capacity, on the other hand, can do fine studying to music—their larger capacities allow them to focus more easily. The caveat is that most students should avoid listening to music while studying math. Perhaps this relates to the fact that math and music use overlapping portions of the brain.[*] Additionally, students with ADHD seem to benefit from white noise and music that other students might find distracting.[30]

What about note-taking? Again, working memory seems to play a role.[31] Those with larger capacity can blithely jot notes while also taking in complicated explanations. But those with lesser capacity have trouble simultaneously taking notes and making sense of the instructor's explanation. They can end up spending a lot more time outside of class trying to reconstruct the instructor's meaning. Researchers observe that college-level students with lesser-capacity working memory can do well by focusing only on the instructor during the presentation of new material and using others' notes for review.[32] But our own experience is that unmotivated students can use lack of note-taking as an opportunity to tune out. Instead, we recommend the following techniques to allow students to engage with the material more actively.

## NOW YOU TRY!

### TIPS TO IMPROVE NOTE-TAKING FOR THOSE WITH LESSER-CAPACITY WORKING MEMORY

- Consider providing a skeleton outline or a handout of your notes with missing gaps for students to complete as you present.[33]
- Mind your pace—don't speak or write too quickly.
- **Give structure cues:** "We'll look at five items, the first . . ." Cues make it easier for students to structure their notes.
- **Take mini-breaks** throughout your presentation of new material to give students time to reread their notes and ask a partner or the teacher for any fixes they might need.

- **Pause after an appropriate interval** of the lesson and ask an open-ended question on the material. Have the students get in pairs and give them thirty seconds (for example) to come up with one or more answers. Brief pauses help students practice retrieving the new information.
- Use an approach described in *Powerful Teaching* called "retrieve-taking." Students don't take notes while you are talking. Instead, they jot down the key points after you pause. You can then clarify the ideas or facilitate a discussion and continue.

## Working Memory: Implications for Teachers

It's probably no surprise to learn that teaching techniques that work well for students with larger-capacity working memories don't meet the needs of students with lesser-capacity working memories.

Let's take, for example, mathematics instruction. Students with very large working memory capacity can do well no matter what the instruction type—student-directed or teacher-directed—and may even flourish when it comes to directing their own learning. But students who struggle with math—which is common in those with lesser-capacity working memory[34]—appear to do *worse* in student-directed learning, and *better* with teacher-directed approaches.[35] You'll learn more about these two types of instruction in chapter 5.

**Research reveals that *practice* seems to have the most significant positive effect on these struggling students.**[36] We'll see later that practice builds information in long-term memory through the procedural learning pathway, which is quicker and more automatic to use. An emphasis on automaticity strengthens lesser-capacity students' grasp of a subject by allowing their long-term memory to enhance their working memory. (Automaticity is involved in the ability to correctly punctuate a sentence, for example, or to add two simple numbers without even having to think about it.) As students gain familiarity with the basic concepts, they can begin to work more independently through student-directed approaches.

Similarly, reading instruction can have different effects based on students' working memory capacity.[37] While all students benefit from a teacher-directed phonics approach, it is even more essential for those entering school with lesser reading ability. At the same time, those with better initial performance can speed through phonics training and go on to flourish under whole-language instruction.[38] Again, as students gain mastery, the instruction can shift to more independent, student-directed approaches.

The challenge, of course, is that a typical classroom contains students with a hodgepodge of working memory capacities. The typical mixed teaching techniques used by many teachers—a combination of teacher-directed and more student-directed approaches—can be effective for large-capacity students. But students with lesser capacities often need more practice and teacher direction to bring them on board so that student-directed approaches can subsequently take hold.

When students watch you explaining *anything* in class, they are trying to make sense of their observations by using working memory. What's happening in long-term memory? you may ask. Not much! That's why when students try to implement what you've just taught them, they suddenly realize they don't know how to do it.

**And this is why instruction that includes multiple opportunities for practice to break up the lesson can be so valuable.**[39] These active periods allow students to begin the sometimes arduous transfer of ideas from working memory into long-term memory, assisted by the helpful reinforcement of the hippocampus. Such active periods also allow students time to *consolidate* the information.

Consolidation is a process in which the brain forms and strengthens new neural links as it "wraps its mind" around an idea or concept.[40] You can think of consolidation as being like a flock of birds. When a student moves into an active practice session or even just takes a little mental break, the information birds can rearrange themselves in mid-flight and land in a different configuration that is a bit better organized. We'll talk more about consolidation in chapter 3.

Let's recall our students Katina and Jared, who spent time studying the material but still struggled when it came to test-taking. We haven't forgotten about them—in fact, in chapter 3, we'll return to them, to get an even better understanding of how to assist them.

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## Analyze Your Teaching:
### Pairing and Repairing

To slow our race-car learners down and give our hikers a chance to catch up, embed ample opportunities for varied and novel practice in your lessons.

**The Setup**
One way to begin teaching students how to edit their writing is to correct poorly written sentences in front of the class through error analysis—where students identify, explain, and fix errors. Teachers ordinarily first ask students what needs to be fixed. The race cars' hands immediately dart into the air. Then the teacher performs a think-aloud as she corrects the rest of the sentence, explaining the rules of grammar and punctuation she is using to correct errors. In her expert hands, the sentence:

*I and my brother catched the bus at thirty forth street and center bullavard.*

morphs, with explanation, into:

*My brother and I caught the bus at 34th Street and Center Boulevard.*

**What's Happening in Students' Minds**
Think about what is happening when students are watching the teacher. *The information is going into their working memories.* That is, if the students aren't daydreaming—which is all too likely when a teacher is droning away.

Don't get us wrong—getting something into working memory is at least a start! However, just turning students loose, without providing anything at all to guide them, is asking for trouble.[41]

**What to Avoid**
After modeling the initial faulty sentence, too often, teachers review additional incorrect sentences together as a class, calling for volunteers to share their errors.

The race-car-type learners are quick to respond. The hikers—and timid students who are too self-conscious to volunteer—are left out. The remaining, less motivated students simply seize the opportunity to tune out.

**What to Do**

Have students individually work through the faulty sentences on their own. Students need private think time to give it an initial try. Afterward, have students compare their responses with a partner. This collaboration increases student accountability and provides a motivating social aspect to the often bland editing exercises.

**Bonus Ideas**

Provide students with plenty of practice and immediate corrective feedback. As you walk around the classroom, pay attention to students having difficulties as well as to those who have mastered the rules. You can differentiate future sentences to match your students' varying abilities. For example, students who have mastered using commas in a series may be ready to detect comma use (and abuse) before and after appositive phrases.

As your students struggle on their own to identify the errors in the faulty sentences, you may wish to point out that when they were watching you, *they were putting the errors and rules in working memory*[*]*—not long-term memory.* That is why working an example themselves can be such a struggle when they first try. (This relates to an important topic in learning called *desirable difficulty*, which we'll explore in depth in chapter 6.) Students will know they have mastered the rules of writing when they don't even have to think about those rules (they've gained *automaticity*).

As students become more and more comfortable with the rules your exercises reinforce, it is time for even more independent practice outside your direct eye. Remember to mix up the types of mistakes students have encountered throughout the year, not just throughout the unit. This provides both *interleaving* and *spaced repetition*—we'll discuss both in chapter 6.

**Generalizing the Principles**

Error analysis can be applied to all sorts of subjects.[42] The teacher fixes a faulty example for students while verbalizing her thought processes. She then provides students with error-ridden examples to fix themselves and supervised time for shared practice with corrective feedback. Differentiate examples to challenge the race-car and hiker learners' levels of ability. All these activities help the material to stick in students' long-term memory.

During the lesson, stay vigilant and work with students who need extra support. Before assigning practice homework problems, make sure students achieve proficiency under your watchful eye. When students do not have a solid foundation, homework becomes frustrating for students and parents alike.

## Key Ideas of This Chapter

- The information in working memory is like a set of balls being juggled by an octopus. Too many balls at once, and the octopus can be overwhelmed.
- The neural links of long-term memory can activate and extend working memory.
- Within any one classroom, there is a great deal of variability in working memory capacity among the students.
- Differences in working memory capacity can mean differences in learning speed. This in turn can demand different teaching approaches so that each student can be successful—and neither overwhelmed nor underwhelmed.
- Teaching strategies geared for those with lesser-capacity working memory can often be useful for all students.
- Breaking information and activities into smaller conceptual parts will combat too-heavy demands on students' working memory.
- Pause periodically to give students a chance to reread and catch up on their note-taking. Pauses are especially valuable for those with lesser-capacity working memory.
- Students with lesser-capacity working memory, and all students learning new, unfamiliar information, benefit from teacher-directed approaches. As students gain fluency, instruction can move toward more independent, student-directed approaches.
- Break up your presentation of new information with active exercises to assist with consolidation—when the brain strengthens its new neural links.

# 3

# Active Learning:

## The Declarative Pathway

As you're struggling with students like Katina and Jared, who study but don't do well on tests, you might wonder whether there is a simple, scientifically validated way to increase student understanding and success.

One extensive meta-analysis of university-level STEM classes found just that.[1] Students in traditional "talk and chalk" classes were 1.5 times as likely to fail as those in courses using active learning. And grades for active learners as opposed to traditional learners improved by a full 6 percent—impressive in tough, engineering-related studies.

Great! This must mean everything we do as teachers should be active then, right?

Not so fast. There is an observation buried in the fine print of that influential research article that puts a new spin on the recommendation. We'll get to that in a moment. First, let's make sure we're on the same page regarding the definition of *active.*

## What Is Active Learning?

Teachers sometimes make the natural mistake of thinking that *active learning* means that the students should be doing something active—that is, physical—with the material. For example, in a chapter on Greek culture and history, a teacher may have students build a papier-mâché Grecian urn. This type of flashy active learning surely must be good pedagogy, right?

But as Jennifer Gonzalez of the popular blog Cult of Pedagogy points out:

> *Draping wet, gluey newspaper around* a balloon has nothing to do with deepening one's understanding of societies and cultures . . . *I've seen far too many "Grecian Urns": projects that look creative, that the teacher might describe as hands-on learning, interdisciplinary teaching, project-based instruction, or the integration of arts or tech, but that nonetheless lack any substantial learning for students. What's worse, because these activities are often time-consuming, they take away from other tasks that would give students the chance to wrestle with more challenging stuff.*[2]

So what *is* active learning? Zoologist turned active learning expert Scott Freeman and his colleagues—authors of the meta-analysis cited above—surveyed university instructors to provide the following working definition: "Active learning engages students in the process of learning through activities and/or discussion in class, as opposed to passively listening to an expert. It emphasizes higher-order thinking and often involves group work."[3]

How can we view active learning from a neuroscientific perspective? We suggest that well-done active learning supports the creation and, most especially, the consolidation of neural links in long-term memory that underlie both a basic and a higher-order conceptual understanding of the material. Active learning, especially for more difficult materials (more on this in chapter 5), is often essential to the *link it* phase of *learn it, link it*.

Recall that *learn it* is when neurons are finding one another and beginning the process of linking together. But *link it* is when students are reinforcing and extending these neural links. Group work can facilitate active learning, but it's not the only way to learn actively. And as we'll see, not all learning is active learning.

Why do we emphasize both basic, factual knowledge and higher-order concepts as being important aspects of active learning—and learning in general? Because neuroscience shows us that for successful learning, students often need to have essential, but sometimes seemingly trivial, information in long-term memory, including definitions and examples. These neural links serve as a foundation for conceptual understanding and a springboard for creative thinking.[4] As Natalie Wexler notes in her prescient *The Knowledge Gap*:

> *It's not so much that particular bits of information are vital in and of themselves—although some certainly are. It's more that people need to have enough facts in their heads to have what one commentator has called "a knowledge party"—a bunch of accumulated associations that will enable them to absorb, retain, and analyze new information.*[5]

To better understand why seemingly rudimentary learning is important, let's look at an example of active learning gone wrong. Say your students have previously discussed (actively!) the concept of the Civil War. The discussion was rich and packed with questions, information, explanations. You felt good about everything your students learned. Until . . .

Flash-forward: An unexpected world event prompts an impromptu discussion of the civil rights movement. You realize from the new discussion that students are confusing the Civil War with civil rights. In fact, they think Abraham Lincoln and Dr. Martin Luther King Jr. were contemporaries!

Clearly this is a case where active learning went wrong. Why? The earlier "go with the flow" discussion meant students didn't necessarily put anything into long-term memory. There was no note-taking to facilitate later retrieval practice, or any teacherly oversight to ensure students lodged the fundamentals of the Civil War into long-term memory.[6] And higher-level concepts such as slavery and states' rights? Nothing at all was retained.

Active learning often involves retrieval processes—which means, as we've mentioned, pulling ideas from long-term memory. Psychologist Jeffrey Karpicke and cognitive scientist Phillip Grimaldi put it best when they noted:

> *Retrieval processes are involved in all situations in which knowledge is expressed, including situations where learners must produce the answer to a factual question, explain a concept, make an inference, apply knowledge to a new problem, and produce creative and innovative ideas. In all of those situations, learners draw upon the past in the service of the present; thus, all situations involve retrieval.*[7]

Let's go deeper, then, and see what's happening in the brain as students are working actively with material you've just taught them. But first, let's get an idea of the neural geography involved.

### Two Important Ways of Remembering

- **Declarative memory** involves facts and events that can be consciously recalled, or "declared." For example, students may recall bad farming practices that contributed to the U.S. Dust Bowl of the 1930s. Or they may recall a quadratic equation. The declarative memory system relates to working memory, the hippocampus, and long-term memory in the neocortex, as covered in this chapter.
- **Procedural memory** often involves how to do something, such as typing on a keyboard, tying a shoelace, or the steps to solving a math problem. The

procedural system involves the basal ganglia as well as the neocortex. We'll learn more about the procedural system in chapter 6.

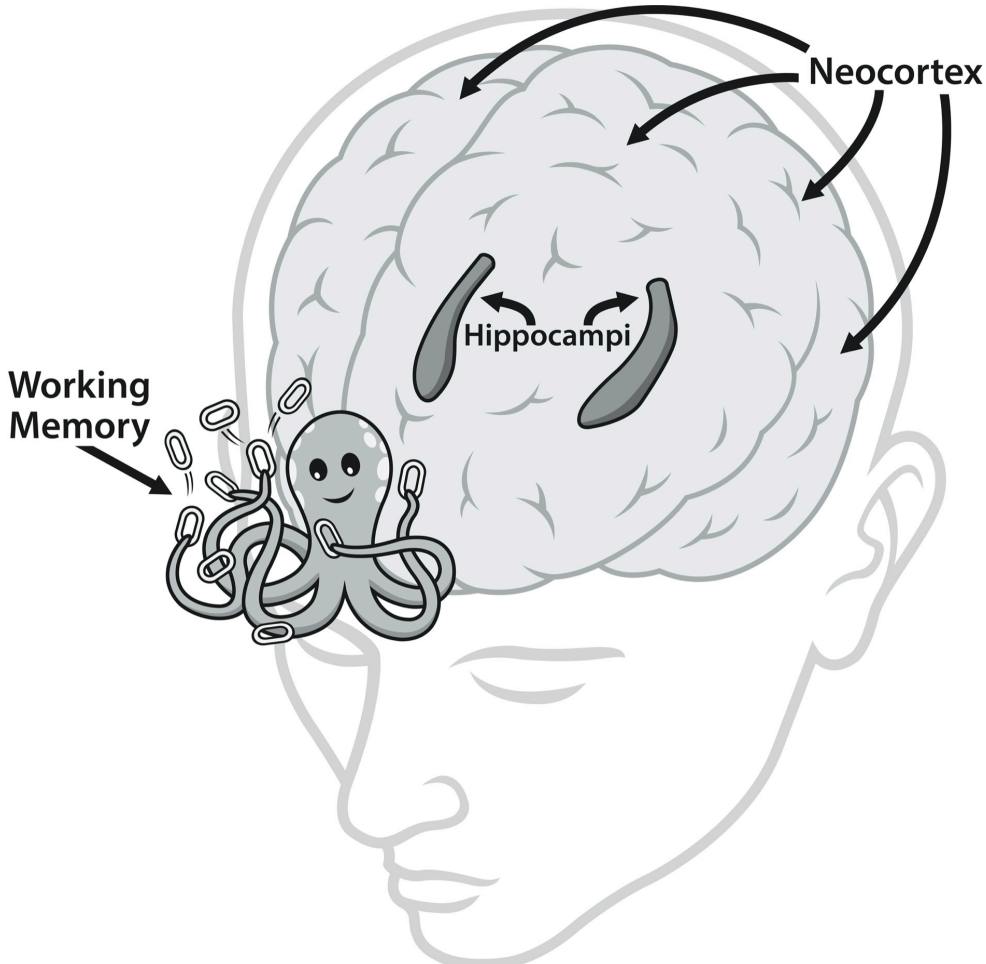
As we will soon see, these two different memory systems can learn the same concept in two different ways, providing a richer way for students to understand the material.

## The Declarative Learning System: Working Memory, the Hippocampus, and the Neocortex

Researchers have long known that the brain has three fundamental parts that are involved in learning: *working memory,* the *hippocampus,* and the *neocortex*.[8] (You'll learn about a final important building block of the brain's learning systems—the *basal ganglia*—in chapter 6.) Your working memory, hippocampus, and neocortex* work together to form your *declarative learning system*. You are mostly* conscious of what you're learning with your declarative system (you can "declare" it). Much like the declarative types of sentences students learn about in English class—it *declares* information like facts and events.

Incidentally, although we say "hippocampus," as if it's only one brain structure, you have two hippocampi—one on either side of your brain, as you can see in the illustration below. One hippocampus is above each ear, about 1.5 inches inside your head. Together, the two hippocampi have a volume of two big lima beans, one on each side. (There are also cortical areas near but not in the hippocampus that are involved in declarative learning, called the hippocampal formation. To simplify all this, we'll just lump these nearby regions together under the term *hippocampus.*)

Your neocortex is spread out over most of the brain. It is only a few millimeters thick, like a dinner napkin, around 24 inches by 24 inches. This neocortical "napkin" follows the curves and folds of the brain's surface; most of the area of the neocortex is buried in the folds. Although it is thin, the neocortex is much larger than the hippocampus. This is fitting, because the neocortex is where the vast repository of long-term memory is stored.



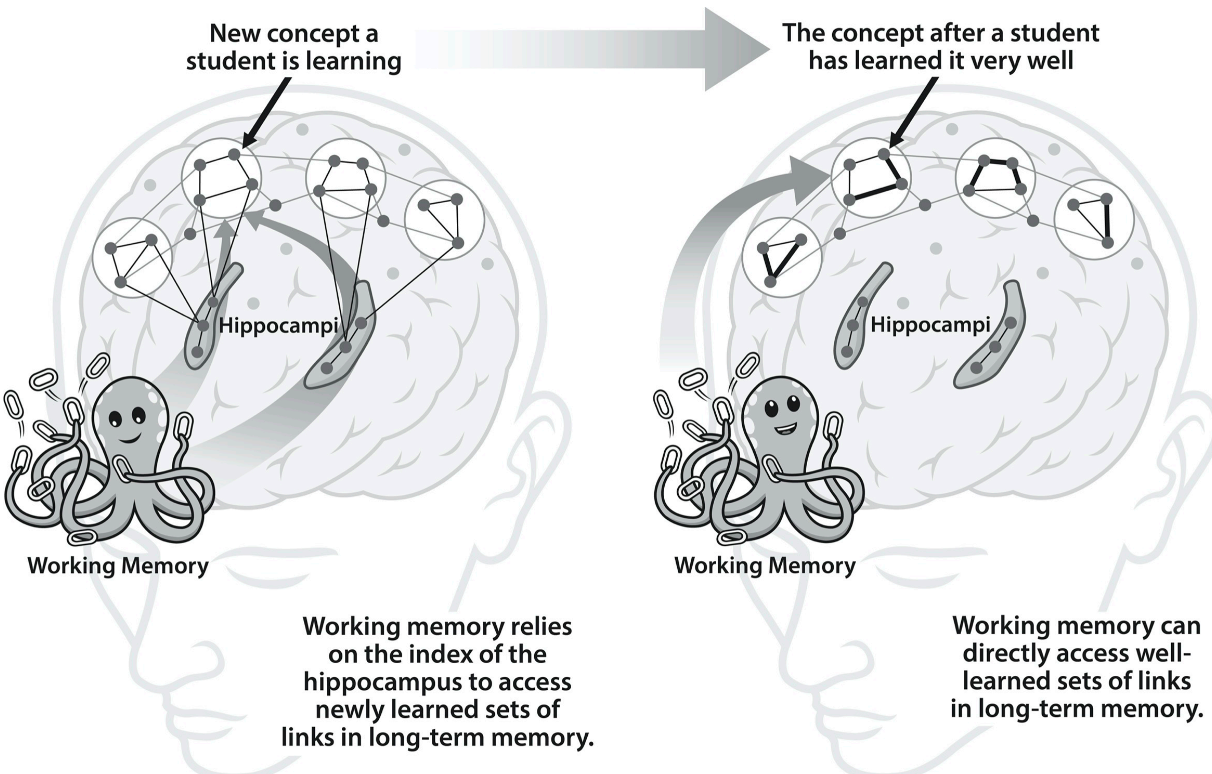

The brain has two major structures that "learn" from *working memory*: the *hippocampus* and the *neocortex*.

In declarative learning, working memory deposits the new information it is gathering into long-term memory in the neocortex. But the neocortex is huge! How can working memory ever find any specific piece of information again?

The solution? An index![9]

Remember that in a book all the information is in the text, and the index just tells you how to find it.

It turns out that the hippocampus is a sort of index. The hippocampus does not store the new information itself; it only links to where the information is stored in the neocortex. Signals from the hippocampus to the neocortex can retrieve and link together information that is distributed in the neocortex.* So each time a student retrieves information, the hippocampus strengthens links between information stored around the neocortex. Eventually, after memories are consolidated in the cortex (a process that can continue for many months, mainly while you are sleeping), working memory is able to retrieve the information directly from the neocortex without using the hippocampus as the index.[10]




Recall from the illustration on this page that each dot represents a neuron. The circles surrounding the sets of neural links ("dot links") represent different new ideas a student is learning and storing in long-term memory. **(Left)** Working memory sends the information to the dot links of long-term memory mostly by means of the hippocampus. **(Right)** As material becomes better learned, working memory can reach and grab the information directly from long-term memory without using the hippocampus.

The hippocampus has limited linking capacity—about enough to recall events, situations, and experiences at most for a few months, which matches the time it takes to consolidate the links in the cortex. The area of the brain that retains that information in the long run—that is, the part that holds our long-term memories—is the neocortex.

The process involved as information flows from working memory to the hippocampus to the neocortex is a little complex, so let's create a story to allow us to better illustrate what's going on.

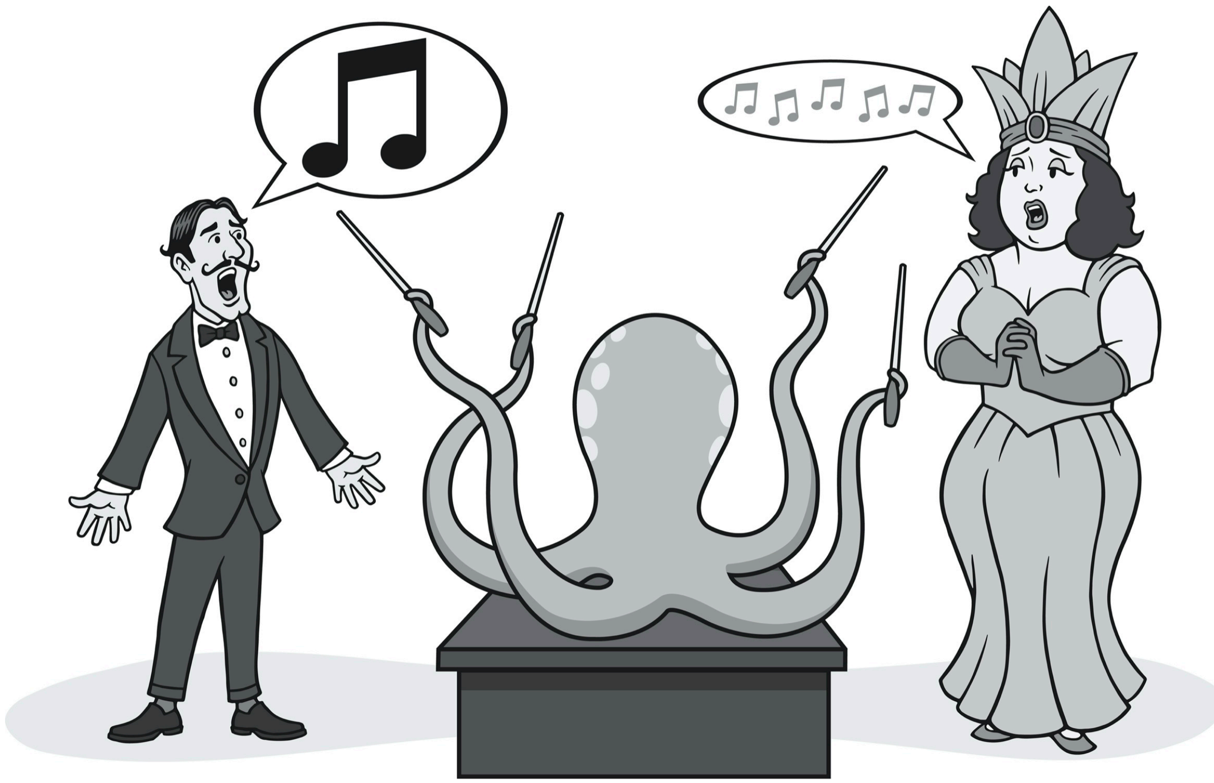
## The Parable of the Choir: Using the Declarative System to Get Information into Long-Term Memory

To understand the essentials of how information moves from working memory into long-term memory—declarative learning—it's best to start with a metaphorical story of a trio of characters, each with their talents and flaws. These three characters represent working memory and two of the brain's learning modules—the hippocampus and the neocortex—and how they interact.

In our story, we can think of working memory as being the conductor of a tiny choir of two singers: Hip, the hippocampus, and Neo, the neocortex.

The conductor, of course, doesn't sing. Instead, she just silently nods and indicates to Neo where and when to activate the notes to sing. (In other words, the conductor deposits sets of links in long-term memory about what is being learned.) Simultaneously, the conductor deposits indexing information (indexing links) in Hip about where to find those long-term memory links in Neo.

That information being deposited can be related to anything—the earliest known recorded history in Nubia, the sequence of events in *Because of Winn-Dixie,* the road to take to get to a new friend's house, the specifics of changing a bicycle tire—or yes, how to sing a song.



The brain is like a little choir with the conductor (working memory), Hip (the hippocampus), and Neo (the neocortex). Here, Hip sings his indexing song to Neo. This helps remind Neo which of her many scattered new connections she needs to strengthen, and which to weaken.

As we know, working memory—that is, the conductor—is forgetful. Even though she's the one who's running the rehearsal, she can easily forget what she's told Neo and Hip just a few seconds before.

The problem for poor Neo is that she has a hard time following the conductor. If you didn't know Neo well, your initial impression would be that she is a bumbling amateur. She is literally scatterbrained. The conductor has told her to put information in various places around the neocortex. She tends to re-sing what she's heard from the conductor very weakly, if at all, unless she's heard the song a lot of times. She is continually asking, "Could you repeat that, please?"

Hip, on the other hand, is quick and attentive. He can remember and sing much of the indexing song the conductor signals to him. But Hip has a bit of a problem. Frankly, he's superficial. His song is shorter—it is only an indexing song, after all. What his indexing song does is to help teach Neo to strengthen some of her many links about what she's learning and weaken others that aren't relevant.

So here we have these two singers—two different types of learners, really—who are following the conductor.[11] Hip can learn swiftly, but he's into only the most superficial, indexing aspects of that information. Neo, because she's got a massive number of links to connect, learns much more slowly and with greater difficulty. But she can learn a *lot*, she can learn it very well, and she has a vast repertoire of songs from the past.

Once Hip has practiced enough with Neo, Neo can sing loudly and clearly, with no assistance from Hip. Neo's vast repertoire means she can also bring in many other different notes from her extraordinarily large long-term memory.

Here's where, from a teacher's perspective, matters get interesting. Despite their differences, Hip and Neo are friends who *help each other learn*. Whenever Hip isn't busy taking in new indexing information, he turns around and sings to Neo, who has information scattered around in many places. Hip asks Neo to retrieve and link together her information—to sing the new song she is learning. This offline teaching by the hippocampus to the neocortex, much of which takes place when you are sleeping, is an essential aspect of declarative learning. It's what enables the neocortex to build solid neural links.

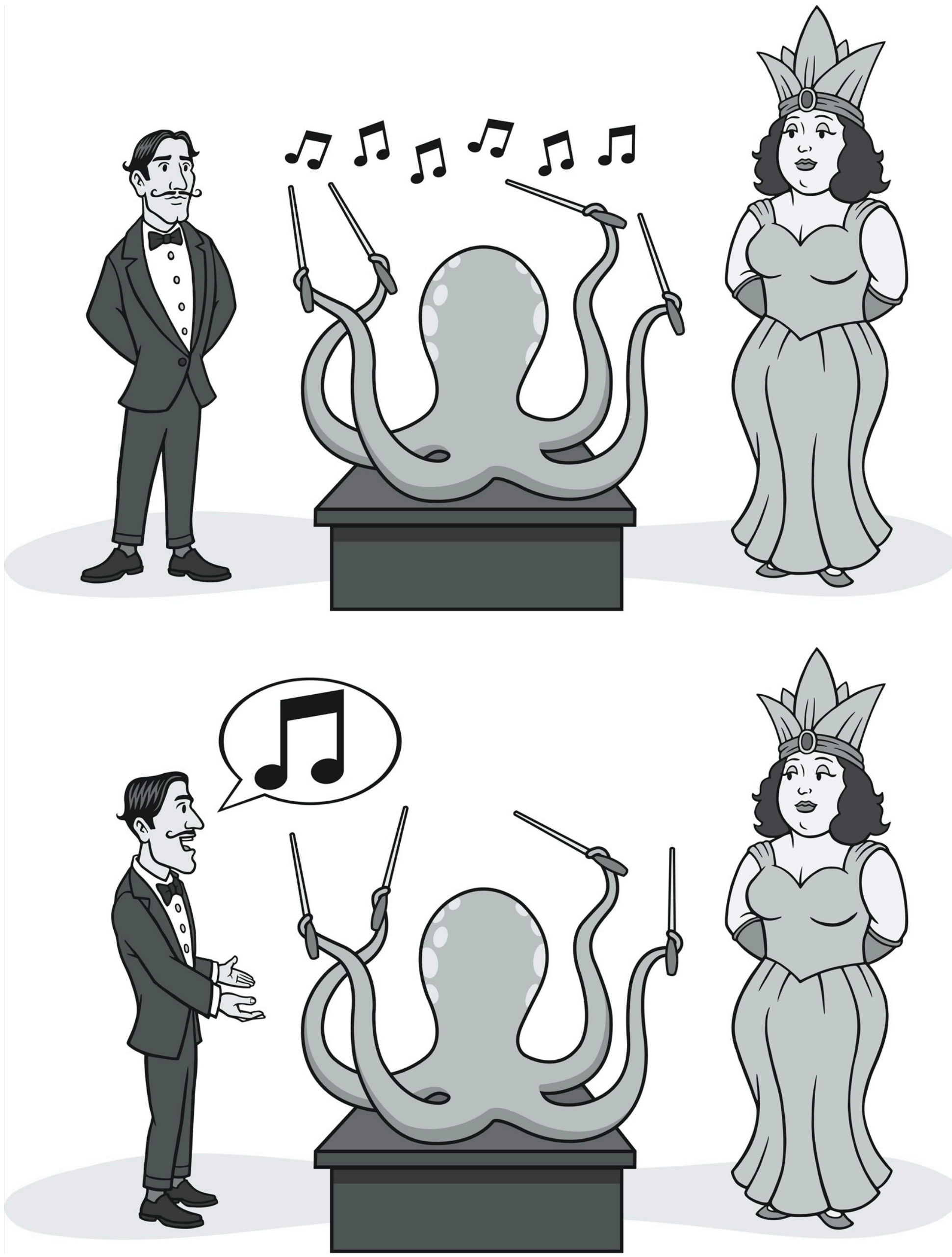
The hippocampus's reteaching isn't the only way the neocortex learns. Some of the information does come directly from working memory. But the hippocampus is the primary teacher in declarative learning because the neocortex isn't quick enough to follow working memory in real time. Hip whispers over and over again to Neo, helping her know which links to strengthen and which to weaken. It can take many days, weeks, and months for this hippocampal shaping of the links in the neocortex to take place—this process, as we mentioned earlier, is called *consolidation*.[12]

What happens when the conductor isn't teaching new information to the choir but instead is calling for the choir to sing a song? In other words, what happens when working memory is trying to *retrieve* information instead of teach it?

Here matters get even more interesting. If working memory calls for recently learned information, the neocortex's grip on the complex song she's learned is weak, so Hip chimes in—reminding Neo where all the various parts of her song are located so she can sing more boldly. But once Neo and Hip have worked together enough times on a certain song, Hip's assistance becomes less necessary. Even though Neo's information is very complex—far more complex than Hip's superficial index—she gradually becomes a master of the material. She begins to belt that tune out quite nicely all on her own.

That's the clue that something is well learned: the hippocampus is no longer needed in order to retrieve it. The better a student knows the material, the more her working memory can reach directly into the neocortex to get it, without the need for the hippocampus.

The hippocampus, as it turns out, is something of a crutch. Remember how some students will cram the night before a test, do all right for the test, and then forget much of it afterward? That's because their working memories have created a lot of indexing links in their hippocampi, along with the usual weak links in the neocortex. The hippocampal indexing links are fresh enough to get students through the exam. But those indexing links quickly fade away, and if the neocortex hasn't consolidated the information through repeated practice, *fuhgeddaboudit!* If the student wants to retrieve the information from the neocortex a month or two later, the hippocampal index is gone, and there's just no way to find the few faded links that might still remain in long-term memory.



Metaphorically speaking, Hip can be in only one of two positions. In the first position, Hip is facing the conductor and learning something new (getting the index links). In the second position, Hip is facing Neo during mental break times. He's urging her to connect her song together—the sequence of notes, the pitch, the intonation of the words, the underlying emotion—so she can put everything together in one glorious outburst. *Hip can't both learn and repeat at the same time.*

Neo has to practice over and over to sing *anything* right. Her advantage, though, is that when she's heard and repeated the song enough times, the song sticks, and she can sing it loudly and well. Best of all, she's got a *massive* memory for songs. She can remember a lifetime of memories without running out of room for more. It turns out that Neo is super talented, just in a very different way from the superficial "I do *only* indexing" Hip.

So what does all this have to do with you as a teacher in the classroom?

## Helping Hip in the Classroom with Small Breaks in Your Teaching

One valuable insight that Neo and Hip reveal is that it's important to have brief "brain breaks" in your teaching, where students have a chance to relax mentally. These breaks are like quiet mental interludes—times when the hippocampus can turn to whisper and repeat the new learning to the neocortex. These whispers from the hippocampus to the neocortex allow a welcome repetition of the material and can also slowly clear indexing links from the hippocampus.[13]

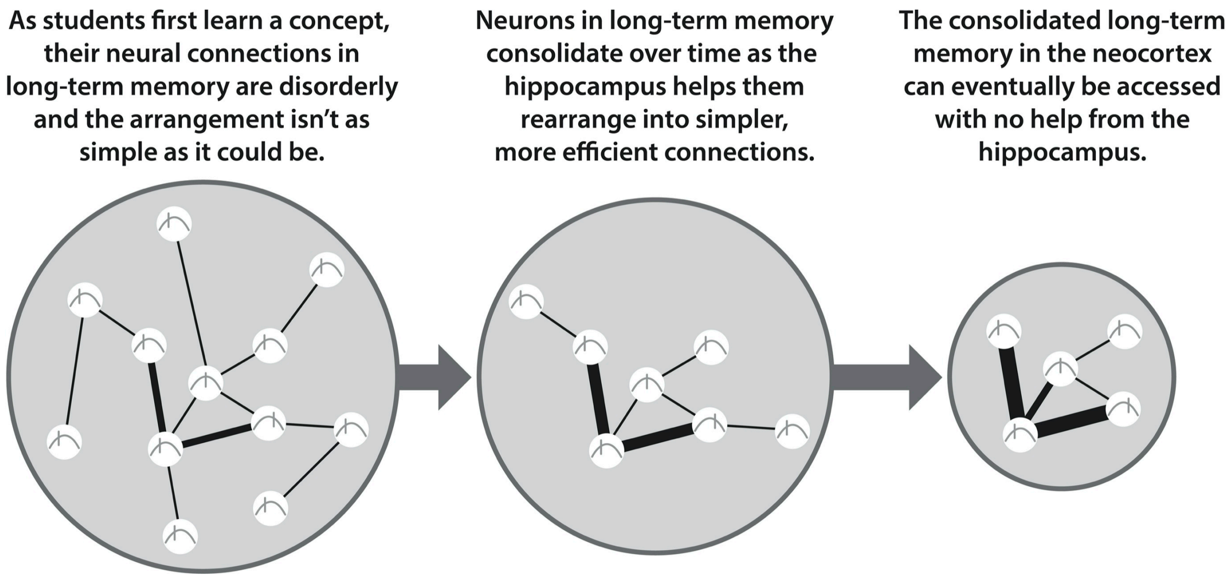
How long should your brain break be? Our brains take an eight-hour break at night when we fall asleep, when memories are consolidated on a global scale.[*] But much of the preparation is done during briefer breaks throughout the day. One study revealed that a fifteen-minute period of eyes-closed rest following learning enhanced the memory of what was just learned far more than when the participants simply went on to another task.[14] But fifteen minutes of eyes-closed rest is not going to fly in today's classrooms!

Fortunately, there's evidence that much briefer interludes are also helpful for learning. Even a pause of less than a minute can work wonders in enabling students to begin making better sense of the material. Why the break? It gives the neurons a chance to consolidate. As cognitive neuroscientist Erin Wamsley notes:

> *Consolidation occurs during the many briefer moments of rest interspersed between and within the activities of our day. Indeed, even seconds-long rest breaks during a learning experience have been shown to trigger memory-related activity that predicts later test performance. Thus, far from being a waste of time, "rest" during wakefulness may end up being a crucial and widely underappreciated contributor to long-term memory formation in everyday life.*[15]

Brain breaks can be as short as twenty to forty seconds—perhaps as students pause and turn to others, as with a collaborative activity, and with another twenty to forty seconds after the activity is done as you bring the class's focus back to you. Of course, the collaborative activities themselves *do* help—not only because of the social connection but because they often provide vital retrieval activities as a student might be muttering to herself, "Now, how exactly are we supposed to do this problem, again?"

When you go on presenting information for too long, you can almost feel the gradual tension, coupled with boredom, begin to arise. A good rule of thumb is that student attention spans will last about their age plus one. So a seven-year-old might be able to focus on you for eight minutes before needing a short interlude of something lighter, or an active break. But of course, it depends on the age and attention spans of your learners (kindergarteners may be lucky if they can give you five minutes of attention), as well as the difficulty of the material.




The consolidation process: When a student first learns something, the neural sets of links are still weak and very disorganized, as symbolized by the illustration on the left. It can take several days for those connections to stabilize and strengthen. Gradually, through the hours, days, and months of the consolidation processes, links keep tweaking and rearranging themselves. The hippocampus, which contains the index, guides this process.*

Notice that what the learner started with (the largest circle) was eventually winnowed down to the core (the smallest circle). You might wonder why teachers add in all the extra stuff at the beginning if it is not going to be part of the knowledge the student is left with. The thing to remember, however, is that the teacher is not putting the links in the students' brains. Only the students can put the links in their own brains, although of course the teachers facilitate the process. Students are, like all of us, imperfect. They can't put everything exactly right into their brain the first time. They get ideas wrong, overshoot, misunderstand, or simply learn in an unnecessarily complex way. That forms the extraneous links that must later be eliminated as the student consolidates his or her understanding of the material.

Memories tend to "semanticize" over time. That is, they erase the original context of the memory when it was made, and just keep the meaning. So you might know you own a bracelet (semantic knowledge), but forget the surrounding circumstances of how you got it. These kinds of semanticized memories—with context stripped away, leaving only the meaning or fact—are generally deeply embedded in long-term memory in the neocortex.

The pause to switch to collaborative-type activities is valuable for students. However, it's essential to remain vigilant during the collaborative activity itself. You'll want to walk around the classroom so you can hear what students are saying and clarify as needed. Unfortunately, it can be easy to fall into the trap of wanting to use the group activity to quickly check your email or get ready for the next part of the lesson. But this is how off-task student behaviors creep in and cause students to lose their focus. After all, if you aren't keeping your focus on your students, it sends an inadvertent signal that it's all right for your students to go off task, too. Worse yet, without your dedicated attention, students may move on to the next lesson with misinformation.

To sum things up, you can see now that active learning provides a critically important interlude where students both retrieve and grapple with new material, both by themselves and with others. In other words, active learning also includes small brain breaks that allow for consolidation. And it's not "Grecian urn" fluff, or superficial touching on important topics like the Civil War or civil rights. No wonder active learning, judiciously integrated into your teaching, can be so powerful!

## NOW YOU TRY!

### IDEAS FOR BRIEF ACTIVITIES THAT CAN ALLOW STUDENTS TO MENTALLY REFRESH

The time it takes students to switch to and from these collaborative-type activities can help their hippocampus offload during declarative learning. But the actual collaborative activity also assists with unloading by allowing students to think in a more relaxed, team-oriented way that reinforces the topic. In a rush to cover more and more content, we tend to sacrifice the strategies that provide opportunities for Hip to unload onto Neo. Now that you know the neuroscience behind why these strategies work, we're counting on you to regularly make time for them.

- *Think-pair-share.* Students think for a minute or two, then pair up and share their thoughts. The quiet think time of *think-pair-share* may be particularly useful for hippocampal offloading, especially if students take a brief mental breather before they begin to focus on the task at hand.
- *One-minute summary.* Students write down what they have understood from what you just taught.
- *One-minute muddiest point.* Students write down what they are confused about.

- *Peer teaching.* Have students "teach" other students, or a partner, what you have just explained, and then reverse their roles, making sure each student gets to work through the material with another student.
- *Brief role-playing.* For example, elementary students can role-play the Earth's rotation around the sun or an electron's rotation around a nucleus.

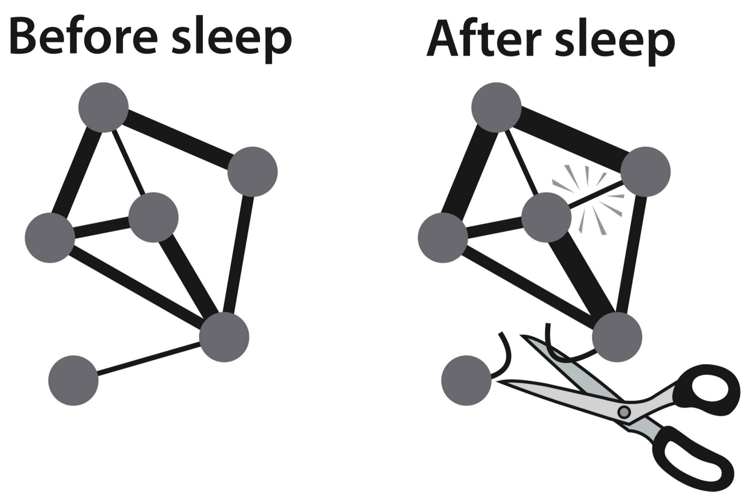
## Well-Done Active Learning Gets "Hip" Out of the Way

The perennial complaint of teachers worldwide is that students can't seem to remember the material they're taught, say, last month, or even the previous week. Why? It often boils down to that superficial behavior of Hip—the hippocampus. If he doesn't repeatedly sing his indexing tune to Neo, telling her which links to enhance and which ones to diminish, new information can fade away.

But there's no time for practice in the neocortex if a student procrastinates and tries to cram the night before a test. (More about procrastination in the next chapter.) Procrastinating hiker-type learners can be overwhelmed as their overloaded working memory tries to assimilate the material. Little of the information even makes its way into the hippocampus and neocortex. Procrastinating race-car learners, on the other hand, can fill their hippocampus with indexing information and provide initial links into the faint information in the neocortex. This can allow them to do well on the following morning's exam. But the seemingly successful cramming process creates two problems. First, if the new learning in the neocortex isn't reinforced by the hippocampus over subsequent days, the neocortical information and the hippocampal indexing links both simply fade away, whether the learner is a race car or a hiker.

The second problem is perhaps even worse. It turns out that sleep, with its different-from-waking bath of neural chemicals and altered activity levels, serves as a sort of sealant for newly formed links in long-term memory.[16] A night of cramming, with little or no sleep at the end, means that whatever information might have slipped into long-term memory in the neocortex doesn't stick.

As a teacher, you want to do everything you can to encourage the creation of solid links in the neocortex, so the student doesn't have to depend on the not-very-long-lasting indexing links of the hippocampus.




During sleep, new synapses (connections) are formed between neurons. Some preexisting connections are strengthened; others are weakened. Some connections are pruned away altogether, as shown by the scissors cutting the connection.[17] As you can imagine, sleep facilitates and is part of the consolidation process.

How can you do this? Frequent formative assessment checks—low-stakes tests, homework, and exercises—keep students learning all along the way. *These checks encourage retrieval practice of the material*.[18] Plentiful research evidence reveals that retrieval practice will speed up the consolidation of links in the neocortex and more rapidly get the hippocampus out of the picture. When students are learning something complex, working actively over a number of days with the material provides plenty of opportunities for long-term memory connections to be developed and strengthened. And, as we'll see soon in chapter 6, lots of practice enhances learning by also building the knowledge through the powerful procedural system.

As Pooja Agarwal and Patrice Bain note in *Powerful Teaching*:

> *We typically focus on getting information* into *students' heads. On the contrary, one of the most robust findings from cognitive science research is the importance of getting information* out *of students' heads. Based on a century of research, in order to transform learning, we must focus on getting information* out . . . retrieval practice. *In fact, research demonstrates that retrieval practice is more potent than other techniques commonly used by teachers and students, such as lecturing, re-reading, or taking notes.*[19]

Well-done active learning includes retrieval practice. It makes students *think* and forces them to check whether they've begun to make links in long-term memory, in the neocortex. The more students can cement what they've learned into the neocortex, without having to rely on the hippocampus, the more they will have truly begun to master the material. *And* their hippocampus is cleared for new learning. Great!

But great, *only* if what students are retaining is meaningful information. As education journalist Natalie Wexler points out, "Standard elementary literacy curricula focus on largely illusory comprehension skills—like finding the main idea—rather than content. Getting fourth graders to memorize the definition of, for example, 'inferences' won't be enough to enable them to make or explain inferences."[20]

Assuming content is meaningful and not a Grecian urn, retrieval practice is what our poorly performing students Katina and Jared were missing when they were studying. They weren't working *actively* with the material, pulling it from their minds. Instead, they were just copying whatever was in front of them or looking at the solutions and thinking that was enough to put the material in long-term memory.

It's *actively* working with the material—trying to *remember* a key idea, for example, or working through the steps to answer a tricky problem *without* looking at the solution—that helps pull out those dendritic spines and encourages them to build and strengthen connections with axons.* Repeated practice, in a variety of contexts, assists not only with the strengthening of neural connections but also with broadening them to other sets of neurons.

## NOW YOU TRY!

### THE WHIP-AROUND

Try the whip-around strategy to help Hip and Neo sort out and remember key information. To do a whip-around:

1. Pose an open-ended question to your class—one that can solicit a variety of responses and calls for more than a simple yes/no or one-word response. (The excitement of the strategy fades fast when everyone repeats the same response.)
2. Give your students a minute to come up with an answer in their head or in writing. Ensure that all students have an answer and are ready to share by having them signal with a thumbs-up. Or if you are online, you can have students unmute themselves to indicate they are ready to participate.
3. Call upon a student to respond, and have subsequent students respond by whipping around the room in an orderly fashion (for example, up and down the rows, or if online, in the order of a list of names you can share on Google Docs). Don't allow anyone—including yourself—to interrupt the flow by adding additional commentary.

For a class of thirty, a typical whip-around can take place in less than four minutes. In our experience, the act of sharing only a few words or a sentence is fun for students and allows them to speak in front of their peers in a nonthreatening manner. There is no stopping for corrections. If the question you asked has absolute right or wrong answers, give an immediate nonverbal response with thumbs-up or thumbs-down. Fixes to incorrect answers occur once everyone has taken their turn. Whip-arounds reinforce learning and make sure all students "get it." To make the whip-around more of a challenge, ask students to avoid piggybacking—that is, using a previous answer. If they must repeat an answer, they should provide a unique twist or a different explanation.

Sample questions:

- How are angles and parallel and perpendicular lines used in real-world settings?
- State a bone in the body, its type (flat, long, short, irregular, or sesamoid), and, for an extra challenge, its function.

- Name a household item and the room where you might find it. (This prompt works great for our youngest learners as well as our second language students.)
- How have organisms changed over time?
- Provide an example of a literary device (personification, simile, metaphor, onomatopoeia, hyperbole) and how it was used in the story.
- How did geography affect the development of colonial America?

## The Contradictions of Good Teaching

You may have noticed that our friend Hip, the hippocampus, has presented contradictory tasks for us as teachers.

1. **Make the mind work:** To build and strengthen links directly in students' neocortices, use retrieval practice. This is an intense and demanding mental process.
2. **Let the mind rest:** For the hippocampus to offload information onto the neocortex, the student should not be involved in intense mental activity.

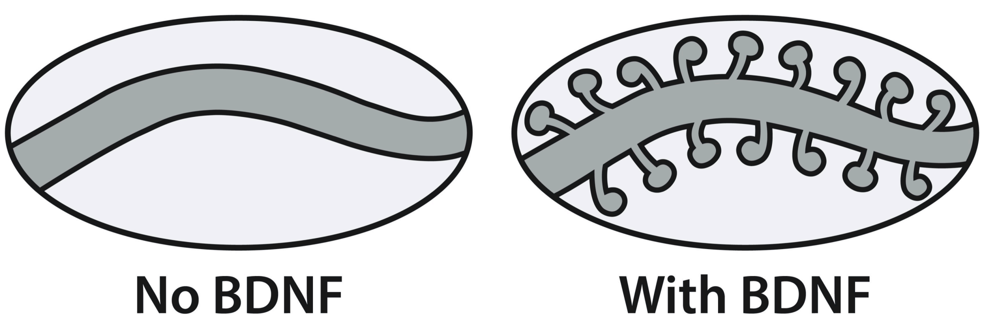
So which is it? Easy does it? Or intense mental workout?

Both! Perhaps the best answer is to think of teaching as a form of coaching. Good athletes develop through a combination of hard physical exercise coupled with relaxation and recuperation. This principle is applied to interval training: brief periods of intense exercise interspersed with longer periods of moderate exercise. (Muscles and neurons are both excitable tissues, so it's appropriate to compare them. This is sometimes irreverently called the meathead theory of brain function.) Students are becoming "mental athletes" and should be coached through a similar alternation of hard and easy mental processes.

## The Vital Importance of Exercise

While we're speaking of physical exercise, we want to point out the value of physical exercise in learning. Exercise produces a fertilizer-like substance in the brain called BDNF (which stands for *brain-derived neurotrophic factor*). BDNF helps new dendritic spines pop out—having these spines already handy makes it easier to create new neural connections. (It's kind of like having a bit of yarn just waiting around to be woven into some material.) Just one session of exercise will build students' BDNF levels, but regular exercise builds those levels even more.[21]

Exercise also helps with neurogenesis—that is, the birth of new neurons that also play an important role in new learning and improvement of mood.[22] Through a variety of effects, physical exercise also helps buffer the negative effects of stress on students' cognition. To achieve this buffering, at least one hour of moderate to vigorous activity per day is recommended.[23] This is why eliminating student recess as a way to give more class time for instruction is a poor idea. Exercise, in fact, helps students focus and learn more efficiently when they are in class, and helps them feel better all the way around.




While sleep strengthens preexisting connections, exercise produces a substance called BDNF, which helps new dendritic spines emerge. In other words, exercise helps neurons grow important extensions that can easily be hooked to other neurons. This is why exercise is such a valuable enhancement for learning.[24]

## How Much of Your Teaching Should Be Active?

The reality is, researchers don't know what percentage of time students should spend on active learning as opposed to listening to or seeing explanations. Optimal times vary by students' age, the type of material being covered, the level of students' previous exposure to the material, and many other factors.

At the beginning of this chapter, we mentioned an extensive meta-analysis that found classrooms with active learning performed impressively better than classrooms using traditional "talk and chalk" methods of lecture. But here's the important point: The amount of "active learning" time varied between 10 and 100 percent of the total class time—the researchers didn't measure the actual amount![25]

In other words, the paper could perhaps just as reasonably have been titled, "Break up your instruction with a few active breaks, and your students will do better." This is a significant finding, strongly supported by neuroscience. And we can all use it to improve our teaching.

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# Analyze Your Teaching:

## Think-Pair-Share

**The Setup**

Although we could pick virtually any topic, let's say you are teaching a lesson on how humans can disrupt the environment's natural cycles. You begin by explaining that our planet is a closed system. It has all the water, oxygen, carbon, nitrogen, and other elements it will ever have. The Law of Conservation of Mass states that matter —in this case, Earth's resources*—cannot be created or destroyed, although its form may be rearranged or changed.

Uncommon sense teacher that you are, you know to tap into students' prior knowledge. You also know that you should make learning active so that neural links are formed and strengthened. You start by asking the following open-ended question:

> *Less than 1 percent of all of the Earth's water is fresh water, which we use to drink, cook, and grow food. So why haven't we run out of fresh water?*

Instantly hands dart in the air. When you call on Jenna, suddenly the answer escapes her. Ray makes a wisecrack, and the class begins laughing. You realize things could rapidly veer off course, so to keep the lesson flowing, you provide the answer. "Mother Nature," you say, "is a master recycler—and one of the best examples of all is the water cycle." You continue to cover the cycle's four main components: precipitation, evaporation, transpiration, and condensation. As your eyes turn from the board to the students, you notice glazed looks. The class is hearing, but they're not absorbing.

What could you have done differently?

**What to Do with Your Students**

Enter *think-pair-share*[26]—developed in 1981 by Frank Lyman, a professor at the University of Maryland.

As a quick review, *think-pair-share* is a collaborative approach where students work together in pairs or small groups to answer a question or solve a problem. The teacher asks an open-ended question and lets students *think* quietly for a moment to formulate an answer. During this stage, students are checking their notes and organizing their thoughts. It adds a layer of accountability to have students jot down their initial response, making it a *think-write-pair-share*. They then *pair* up to *share* their ideas with their partner(s) and decide which one is best or maybe think of an even better idea, and ultimately, *share* their final answer with the class. When the teaching is face-to-face, it's easy to have students partner with the person next to them. Pairing students online can be just as easy. With a few quick clicks, you can put students in breakout rooms.

It's worth revisiting *think-pair-share* here, because we can now understand the critical *think* component that is often overlooked. *Think* is when students can not only reflect on what you've said but also give their little hippocampi a "brain break" to begin offloading and making sense of what you've been explaining. You may even want to set a timer for some dedicated *think* time. When the timer sounds, students can go on to pair and then share.*

When students share their thoughts with a partner, two things are happening. First, the students are learning from each other—gaining another perspective, working through stumbling blocks, and practicing to better verbalize their answer. Second, they are gaining confidence in either sharing answers with the larger group or asking for assistance. (Asking for assistance, even one-on-one, is difficult for many students. It can be difficult for us adults, too!) To further build students' confidence, circulate among pairs (or join breakout rooms) as they are sharing and occasionally check in to see if they are on the right path. To ease into a whole class discussion, ask one pair who clearly has the right answer if they would be comfortable sharing it with the class. Consider choosing the partner who is most shy or often reluctant to share responses with the whole class—knowing her answer is correct and receiving a personal invitation from you will build her courage.

Sometimes it is also useful to ask students with minor errors if they are willing to share their answer with the class.[27] Fixing errors together allows you to model problem-solving strategies and gives students a moment to step back and assess their thinking. Crucially, allowing students to present errors gives you a chance to show the class that making errors is no big deal and that your class is a warm and welcoming environment even when a student makes an error.

It's important when encountering wrong answers to ask the class what they think but to refrain from leaping in to make the correction yourself. Those silent seconds before you hear students' thoughts may seem interminable, but this is when genuine learning can take place.

**What to Avoid**

Be careful not to go back to your desk to check your email or to organize your materials while students are sharing their answers. Not only does circulating among your students keep them on track, but also it builds rapport by showing that you are genuinely interested in their understanding of the material.

**Generalizing the Principles**

Think-pair-share can be used with any prompt that makes students think. It is widely used across content areas from the humanities to social sciences to STEM.

Not sure where to begin? Below are some sentence starters to try.

- Explain ___ in terms your younger sibling or friend could understand.
- In one minute, brainstorm as many examples or ways of doing ___ that you can think of.
- Explain what could go wrong if ___.
- Describe the main character in a story using one word. Support this word with specific thoughts and actions of the character from the story.

## Key Ideas of This Chapter

- A commonly understood definition of active learning is that it engages students in the process of learning through activities and/or discussion in class. It frequently involves some form of retrieval practice, as opposed to passively listening to an expert. Active learning emphasizes higher-order thinking and often involves partner or group work.

- From a neuroscientific perspective, active learning supports the creation and consolidation of neural links in long-term memory that underlie both a rudimentary and a higher-order conceptual understanding of the material. It is often part of the *link it* phase of *learn it, link it*. Not all learning is active learning.
- The declarative learning pathway sends information from working memory to both the hippocampus (indexing the information) and the neocortex (storing information in long-term memory).
- When the hippocampus has a break in the incoming stream of information from working memory, it can turn to the neocortex and reinforce its learning by telling it over and over again which links to strengthen and which to weaken.
- Brain breaks occur naturally while students transition to a collaborative exercise such as *think-pair-share,* or when they do low-key thinking about the materials on their own. Just as athletics requires strenuous physical activity coupled with rest, learning develops through hard mental work paired with mental rest.
- Encourage retrieval practice, which speeds consolidation of links in the neocortex. Retrieval practice allows the information stored in long-term memory to be accessed more directly by working memory without going through the hippocampus.

# 4

# Remedies for Procrastination

You can practically smell the tension in the room. Alicia has her notes out, taking one last look while she can. Her pencil taps nervously, which irritates Michael, beside her. Diego is popping his knuckles, while Tamika, a star student, smooths her hair with nervous confidence.

But Sam. Ah, Sam! He just looks tired. Sam always looks sleepy right before tests. Once he fell asleep *during* the test, his slobber marking up the few answers he'd given. (You remember how gingerly you handled the paper to grade it.)

Sometimes students in your class are tired because their home life is rough. Not Sam. Yes, his parents are busy professionals, but they love their son and have a happy relationship with him and each other. And indeed, Sam's a smart kid—but he engages only with what he thinks is practically useful. Forget commutative and associative relationships in math. Want your car engine rebuilt? Sam, at thirteen, is your guy.

So what gives with Sam and tests?

## Procrastination: A Top Problem for Students

You may have already guessed from the title of this chapter: Sam is a master procrastinator. But at the same time, he doesn't want to disappoint his parents. This yin and yang of motivations mean he tends to put off studying until the very last minute—say, midnight before a test. He crams as much as he can before falling asleep a few hours before daybreak. Even though he's a smart kid, few can learn under such stressful last-minute conditions.

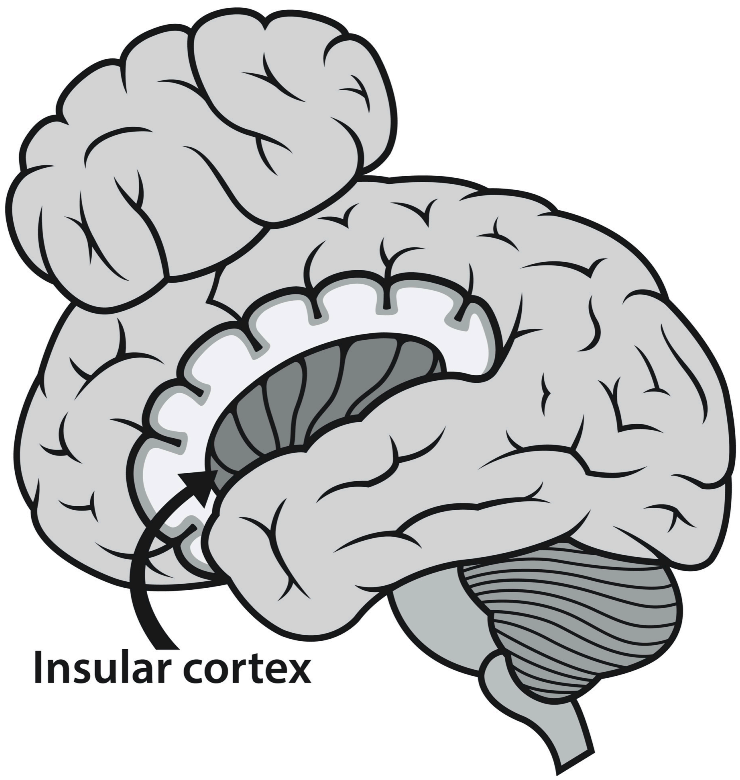
You've probably known plenty of students who are worse procrastinators than Sam. Sometimes they genuinely intend to study but simply put everything off until the last moment. They then realize—too late—how hopelessly they've boxed themselves in. At that point, even cramming is useless. They give up.

If you wanted to pick the top problem for students, procrastination would be a great choice. Psychologist Piers Steel estimates that "80–95% of college students engage in procrastination, approximately 75% consider themselves procrastinators, and almost 50% procrastinate consistently and problematically."[1] College students are that way because they've had plenty of time to develop habits of procrastination in their K-12 years. You can make a *big* difference in students' lives by tackling their tendencies to procrastinate early on.

## What Happens in the Brain When Students Procrastinate?

First, it's useful to know why procrastination happens. Psychologists have pointed to myriad reasons. Perhaps the most fundamental is that when Sam and your other procrastination-prone students (and even you!) think about something they don't like or don't want to do, it activates feelings of pain in the insular cortex—a part of the brain that processes pain signals.[2] How does someone like Sam deal with these uncomfortable feelings? Simple. He just thinks about something—anything—else. Avoidance works like a charm in taking away the pain of the moment. But the problem is, he's just procrastinating. There'll be long-term pain to pay—like stressing out at midnight and then falling asleep during the test.

Worse than that, Sam has short-circuited the *learn it, link it* process. His brain needs time to consolidate information and build new neural links. When Sam gets little sleep the night before his big exam, his brain just can't seal into place the new dendritic spines related to what he's stayed up late to learn.[3] The new learning is like water being poured through a strainer—it just flows right out again.




When students just think about something they don't like or don't want to do, feelings of discomfort and pain pop up from the insular cortex–a pain-processing center of the brain.

## Procrastination in Race-Car Students

Surprisingly, race-car students can be among the worst procrastinators. They get into the habit because in their earlier years, their studies came easily. A last-minute glance at the material was enough to do the trick. But fast-thinking race-car students can face a vicious downturn in their grades as they begin to experience tougher material. The transitions from middle to high school or from high school to college can be particularly difficult because these students simply haven't learned how to study in a way that keeps pace with the class.

### Procrastination in Hiker Students

Hikers, with their lesser-capacity working memory, can still handily outperform race cars. They achieve this feat by creating lots of well-practiced, broad-ranging sets of links in their long-term memory. Even though their working memory may not be able to hold much, the sets of links they've laid in long-term memory compensate by doing a lot of processing that minimizes the load on working memory. Hikers can do difficult mental processing, just like race cars, except that the hikers do much of their processing in long-term rather than working memory.

The caveat is that hikers need more practice than race cars—it takes time for the hikers to build those long-term memory links. It is also why procrastination can cause challenges for hikers.[4] Fortunately for them, motivated hikers learn early on that procrastination is dangerous. Race cars, on the other hand, may not learn the dangers of procrastination until much later, when procrastination becomes a harder habit to break.

## What About Motivation?

At this point, you may be thinking, *Neuroscience must surely have* something *informative to say about motivation!* Yes, it does. In fact, neuroscience reveals that the "commonsense" (and thus suspect!) motivational approach of just making learning more fun can backfire. We'll talk more about motivation in chapter 7.

For now, it's perhaps best to think of motivation in learning in terms of learning to ride a bicycle. Learning to ride a bike can be difficult—you expect to fall off and get cuts and bruises. Yet the desire to ride in the same way as all the happy, successful bike riders in a neighborhood motivates budding bicyclists to work through the initial crashes and pain.

Great teachers help students work through the more challenging aspects of what they are learning by providing intermediate incentives, making the rewards seem more immediate and the day-by-day outcomes worthwhile. Ultimately, students can catch sight of the promised land—a sense of what it's like to have mastered the material. The inspiration and motivation excellent teaching can unleash is not, at least as yet, something we can put into a bottle.

## NOW YOU TRY!

### TEACHING YOUR STUDENTS HOW TO TACKLE PROCRASTINATION USING THE POMODORO TECHNIQUE

Perhaps one of the best techniques for tackling procrastination, as well as for teaching students how to concentrate and avoid nefarious multitasking, is the Pomodoro Technique. Italian Francesco Cirillo developed this approach during the 1980s. (*Pomodoro* is the Italian word for tomato—Cirillo used a nifty tomato-shaped timer.) We now know that Cirillo's method is right in line with what neuroscience tells us about how best to tune up one's focus.

The Pomodoro Technique is straightforward. When a task is important but tempting to put off, all that students (and you) need to do is:

1. Put away or turn off all distractions—especially smartphone notifications.
2. Set a timer for twenty-five minutes and focus as intently as possible on the task during those twenty-five minutes.
3. Relax mentally for five minutes.
4. Repeat as needed. Take a half-hour break after the third or fourth Pomodoro.

That's all there is to this powerful technique, which teaches students to work in short, concentrated bursts while also giving them practice in avoiding the addictive call of social media.

The relaxation part of the Pomodoro is particularly important. We, as teachers, tend to think that the only time learning takes place is when students are focusing. But as we relayed in the Parable of the Choir (with our key players: the conductor, Neo, and Hip), the hippocampus needs frequent short breaks for teaching the neocortex. There's a lot of valuable learning going on while your brain shuffles the new information into place—even if it seems you're just taking a break.

How students handle a relaxation break is particularly important. If they use the break to grab their cell phone and catch up on messages and social media, this focused intrusion can overwrite what they've just gotten into their hippocampus instead of allowing their hippocampi to offload.[5] (It's a little like new passengers crowding into a subway car, which pushes other passengers out the other side of the car so they get off at the wrong stop.) The best breaks are mentally relaxing, with activities like closing your eyes, taking a short walk down the hall, getting a drink, going to the bathroom, petting a dog, drawing, or listening to a favorite song (maybe dancing to it, too!).

Although we caution against the use of cell phones, we admit that there are many Pomodoro apps (Forest is particularly popular) that can gamify a Pomodoro and make it more enjoyable.[6]

Although the Pomodoro technique is best used by students at home, you can also use it creatively while teaching, where you can take the opportunity to model the technique. To do a Pomodoro, have students work on a task silently in class, then enjoy a relaxing little break when they are done. Adjustments in time for the technique will need to be made, of course, depending on the length of the class and your students' ability to work independently. The rule of thumb we'd mentioned earlier for determining typical attention spans can also apply to the Pomodoro. If you feel your students may not be old enough for the full twenty-five-minute Pomodoro, give them a Pomodoro equal to their age in years plus one. So, for example, a nine-year-old might have a ten-minute Pomodoro.

## Why Do Students Procrastinate?

I procrastinate. You procrastinate. We *all* procrastinate—especially our students. Here are some reasons offered by seventh-grade language arts students who answered two questions—*Why do you procrastinate?* and *What are the consequences?*—along with our suggestions for combating procrastination.

- I procrastinate when I am in class and I don't know how to do the work. I fail and get picked on.
- I like to do the easy work first and procrastinate on the hard stuff. If it's too hard, I just tell my teacher that I tried.

Knowing how to get started can be a stumbling block for some students. Working one-on-one or in small groups at the very beginning can get those students on the right track. Staying on a challenging task is another common struggle for many students. Return to those students as the work gets more challenging to check on their progress. Then assist as needed.

- I procrastinate doing my homework. I usually zone out and lose concentration. When I realize that I am procrastinating, I come around and kick myself into high gear to get back to work.
- I sit there and stare at the work I have to do and think about how many other things I could be doing. Usually the teacher will snap at me and that gets me back to work.

Whether at home or school, the Pomodoro technique is ideal for the student who knows what to do but lacks attention. When students have a short break to look forward to, such as talking to their friends, showing off their latest dance moves, grabbing a snack, or watching a short YouTube video, they are more inclined to stay on task.

For some students, the Pomodoro technique may not be enough. For those students, check back with them more frequently to make sure they are on task. You may need to give them smaller goals—for example, instruct the student, "You have two minutes to work through the first problem." Then be sure to circle back to hold the student accountable for making progress.

- When I procrastinate, it is usually when I have a project for school. I wait until the night before it is due and then my mom yells at me, but she'll make sure I get it done on time.

This student has learned that she will be bailed out by her parent, which reinforces habits of procrastination. We teachers can help students set daily goals to be accomplished at home or during study halls leading up to the project's due date. In upper elementary and middle school, communicating the project and daily goals with parents through an assignment book or email keeps students accountable.

Students have a multitude of reasons for why they procrastinate. Some even believe themselves when they say, "I work better under pressure." But you know the truth because you have seen their rushed, haphazard work.

Today's students *are* busy, so they're not making it up when they say, "I have too much to do." On top of their taxing school schedule, they are often committed to after-school sports, clubs, dances, traveling teams, social media, YouTube, jobs, and more. This deluge of activities is creeping to younger and younger ages. No wonder students are overwhelmed and put your assignments off until the last minute. They are prioritizing what is in front of them *right now,* not thinking ahead to the next few days or upcoming weeks.

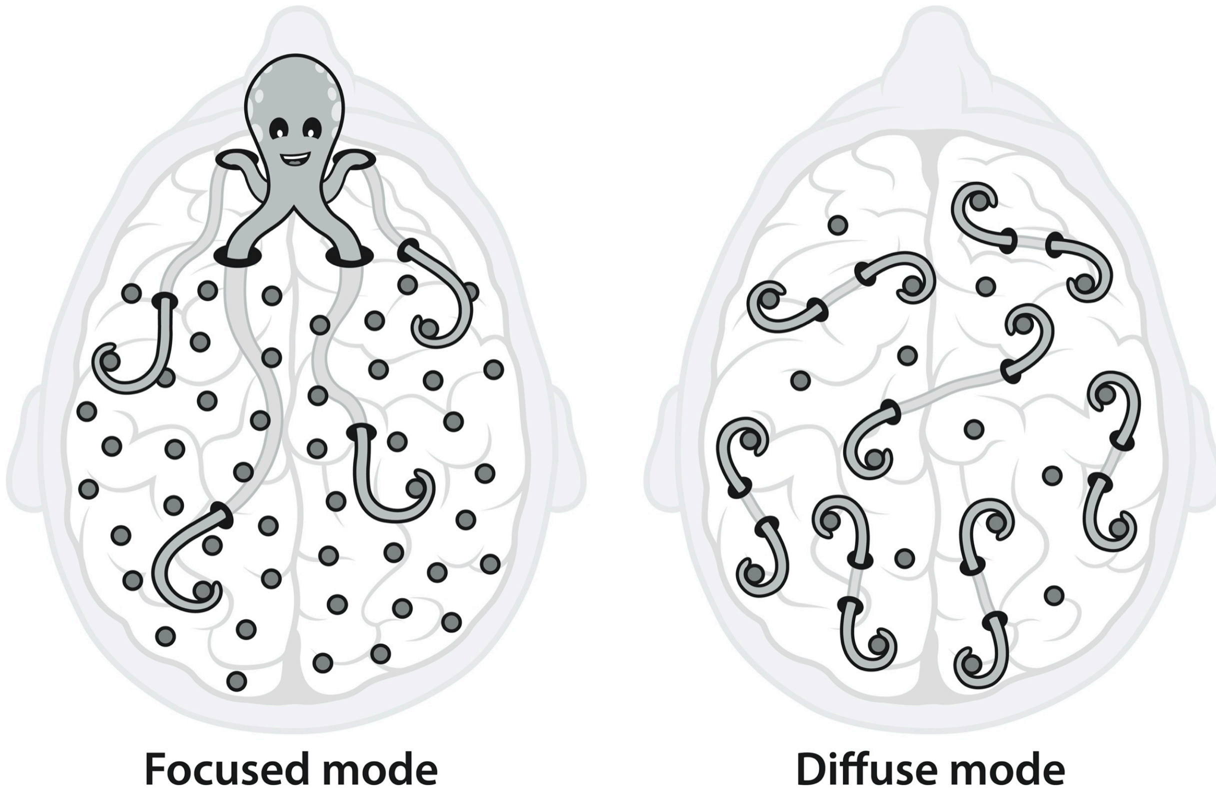
## Why Procrastination Is Especially Harmful to Students

You see students in the lunchroom, in study hall, even lining the hallways as they frantically memorize their notecards during the final hours leading up to their big exam. Suppose, for example, that students are studying for an exam where they need to know all twenty-seven amendments to the Constitution. Some students have spent time studying and quizzing themselves days before and even in the final moments leading up to the test. Other seeming superstar students procrastinate until the night before, memorize information in a few hours, and ace the test the next day.

Yet these same superstar students can end up flunking a test involving a deep understanding of democracy or the function of the Supreme Court. Why? Because although good learning always consists of creating links in long-term memory, it's generally not as simple as memorizing terms. Deep learning often also involves figuring out difficult concepts. This kind of knowledge takes time, whether a student is in kindergarten, middle school, high school, or college.

Why does deep learning take time? *Because it involves making creative new neural connections.* It's not a ho-hum process where some random neuron just links to a cozy neighboring neuron. It's more of a wild process of testing out new neural connections, and if those connections don't help make sense of the concept, then trying a different set of connections. And still different ones. Sometimes *dramatically* different sets of connections are needed to understand tough concepts! There's a lot of subconscious sorting going on under the neural hood when students are learning something new and challenging.

The best way for a brain to find and make those dramatic new connections is for it to go from *focused* into *diffuse* mode.[7] As you may have guessed, focused mode is when you're focusing intently on a problem as you're trying to solve it. (Or when a rambunctious student settles down and focuses intently as soon as he finds an iPad in his hand!)




Switching between *focused mode* (where working memory is focusing as it reaches toward the sets of links in long-term memory) and *diffuse mode* (where random connections can form) helps students to grapple mentally with tough new ideas.

In focused mode, working memory is making connections among the neurons of the hippocampus and neocortex. You can see this process on the left in the illustration above. Diffuse mode, on the other hand, is when the brain takes a bit of a break from external focusing, as shown on the right in the image. In diffuse mode, working memory gets out of the picture and the brain subconsciously starts to make random connections. Diffuse thinking is what you're doing when you're daydreaming or thinking randomly as you walk down the hall, take a shower, or fall asleep. You are much more conscious of focused than of diffuse mode thinking.

It's important to tell students that it's perfectly normal *not* to understand something difficult on their first attempt. When students start to get stuck in their learning, some tend at first to try even harder. After all, we teachers often speak of how important it is not to give up. But like a house of cards that collapses with even the tiniest extra weight, some students may eventually give up in disgust, saying things like “I’m just not a math person,” or “I can’t . . . ,” or worse yet, “I hate . . .” It doesn’t matter if these students have been told about growth mindset—their emotions ride roughshod over their reason. Their frustration causes them to give up altogether and do anything to avoid the feelings of pain popping up in the insular cortex.

But when a student starts to fall into frustration, that’s precisely when she should back away and take her mind *off* the concept. It’s only when she gets her focus *off* the concept that she can go into diffuse mode. Diffuse thinking allows a student’s brain to work behind the scenes, randomly exploring new connections while she’s taking a break, or eating lunch, or clowning around during recess. Later, when she returns to her previous point of frustration, it can seem like magic. What made no sense at all before can suddenly seem easy!

Learning often involves going back and forth between focused and diffuse modes. (Interestingly, research may eventually find ways to move us toward one state or another by using certain breathing techniques.) If you teach students about the focused and diffuse processes before their frustration kicks in, the forewarning can serve as preventive medicine. Encourage students to learn until they find themselves growing frustrated, at which time they should take a break. Students can return to the point of frustration after either a few hours or the next day, after a night of sleep. Remember, sleep is when the neural bath of chemicals in the brain aids in the learning process.

As you can imagine, toggling between modes in learning takes time. And time is exactly what students don’t have when they procrastinate, waiting until the last minute to do an assignment.

Teach students to work on a tough concept until they begin to struggle. At this point, they should let go and “let link” with the diffuse mode as they work on something different or relax. When students return to the concept, they’ll be able to make surprising progress. It’s a bit like launching a paper airplane. You need to put effort into getting the plane in the air before it will begin to soar on its own.

Knowing when frustration has just reached a peak, so it's time to switch to something else or take a break, is a valuable learning meta-skill. It comes in particularly handy on tests, where students often can't unstick themselves once they become stuck on a problem.

### The Hard-Start Approach to Test-Taking

For students who have spent quality time with their studies, a good way to do well on a test is to use the *hard-start approach*. To use this approach, as soon as a test reaches their hands, students should quickly scan it to find the *hardest* question. That's the question they should attempt first. But students should pull themselves off the question as soon as they feel themselves getting stuck, which is usually a minute or two after starting.

To use hard start, after getting stuck on the tough problem, students should force themselves to move on to simpler questions. Working on simpler problems for a bit allows the diffuse mode to simultaneously work on the more difficult question in the background. Later, when students return their focus to the difficult question, they can often finish it, or at least make more progress.

The hard-start approach is far more effective than starting with the easiest questions first and tackling the toughest question at the end of a test, when students are already mentally tired and have the stress of too little remaining time. It takes advantage of the diffuse mode to use the brain as a sort of dual processor, working on the tough question in the background.

Of course, if a student hasn't prepared well, it's best to just start with the easy questions and get what points they can.

## NOW YOU TRY!

### MORE TOOLS TO HELP YOUR STUDENTS TACKLE PROCRASTINATION

1. Create to-do lists with students. Crossing off tasks as they are completed will give students a sense of pride and accomplishment. Some students will also need assistance prioritizing tasks and creating a schedule.

2. Help your students sort through their chaos. It's hard for them to be productive when their lives are spilling all over the hallway. Even when students do the work, they may not be able to turn it in because they can't find it. Organization is a key to student success. A task that can ordinarily take only ten minutes to complete may take students more than an hour if they need to scramble through a messy locker, notebook, or desktop to find it.


3. Hold students accountable. If you don't regularly check assignments, students will not do them. At the beginning of class, have students show and discuss their assignment with a partner or small group while you circulate the classroom doing your own checking. When you *and their peers* check assignments, it makes completing your assignment one of their priorities. A side benefit—starting the class this way will refresh students' memories before the ensuing lesson. Awarding a few points helps, too.

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# Analyze Your Teaching:

## Break It Down—Tackling Tough Assignments

**The Setup**

You have just wrapped up an intense week on the major battles of World War II. Your students' assignment? They have two weeks to write an essay about two events that had an impact on the outcome of the war. (Notice how open-ended this assignment is. Later you can provide specific example assignments for students to evaluate without having to worry that students' only recourse is to copy your examples.)

You expect multiple-paragraph essays filled with elaborate explanations of military strategies and examples of how both culture and technology influenced key events. After all, you spent days covering these complex ideas, while your students took copious notes.

But when you sit down to read the essays, you're shocked. Your students wrote in generalities, repeating random bits and pieces of what they could remember. You're wading through rushed, haphazard fluff.

Soviet soldiers on the attack at the Battle of Stalingrad. Sometimes it can feel like a battle just trying to communicate these important historical events and make them stick in students' minds.

**What's Happening in the Students' Minds**

Most students think to themselves, *I've got plenty of time*—especially for assignments that are not due immediately. But time has a way of running out for students who are prone to procrastinating. They wait until the night before—or worse yet, the study hall before class—and scramble to come up with some disconnected fragments from their notes.

**What to Do with Your Students**

Procrastination is a major factor behind students' poor performance. How to prevent it? Scaffold the assignment by breaking the essay into intermediate stages with separate due dates, rather than leaving students to their own devices. (Yes—the "device" pun is intended—checking social media is much more engaging than writing an essay on World War II.)

Your goal is to coach students through the process of producing a quality essay by giving them intermediate feedback. After all, the last thing you want is for students to get a graded essay back and realize—too late—that you were serious about good quality.

Below is a sample "intermediate task" approach to writing an essay. Check that students are meeting each deadline and offer critical feedback throughout the process. As you circulate among the students each day to review their assignment, have them work with a partner to share the day's task. While the rest of the class is engaged in writing or reviewing each other's work, you can offer assistance to students who are struggling.

| SAMPLE "INTERMEDIATE TASK" APPROACH TO WRITING AN ESSAY | | | |
|---|---|---|---|
| **Due Date** | **Task** | **What this task helps students do** | **What students can do with a partner** |
| March 6 | Draft of thesis statement with two tentative ideas supporting it | Helps students decide early on the two events they want to investigate | Provides an opportunity for students to brainstorm with a partner. Afterward, conduct a whip-around to hear each student's thesis quickly. |
| March 7 | Provide three reference citations. Each citation should be followed by a bullet point describing the idea(s) the reference supports. | Helps students search out and *read* references related to their two chosen events. Also helps students get the reference in the proper format. | Students share their references with their partners. The more research, the better. Instead of three different references, students potentially have six. |
| March 10 | Outline of the essay | Forces students to organize their references for each event into a logical argument. When you think aloud, you help students learn how to organize their own material. Show students a sample outline of an exemplar essay on a different topic. Conduct a think-aloud verbalizing your thought processes as you work through the flow of the outline. | Have students replicate your think-aloud with their outline to their partner. The partner offers suggestions, and they discuss logical arguments to be made in each section of the essay. |
| March 12 | Draft of introduction | Helps students think of ways to pique their | Make this a friendly competition among |

| SAMPLE "INTERMEDIATE TASK" APPROACH TO WRITING AN ESSAY | | | |
|---|---|---|---|
| Due Date | Task | What this task helps students do | What students can do with a partner |
| | | audience's interest. A historical anecdote? Startling statistics? Imagery? Students may choose a combination of more than one attention-getting technique. | groups of four, sharing their most compelling introduction to the class for a vote. |
| March 14 | Draft of body paragraphs covering the first event that influenced the war's outcome | Students will now have done the preparatory work to make the development of rich body paragraphs easier. Remind students to use their references and outline as a guide. This forces students to move beyond their personal opinion and into their sources of evidence. Ask students to highlight material in their essays from their references to allow them to become visually aware of whether they have a potential plagiarism problem. | To guard against fluffy factoids (e.g., "World War II was a big war that killed a lot of people"), have partners share background material from their resources, including at least two challenging original ideas that have not been covered in class. In this stage, also encourage partners to watch for potential inadvertent plagiarism. Too often, students have an overreliance on the words of their sources. |
| March 17 | Draft of body paragraphs covering the second event that influenced the war's outcome | Repeats the previous exercise to keep students on track and to allow them to consider multiple ideas | Students often have a hard time elaborating on relevant details. Have partners answer the question *What would you like to know more about?* |

| SAMPLE "INTERMEDIATE TASK" APPROACH TO WRITING AN ESSAY | | | |
|---|---|---|---|
| **Due Date** | **Task** | **What this task helps students do** | **What students can do with a partner** |
| March 19 | Summary | Students return to their attention getter to double-check that it is still relevant and consider how they can tie it into their summary. This task also forces students to check the flow of their evidence and to find highlights to include in the summary. | Have partners highlight transitional words, phrases, and sentences to make students aware of the flow of their paper. This is also the time to be on the lookout for errors in CUPS (capitalization, usage, punctuation, and spelling). |
| March 21 | Final copy due | Take five minutes to make sure students are turning in the assignment in the way you want it formatted. Names on the front, the outline is attached, and so forth. Nothing is worse than grading a mess of disorganized papers. | Have partners do a double check that the assignment is ready to be collected. |

Students often don't have the time management skills to break a large task down and chip away at it—especially when they are constantly feeling the pull of video games, sports, texting, and other social activities. By creating specific shorter assignments that serve as the building blocks for the whole project, you model effective strategies to guard against procrastination. In this case, not only did your students learn the effects of major battles on World War II, but you also taught them how to tackle a big project without procrastinating. In doing so, you are modeling a lifelong skill. Take time to celebrate their achievement! (And remember, some students will need to see this approach modeled many times before it begins to stick.)

To keep students focused as they work on each stage, try having them use the Pomodoro technique. Set a timer for twenty-five minutes once all students are ready to go—meaning pencils are sharpened, or a Google Doc is open—then press start. When time is up, as a reward, students get three to five minutes of "free time"—that is, conducting whole-class yoga poses, talking to their neighbors, or taking a quick trip to the bathroom. If students know there will be a break after a reasonable period of focused work, they can hold out for the bathroom, curtail other interruptions, stay focused, and be productive during their work session.

The key idea of this chapter is to prevent students from procrastinating. The schedule for breaking the assignment into intermediate stages is essential to keep students from waiting until the last minute. But we would be remiss if we didn't include two essential ingredients to quality instruction—rubrics and examples.

Right from the start of each major assignment, it helps if you present students with a scoring guide—a rubric—that outlines and describes the key attributes and skills you will be assessing. That way students will know where to focus their energy as they complete the assignment. We suggest developing the rubric as you construct an exemplar of the assignment. In the process of creating your own example, you'll be able to clarify your expectations and plan mini-lessons for potential pitfalls students may encounter.

## Three Parts of a Rubric—Along with Guidelines That Get Results[8]

1. **Criteria you'll be assessing.** Measure what matters most. This means focusing on your learning outcomes—the essential knowledge and skills of the assignment. It is all too easy to include fringe criteria that don't align with the purpose of the assignment. (While aesthetics and time on task are nice, should a student really be losing points for using 11-point font rather than 12-point?) In a typical writing assignment, the criteria may involve, for example, *focus*; *content*; *organization*; *conclusion*; and *CUPS* (capitalization, usage, punctuation, and spelling). You may know in your mind's eye what *focus* looks like, but your students can't read your mind and most likely won't share that vision. Be explicit. This leads us to the next part of the rubric.
2. **Explicit description of the expectation for each criterion.** For example, by *focus,* you may mean including a thesis statement in the introduction and substantiating it with multiple arguments throughout the essay. *Content* likely includes the logic of the arguments, the accuracy of the information, and a minimum number of references. Your students need these clarifications. That way, they can easily go back to what they have written and self-assess before submitting a finalized product. The more specific your expectations, the better your students' results.
3. **Point value or rating scale.** Before arbitrarily assigning 10 points for each category, think about the cognitive demands of each. Developing support for an argument by synthesizing multiple resources is much more

challenging than catching grammatical errors. (Although grammatical conventions are important, too.) Instead of assigning a point value directly to each criterion, consider a slightly less direct approach that uses a rating scale with different levels for each criterion. Thus points could be assigned for exceeding expectations (4 points), meeting (3 points), approaching (2 points), or beginning (1 point) expectations. When using a rating scale, clarify the expectations for each rating.

One issue is that rubrics often help teachers assess students' *declarative* explanations of the material. But as we'll see in chapter 6, the fact that students can write or mouth the words you are looking for does not necessarily indicate they understand what those words mean. As research has revealed, rubrics can sometimes provide a false sense of security about the accuracy of grading decisions.[9]

**Taking Analysis to a Higher Level**

Often students do not understand what is required of them by reading rubrics alone.[10] It's helpful to discuss and show examples of the specific criteria you are assessing before students put pen to paper or fingers to keyboard. A single example may not be enough—you also run the risk of having students regurgitate your work. Examples *and* non-examples together allow students to visualize success.

1. Give each student a copy of a mediocre sample essay or project similar to the assignment they'll be completing in your class. Make sure the example contains the types of mistakes students are prone to making. Have them grade the second-rate example using your rubric.[11]
2. Pair students with a classmate to reconcile their rubrics. Conduct a whole-class discussion of students' general impressions.
3. Show students the ratings you would give that same assignment and discuss.

Once you begin doing this, don't be surprised if you see first attempts that are better than anything you've ever gotten before—except, of course, from top students who often exceed your expectations. *All* of your students will begin to understand what you are looking for and what mistakes to dodge.

**What to Avoid**

Too often, teachers assign writing by reading the prompt aloud to students and asking if they have any questions. Students can be like the proverbial panicked deer in the headlights—their shock and utter confusion means there's no thought of raising a hand to ask a question. With no questions to answer, teachers falsely assume students know what to do and move on to the next unit.

**Generalizing the Principles**

These practices can be generalized to many subjects and types of assignments. For example, in math class, after guided practice, students typically use the last part of class to work independently on assigned problems. Setting a timer and allowing students a two- to three-minute break will keep them focused and on task rather than enabling them to procrastinate until the end of the period.

As your students become more familiar with your expectations, provide them with the assignment and have them break the assignment into intermediate tasks. Students should also give themselves deadlines along the way to completing the final project. Self-responsibility is especially vital for work you want students to complete outside of class.

Habits like procrastination are like a slow-acting poison. They can filter through to secondary school and have a stultifying effect on college grades and long-term careers. Learning to divide larger projects into manageable tasks is a life skill that you want your students to master.

## Ideas to Keep You from Procrastinating

Teachers (Barb, Beth, and Terry included!) tend to procrastinate when it comes to grading. When it comes to essays, however, since you will have checked over parts of your students' essays as they were working on them, grading can become less burdensome. You may think that breaking the essay into smaller portions creates more grading. And it does—to a point. But after students receive their first feedback, they begin to realize you are serious about good work. As a consequence, they'll start to produce better quality.

But, let's face it, grading written assignments takes time and concentration. Much like our students, we teachers can also become distracted as other job-related duties, family commitments, and entertainment beckon.

To combat your own tendency to procrastinate, adopt the techniques that you use with your students. For example, if you have a stack of sixty essays, you might scan them all without any grading to get the whole picture before you assess individual papers. During this initial step, keep your pencil out of your hand so that you aren't tempted to slow this step down.

Next, sort the papers into piles that will require different amounts of attention. Grade one pile before you leave school. Take another pile home to assess during commercial breaks (if you watch television), or after you've spent quality time with your family or yourself. Do the last pile by getting up a bit earlier than usual the next morning.

If you sit in front of a whole stack of sixty essays, you'll spend more time dreading the task than getting started. Ultimately, this means the friendly Pomodoro timer is not just something for your students! Set that twenty-five-minute timer for yourself as well, and afterward, give yourself a three- to five-minute break to relax, fold a stack of laundry, or reward yourself with a cup of tea or a glass of what have you.

## Key Ideas of This Chapter

- Procrastination is one of students' top challenges. Giving your students concrete tools to tackle procrastination can be one of the most important gifts you can give.
- When you just *think* about something you don't like or don't want to do, it can cause feelings of pain that encourage you to think about something different. The result is procrastination.
- The older a student is, the more ingrained a procrastination habit can become, and the harder it can be to change.
- The Pomodoro technique is particularly useful in teaching students how to get on task, stay on task, and avoid distractions.
- The brain alternates between focused and diffuse modes when learning. Focused mode involves intense concentration, while diffuse mode involves mental relaxation.
- Students tend to procrastinate on challenging assignments. Advise your students to work (focused mode) until they become

frustrated, then take a break (diffuse mode), alternating between modes as necessary to make progress and reduce anxiety when learning tough subjects.

- The hard-start technique for tests involves starting with the hardest question first, then pulling away and working on easier material as soon as "stuck" feelings arise. The diffuse mode can then go to work in the background to enable students to make progress later when they return to the tricky problem.
- It's essential to nudge students away from procrastination. You can do this by:
  - Creating to-do lists
  - Cleaning up chaotic environments
  - Increasing accountability

# 5

# How Human Brains Evolved—and Why This Matters for Your Teaching

Paulo is a born athlete. Doing a backflip comes as naturally as breathing to him—he jumps up and balls his legs up toward his chest. Voilà—he flips right over and lands neat as you please on his feet. Baseball? Soccer? No problem. He's a star.

Even learning to ride a bike came easily for Paulo. Five years earlier, he'd watched his big brother Robert teetering toward stability on the new bike their mom had scraped together to buy. Then when Robert went in for lunch, Paulo hopped on the far-too-large-for-him bicycle and zipped off to join his friends as if he'd been bicycling all his life.

But here's the important point: *Both Paulo and Robert learned to ride a bike.* And Robert, even though he was slower and took more falls as he was learning, never told himself, "I guess I just don't have the biking gene." In fact, even though learning to ride resulted in skinned knees and elbows and a lot of nerve-racking moments, Robert kept on through the pain until he got it.

Why does it seem natural that students believe they can become good at riding a bike, even though they learn at different speeds and it's sometimes painful? But in school, when students might learn certain subjects more slowly and with more difficulty than others, they give up on themselves, believing they don't have a talent for a particular subject?

There are other mysteries in learning. Put babies around native speakers of a language, and the language will be absorbed with ease. Put babies around a bunch of books, and you may find chewed corners on the covers, but the babies still won't know how to read. Why do many students struggle with reading when they seem to absorb their native language like a sponge? And why do students often struggle when it comes to math?

To answer these questions, we need to explore two different issues. First, why is some information, like recognizing a human face or speaking a first language, easier than other information for virtually *all* students to learn? Second, why are some subjects, like reading and math, harder to learn for some students than others? Why can a six-year-old without access to any education system learn her native language with ease but be unable to learn to read or do math without plenty of guided instruction?

## The Timeline of Brain Development

To understand how learning takes place, we should first give you a sense of how human brains change and grow as babies develop into adults. In early infancy, neurons are like migratory birds. They are born and then shift toward their final neural homes, while their axons extend out to find their targets—other neurons. A rich nest called a *neuropil,* which is filled with intertwined axons and dendrites, forms. The growing neuropil provides a bounteous crop of new connections (synapses) between neurons. All this growth and activity peaks at around two years of age.

But then, like the onset of winter, pruning sets in. As children move toward adolescence, axons are snipped away, decreasing the number of synapses. During this process, a child's environment matters. A healthy, varied environment allows more of the neural connections to stay intact. A restricted, stressful environment can cause too much pruning—like plants that have most of their foliage sheared off.

Your vision and hearing are processed in the back of your brain. This behind-most area matures first, in early childhood. Mental maturation—which means pruning and loss of flexibility—gradually moves toward the front of the brain. The very last area to mature is the prefrontal cortex, where planning and judgment take place. (This explains why middle and high school students can sometimes behave in surprisingly immature ways.) The ability to adjust the brain's connections doesn't stop at maturity, however. New synaptic connections as well as pruning continue throughout people's lifetimes.

## When It Comes to Learning, Some Stuff Is Easy and Some Is Hard

As we've mentioned, babies quickly learn to recognize faces, even though this feat is so difficult that it took many decades of intense research for facial recognition algorithms to come into being. It's rare, in fact, for people to *not* be able to recognize faces (a condition known as *prosopagnosia*—some people with prosopagnosia can't even recognize their own face).

Likewise, babies can pick up their first language quickly and naturally. Their tiny little brains soak the words up effortlessly. Around a child's first year, their vocabulary learning begins to accelerate through a fast-mapping process, where a toddler needs to hear a word only a few times before she's got it.[1] Between twenty and twenty-four months of age, researchers estimate that children suddenly triple their productive vocabularies. All this while also assimilating the syntactic structure!

Recognizing faces and learning how to speak a first language—what we might call the *easy stuff*—has been termed *biologically primary material*.[2] Our brains naturally learn this type of information. Neurons seem to link together as if by magic, even though it's magic honed by thousands of generations of evolutionary selection. Babies with the neural architecture to recognize and speak with those around them survived. Those who couldn't, died.

### Easy Stuff Versus Hard Stuff

Our brains are naturally geared to learn some types of information easily. Other types of information, material that wasn't needed when our species was evolving, can be more difficult to learn. Although it's simplest to think of two separate categories–easy stuff and hard stuff–the reality is that these two seemingly separate categories overlap.

**Easy stuff (biologically primary material)**

- Recognizing faces
- Learning a first language

**Hard stuff (biologically secondary material)**

- Learning to read or write
- Doing mathematics

In contrast with the easy stuff is what we'll call *hard stuff*—that is, biologically secondary material. Those are skills and abilities that our species hasn't evolved to do—even though by the time we might reach adulthood and have had plenty of practice, it might seem easy. We certainly didn't evolve to casually grab our laptop to scan news headlines or to work out our taxes using sophisticated math programs. And our students do not naturally know how to solve for *x* or use a semicolon correctly. To do these and other types of activities expected of a responsible adult, we have to go through years of specialized training in reading, writing, and complex math, not to mention geography, politics, economics, and history.

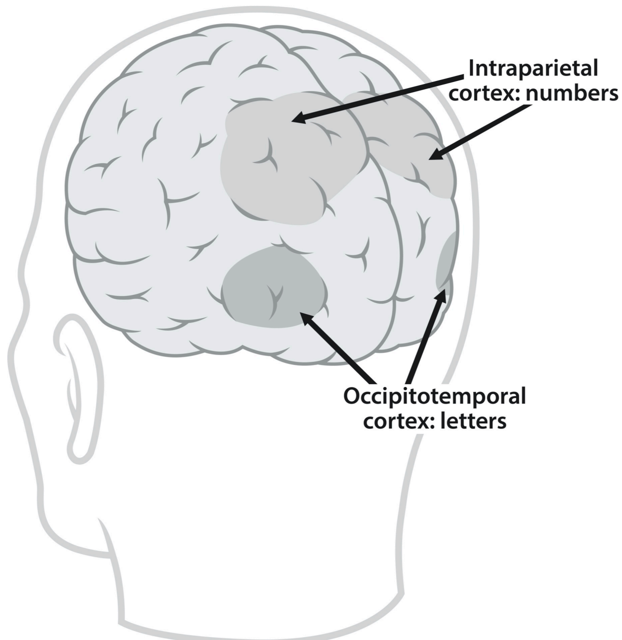
Evolution involves a constant process of developing tools, including teeth, fins, hooves, and beaks. It's a bit like gambling. With each new generation, there's a random throw of the genetic dice, and critters with the tiniest improvements in their tools are more likely to win—which means they get to pass their genes down to the next generation. Brains, of course, are part of those tools. Evolution has selected and shaped brains just as it has everything else.

While evolution was winnowing tools and brains, one type of brain—that of humans—developed a particularly flexible multipurpose cognitive processing ability. This broad-ranging flexibility is surprisingly different from the cognitive abilities of other species.* In fact, by *repurposing* neural circuits that were originally developed for other uses, human brains can accomplish feats that were undreamed of in previous evolutionary times. For example, as we'll see, the "recognizing the face" part of the brain can be repurposed to allow us to learn to read.

In other words, to learn hard stuff—secondary materials—our brains have to stretch and rewire in ways they have not had to do in the previous eras of human evolution. (But keep in mind that by the term *hard stuff,* we mean stuff that we haven't evolved naturally to do. There are plenty of in-between hard and easy things to learn—even learning to drink from a glass of water isn't necessarily easy!)

The *neuronal recycling hypothesis,* developed by leading neuroscientist Stanislas Dehaene, independently comes to similar conclusions.[3] Abilities like reading and math involve reconfiguring parts of the brain commonly used for other purposes. But Dehaene's conclusions go a step further. When the brain does its reconfiguring, it always selects the areas with functions that are the most similar, from an evolutionary perspective, to the new abilities a person is trying to acquire. Letters, as well as ideographic characters like Chinese, always seem to invade the occipitotemporal cortex—a part of the brain that ordinarily detects objects and scenes. This occipitotemporal invasion happens no matter where or in what culture around the world the person learns to read. Number representations invade the bilateral intraparietal cortex, a part of the brain that codes for a rudimentary sense of quantity—again, regardless of culture.

In other words, as Dehaene concludes, although the brain is plastic, it's not super-plastic—new skills can't just grow anywhere but instead are limited to some degree by preexisting neural connections and anatomical constraints. Limited plasticity is why some brain damage can be repaired by shifting functions to other related areas, while other brain damage requires too much rewiring to make a fix possible.*



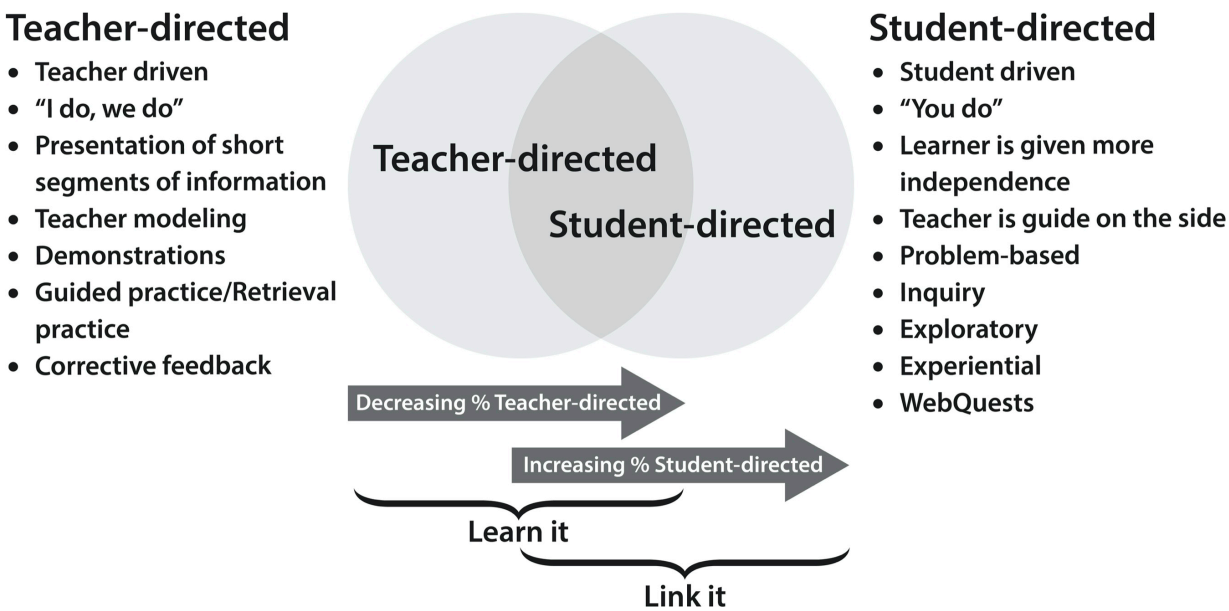

Letters always seem to invade the occipitotemporal cortex, which ordinarily detects features of objects and scenes. Number representations invade the bilateral intraparietal cortex, a part of the brain that codes for a rudimentary sense of quantity. These invasions occur no matter what culture a person is raised in—like migrating birds that always return to the same areas.

## Why Direct Instruction Becomes More Important as Students Grapple with More Difficult Material

Repurposing neural circuits isn't easy. Learning a new concept or technique can often take days or weeks of deliberate practice with corrective feedback. And it can take years to become an expert in, say, mathematics, teaching, or medicine. That's why educational systems have developed around the world—to facilitate the repurposing. Regrettably, once children exit the more enjoyable learning that occurs in preschool and kindergarten, and schoolwork begins to get more difficult, children can lose their intrinsic interest in learning. Teachers unfairly bear the blame.

Children without access to quality education systems, or those discouraged by either family or culture from taking advantage of the type of learning that quality education systems provide, are at a disadvantage in the modern world. Their brains don't get the "repurpose" training that lies at the heart of a good education. The result? As older students and adults, they can find it challenging to grapple with ideas and skills that others with a better education find straightforward.

What is the most effective way to rewire students' brains as they begin grappling with more and more difficult material? Evidence indicates that the more biologically secondary—that is, the tougher—the material, the more direct instruction is needed.[4] Why? Perhaps it's best to begin by describing what direct instruction means.




Often, teacher-directed instruction and student-directed instruction are viewed as opposing methodologies. But in practice, teacher-directed instruction sets students up for successful student-directed learning. The more difficult (biologically secondary) the material, the more that students need coaching (teacher-directed approaches) to launch them toward independence (student-directed approaches). As students strengthen their neural links, they gain autonomy in their learning.

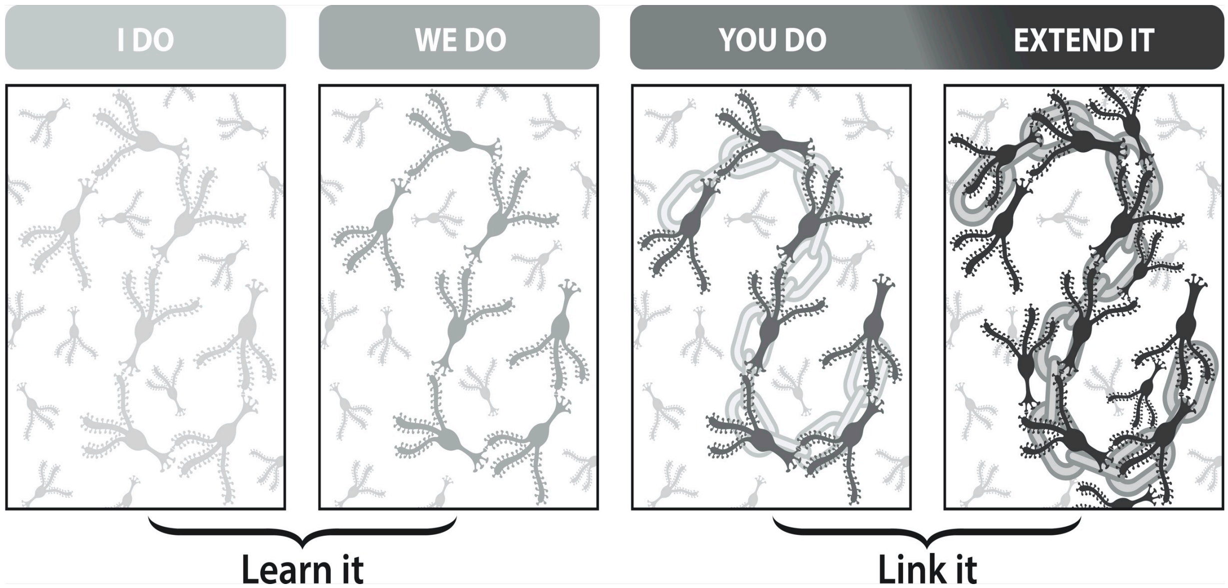
## Teacher-Directed Instruction Leads to Student-Directed Approaches

### What Is Direct Instruction?

In teacher-directed learning, *the teacher* leads the lesson and scaffolds instruction until the students master the material. You can think of the teacher as a movie director who uses scripts to provide actors with lines and side notes—giving them cues for placement and sometimes heartfelt examples to elicit emotion. Like the best directors, the best teachers are hands-on, straightforward, watchful, and explicit. But good learning, of course, goes beyond a script—it ultimately involves improv that the students can do on their own. The teacher's support should gradually fade as students experience more and more success.

Direct instruction* is often used synonymously with *teacher-directed learning*..[5] Teachers frequently refer to it as "I do, we do, you do." The teacher introduces new content or skills and provides students with expert guidance. New or difficult information is broken into easier, more digestible segments so as not to overwhelm students, and the teacher supervises students as they work toward proficiency.

Direct instruction uses the *learn it, link it* approach to teaching. During the *learn it* phase, the teacher presents new concepts or skills ("I do"), and scattered neurons search to make connections. But direct instruction doesn't stop at the teacher explaining the concept. That would be a simple lecture, which doesn't form lasting links between neurons. Instead, in direct instruction, the teacher explains the new content with different examples and demonstrations, as students follow along and get plenty of chances to practice. During practice, the teacher vigilantly offers corrective feedback (This is the "We do" stage). So the *learn it* phase encompasses both the "I do" and "We do" stages of direct instruction.




Here we can see how the *learn it*, *link it* set of connections we described in chapter 1 relate to the *I do*, *We do*, *You do*, and *Extend it* stages of direct instruction.

During the "You do" stage, students practice multiple times on their own and are able to demonstrate their understanding independently. The *link it* phase begins at the "You do" stage of direct instruction, but it doesn't stop there. Not only do we want students to be able to strengthen their neural links, but we also want them to extend their learning even further. While students practice under a variety of conditions, they add new information and consider different perspectives.[6] In doing so, they are strengthening and extending their neural pathways with additional links. As David Geary notes: "Many of these are links that are not naturally very strong, and so for much of secondary learning a lot of practice distributed over time is needed to make sure the new links stay linked (that is, to be sure the student retains the new knowledge over the long term)."[7]

This "I do, we do, you do" approach scaffolds the instruction of more difficult materials and gradually releases the responsibility of the material over to the student. At first the teacher takes responsibility for successfully working through the problem, concept, or skill. During guided practice ("We do"), she slowly releases that responsibility to the student. A word of caution about scaffolding—when scaffolds are removed too early, newly learned information isn't built and solidly reinforced in Neo (long-term memory in the neocortex). This is why our students can become frustrated at the kitchen table when they're doing their homework or why they suddenly freeze on the exam. They needed more time with their teachers in the "We do" stage of direct instruction.

Once students have demonstrated proficiency with the concept in class under the teacher's watchful eye, it's a good idea to assign a few representative problems for homework. Ideally, students complete homework after school or the following day in study hall, when several hours have passed. The homework interrupts forgetting and solidifies the new knowledge.

Does direct instruction contain active learning? You bet, and plenty of it! Direct instruction is effective with *all* types of learners but most especially novice learners or learners with lesser-capacity working memory.[8] The approach allows students who struggle with attention to attend to the essential ideas in a lesson. Want to teach students how to solve chemical equations? Direct instruction. Want to explain the factors that led to the end of the Cold War? Direct instruction. In either lesson, the teacher takes large pieces of information and breaks them down into understandable parts for students to try and do *or* retrieve and rehearse. Remember, teaching is ultimately about what we get out of students' heads, not what we try to put in.


**Example of direct instruction over a one-hour class period**

Direct instruction intermixes presentation (or demonstration) with plenty of active learning, as this illustration shows. What's the optimal mixture of active learning to presentation? There are no definitive conclusions from research—but we do know that mixing it up is important! As we'll see later, being a little unpredictable in how you mix presentation with active learning can enhance your teaching effectiveness.

**PRINCIPLES OF EFFECTIVE INSTRUCTION**

The following list by educational psychologist Barak Rosenshine[9] provides a good overview of what effective teacher-directed instruction entails. (You probably already use these strategies on a regular basis.)

- Begin a lesson with a short review of previous learning.
- Present new material in small steps, with student practice after each step.
- Limit the amount of material students receive at one time.
- Give clear and detailed instructions and explanations.
- Ask a large number of questions and check for understanding.
- Provide a high level of active practice with many examples for all students.
- Guide students as they begin to practice.
- Think aloud and model steps.
- Provide models of worked-out problems.
- Ask students to explain what they have learned.
- Check the responses of all students.
- Provide systematic feedback and corrections.
- Reteach material when necessary.
- Prepare students for independent practice.
- Monitor students when they begin independent practice.

## Direct Instruction Versus Lecture and Other Forms of Passivity

A Charlie Brown cartoon provides testimony to the ineffectiveness of lecture. Charlie's teacher is providing a wealth of knowledge to her students, but all they hear is "*wah waaah wah wah* . . ." This is not to say listening and watching are useless in learning. Listening to a presentation can involve intense cognitive processing. The processing can be so intense, in fact, that it doesn't take long for students to tire and tune out. That's why listening to a lecture—sometimes described as "talk and chalk"—is called a passive activity. Students may *look* attentive but not be following at all.

How can lectures be transformed into direct instruction? The teacher chunks carefully thought-out nuggets containing the key ideas of a lecture into short snippets. These brief golden nuggets of information are then interspersed with plenty of retrieval, practice, small-group discussion, and other ways of allowing the student to work more actively with the material than just listening and watching.

The reality is, learning complex, biologically secondary material is not a spectator sport—it demands that students actively grapple with the material. The grappling can be as simple as reviewing notes with a partner after a five- to seven-minute presentation.

Teachers also want to avoid extended passivity by allowing students to watch or listen to lengthy videos or audio texts.* While it may seem like a great break for students to watch *Hamlet* after reading and analyzing the play (not to mention giving you a chance to catch up on grading), it can be a waste of precious instructional time. The last thing parents want to hear when they ask their child what they did at school today is "We watched a movie." They can do that at home. Likewise, off-task behaviors sneak in when students are watching or listening passively.

### The Drawbacks of "Round Robin" Reading

For many students, having to read in front of the entire class is like learning to handle a writhing reptile. The popular round robin method to practice reading in class, where students read paragraphs one by one, doesn't make things any easier. Instead, it heightens the feeling of anxiety as the reptile of reading draws closer.

In many ways, round robin reading mimics the worst aspects of lecture, forcing students to listen for extended periods when no one is the wiser if they are tuned out.

When segments of videos are shown as part of high-quality direct instruction, it's a good idea to set a purpose for viewing and to provide students with guiding questions (fill-in-the-blank, multiple-choice, and short-answer).[10] Students complete the guide while watching. It's also a good idea to pause intermittently to offer additional commentary, clarify any confusing parts, and solicit students' opinions and impressions. As a follow-up, you can have students do something related to the video and what they saw or how it made them feel about their world.

We want to emphasize that lecture and direct instruction are *not* the same because so many people confuse the two. Coauthor Beth, for example, will use the term *direct instruction* with a colleague and hear, "Yeah, lecture," in response. Or a teacher might reply, "Yes, I use direct instruction—I explain the material in class for most of the period and then give students practice for homework." These extended periods of lecture are *not* direct instruction. They are instead frustrating monologues, after which students are left to try to do the practice on their own. No wonder students (particularly hikers) can find learning so frustrating!

## Direct Instruction Versus Student-Directed Approaches

Direct instruction, or teacher-directed learning, can be thought of as being on one side of a continuum of instructional approaches. Student-directed learning is then on the other side, and is our umbrella term for approaches requiring minimal guidance from the teacher—including discovery, inquiry, problem-based, experimental, and constructivist learning.[*] We prefer the term student-*directed* learning to the more mainstream student-*centered,* because student-*directed* is more descriptive of what is happening. In most instances, students are *directing* their own learning.

In a student-directed approach, students are treated like experts who investigate, discover, and construct their own meanings. In this case, the teacher provides the students with the necessary materials for learning but holds back on providing specific guidance, information, or answers.[11]

Both direct instruction and student-directed learning call for active learning. Where direct instruction requires the teacher to take students slowly through the content piece by piece and have students demonstrate mastery along the way, student-directed learning gives more independence to the learner. The teacher serves as the expert guide on the side, while students derive their own meaning from experiences they have or the experiments they conduct.

All too often, student-directed approaches are begun too early when teaching specific materials. Novice learners can find themselves easily frustrated because they are put in situations where they have to try to teach themselves complex material they may be only vaguely familiar with. The truth is, when it comes to concepts learned declaratively, students can take over the wheel to drive their own learning only after they understand the rules of the road and can implement proper driving techniques.

There is a time and a place for both direct instruction and student-directed learning. During the "I do" and "We do" stages of direct instruction, students *learn it*. Once students have demonstrated proficiency on their own, student-directed experiences are appropriate because the material is in the neocortex, even if it's not quite stable yet. At this point, students are equipped to *link it*—that is, strengthen and extend their neural links independently. In this way, the two sides of the continuum work well together. After all, the goal of education is to teach students new information and skills so they can become independent learners. As a bonus, by allowing students who have mastered the material to move on to student-directed approaches, such as a WebQuest,* the teacher has extra time to work more intensely with the hiker-type learners who might still be struggling with the material.

## NOW YOU TRY!

### KEEPING STUDENTS ENGAGED

**When students** give confused looks or make more eye contact with their electronic device than with us teachers, we have been talking too long. Keep hiker and race-car learners engaged during direct instruction with frequent, formative assessment checks like the ones we've introduced throughout the chapters thus far:

- Pause and recall
- Pairing and repairing
- One-minute summaries
- One-minute muddiest points
- The whip-around
- Think-pair-share

Or try a "state change" to reset students' interest:

- Tell a brief *related* story
- Pose a question that sparks curiosity
- Add humor
- Play a bit of music
- Add movement
    - Stand up and stretch
    - Take learning outside

## Why Is Direct Instruction Necessary?

A sweet aspect of easier, biologically primary materials is that learning is not only a breeze—it's fun. Recognizing and making friends—an essential primary activity—is something that most students naturally enjoy. Likewise, chatting with those friends or playing with toys or one another—these are all activities we're born to do.

But the relaxed, fun nature of these primary activities can mislead teachers, students, parents, and community members into thinking that *all* learning should always be easy and fun.

It doesn't work that way.

Secondary material, by its very nature, is harder to learn.[12] It can take focused effort and a lot of work. *Desirable difficulties,* an important area of research pioneered by UCLA cognitive psychologist Robert Bjork, involves the idea that learning well requires concerted effort.[13] So does the concept of *deliberate practice,* the idea that one of the best ways to move swiftly forward in learning is to put effort into studying the hardest aspects of the material.[14]

Learning secondary material may seem easy to teachers, but it isn’t that easy for new learners. That’s part of why, in past millennia, even simple arithmetic was rarely known.[15] The roadblock to learning this kind of secondary information is that students’ working memories are limited. The first time a student sees a problem, it’s difficult to know how to solve it; there are often thousands of incorrect options but only a few right ways. Yet working memory can hold only a few options at a time. If student-directed approaches are used too early, it can take students a long time to work through all the possible ways toward the right answer. They can simply give up in frustration.[16]

You can think of primary learning as involving neural pathways that very nearly lay themselves. It's easy to see where the paths should go in the lovely, bright landscape, as shown on the left. But secondary learning is like trying to carve out a pathway in a dense neural jungle. Not only is it hard to scramble through the vines and sprawling dendritic trees, but it's also difficult to even know what direction you are supposed to be going in. Each step provides further opportunity for confusion and error; within just a few steps, you can find yourself going in circles.

Ultimately, laying a new set of neural links involving secondary materials—for example, understanding the process for a bill to become a law, the workings of the digestive system, or the balancing act of algebra—means moving aside, stretching, and repurposing neural links. This isn't easy. That's why direct instruction—carefully scaffolded guidance from you as the teacher—is so critically important. Students need to *learn it* to lay the initial faint neural connections so they can then more solidly *link it*. It should come as no surprise, then, that countries that primarily use direct instruction show higher achievement scores.[17] Discovery-based learning can be useful *after* difficult concepts and skills are mastered. But when it comes to introducing more difficult material without careful teacher guidance, students can become lost in the forest. Hiker students with lesser-capacity working memories generally suffer the most.

This is a point, however, where we should clarify. A working memory with lesser capacity is *not* a drawback. It's just a difference that means other approaches to teaching and learning are required. Coauthor Barb's lesser-capacity working memory, for example, provides the fuel that underpins her creative success. Does she have to work harder sometimes to master new material? Yes. But she feels that her hiker brain allows her to see the world with fresh perspectives that her larger-capacity working memory colleagues can overlook.

Is it possible to provide too much guidance? Yes. Students suffer when we let them off the hook for learning. There is something of a delicate dance related to resiliency. If parents or teachers are overly helpful, students may learn that admitting defeat gets their work done for them, either by their parents around the kitchen table or by the teacher the next day, who says, "That's okay. At least you tried." This, again, is why direct instruction to scaffold students toward the answers without simply giving them the answers is so valuable.

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## Analyze Your Teaching:
### Direct Instruction

**The Setup**

You are teaching eighth-grade biology. Today's lesson is a follow-up on heredity, where you introduce students to the Punnett square—a way of predicting genotypes and phenotypes. (In reality, this could be any grade level and any content area where students are learning facts, concepts, or procedures.)

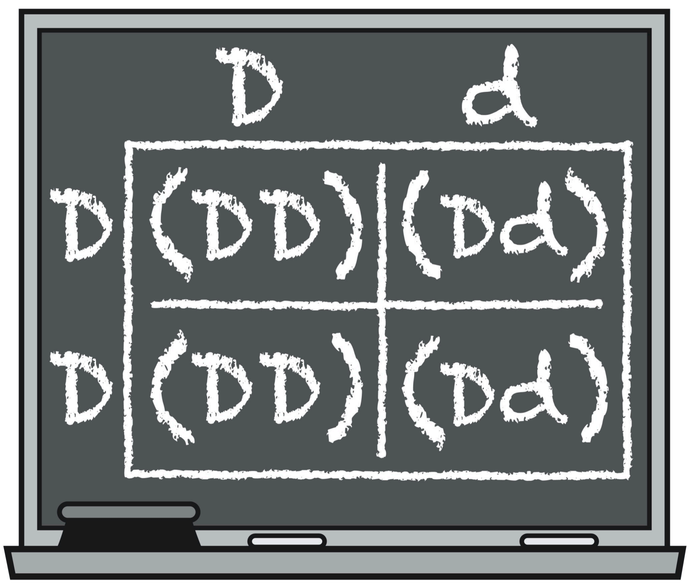
**What to Do with Your Students**

To get the lesson started, you grab your students' attention by asking whether they can wiggle their ears or roll their tongue. These oddities, along with characteristics such as hair color and height, are examples of heritable traits. In piquing their interest, you have simultaneously connected their new learning to what they already know.

You refresh your students' memory from yesterday's class through a *think-write-pair-share*. You ask students to explain how biological traits are passed from one generation to the next. Their answers indicate they are ready to continue. But if they didn't remember some of the key ideas, now is the time to provide fixes and add those essential details.

When you asked your students to roll their tongues, you made the lesson personal and provided a hook. When you asked them to review yesterday's material, you tapped into your students' prior knowledge. All of these introductory parts of a lesson are part of direct instruction, as well as of other instructional approaches.[*]

However, before diving headfirst into the body of the lesson, students need to know their final destination. In other words, students are more likely to hit the target if they know where they are aiming.[18] Explain that in today's lesson, students are learning how to complete their own Punnett squares. Students are then primed to listen, apply, practice, and practice some more in a systematic way that doesn't overwhelm them with too much at once.




A Punnett square. The mother's genotype is shown on the far left, and the father's genotype just above the square. Alleles are coded using a capital letter for dominant alleles and lowercase for recessive.

It's worth pointing out that scientists didn't understand anything about the heritability of traits before Gregor Mendel. Secondary knowledge sometimes takes centuries to generate.[19]

### Part 1: Making the Punnett Square

#### *I Do*

In this stage, you are presenting facts and examples. The more complicated the example, the slower your presentation. Your students listen as you reinforce the vocabulary they have already learned but this time in new contexts. You explain an example where an offspring who received a dominant allele for dimples and a recessive allele for no dimples produced an offspring with dimples. You tell them that dominant alleles beat out recessive alleles. This is why some of our traits like dimples match those of our biological mothers, and others match those of our biological fathers.

Students are now curious as to how you can predict which traits will most likely be inherited and which traits will not. You assure them it's not magic—they, too, can figure this out by using a Punnett square. Now they see the relevance to their own life—not to mention that playing with Punnett squares can be fun!

You draw a 2 × 2 Punnett square on the whiteboard. As you talk students through filling in the Punnett square, you write the steps you are verbalizing on the board. You anticipate where students might get stuck and include additional explanations and useful tips.

#### *We Do*

After watching you explain the steps, students need practice. Have them work with a partner so they can verbalize their thought processes and get comfortable speaking the new vocabulary they are learning: heterozygous and homozygous, dominant and recessive. As students complete their Punnett squares, you are circulating and hovering over them—listening to how they use the new terminology and watching for any errors. If students haven't grasped the concept, take time to show them their mistakes and reteach as necessary.

#### *You Do*

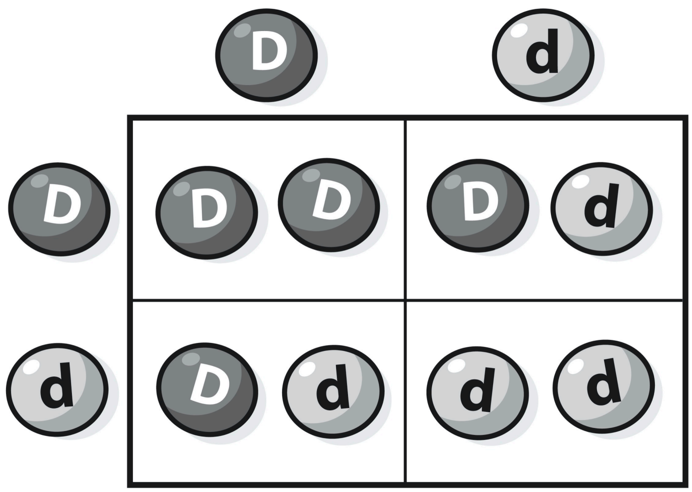
You provide students with a few new problems to work through *on their own*. This on-their-own practice helps solidify the learning and build automaticity. Resist the urge to introduce more difficult material too soon. Only once your students show mastery are you ready to move on to the next segment of your lesson, where you kick things up a notch.

### Part 2: Deciphering the Square

#### *I Do*

Punnett squares can get more complicated when you add in probability and ratios. There are different ways parents' alleles can combine. Using M&M's or Skittles allows students to visualize the passing of genes onto offspring.

| Phenotype | Genotype | Skittles Key |
|---|---|---|
| Dimples | Homozygous dominant (DD) | D = dark gray |
| No dimples | Homozygous recessive (dd) | d = light gray |
| Dimples | Heterozygous (Dd) | |




The genotype reveals a 25 percent chance for homozygous dominate, 50 percent chance for heterozygous, and 25 percent for homozygous recessive—making it a 1:2:1 ratio. The phenotype is inferred from the genotype, making it a 75 percent chance for dimples and a 25 percent chance for no dimples.

Work through three or four *different* scenarios that gradually get more challenging. Leave your examples on the board so students can refer to them in the upcoming "We do" practice stage.

***We Do***

Provide students with plenty of practice. Here is where you will be able to differentiate your instruction based on students' readiness. Students with more prior knowledge in statistics pick up on this layer of the lesson quickly. For those students, mix the practice up right off the bat. Maybe give them a few preview problems so they can leap ahead. Other students will need you to review and, in some cases, reteach. Their practice should initially be very similar to the models you have directly taught.

***You Do***

When you gauge that your students have had enough practice, remove all support. Make sure there is no evidence of the models left in sight. At this point, students shouldn't be in a complete panic. They can still rely on your feedback to help them find their errors.

The more traits, the more variations—and the more confusing this all becomes for students. Continue taking students through the "I do, we do, you do" model of direct instruction, making sure you don't give too much "I do" before you start them on the "We do." Once students have repeatedly demonstrated mastery of the concepts, you can turn the lesson over to more student-directed inquiry or problem-based learning. In this way, you will have more time to work one-on-one and in small groups with the students who aren't quite getting it. You will also want to ask them about these concepts in later weeks and give a refresher to students who don't remember.

**What to Avoid**

Be careful not to drone on during the "I do" stage. It is easy for us teachers to slip into lecture mode when we have our students' full attention. But students' working memory capacity is limited. Rule of thumb: Students with lesser-capacity working memory need shorter segments of information presented at a time ("I do") coupled with more opportunities to practice retrieving the information ("We do").

Be careful not to talk too fast as you present. Students need time to process new information. Think of the time it takes Hip to relay what you have said to Neo. That should help you slow down.

## The Curse of Expertise

Roman Hardgrave, the Head of Learning Design at Marginal Revolution University, observes:[20]

> Teachers need to (a) first realize how their expertise gets in the way of teaching, and (b) build a system to try and proactively locate those areas where they aren't communicating effectively and correct them.
>
> I see this all the time when working with instructors on videos—they say something that seems completely intuitive to them but is confusing to beginners. It's often just using jargon that they haven't properly introduced yet.

To correct it, the first step is thinking about what was difficult when you learned it. The second step is being on the lookout for signs from your students that you're glossing over something difficult. Say, a bunch of students all making the same mistake. Or if you ask a student to explain something, how is their explanation different from yours? You'd want to take those signals and go back and correct your teaching.

**Generalizing the Principles**

Direct instruction works with a wide range of concepts and skills. Whether you are teaching your students content-specific vocabulary, the procedure for finding the slope of a line passing through two points, the weather patterns in the northern hemisphere, or the basics of writing a thesis statement, starting with direct instruction levels the playing field for all learners.

When planning your lesson, try to think of what you wrestled with most when you first learned the material.[21] Chances are that balancing chemical equations or finding examples of irony in *To Kill a Mockingbird* didn't come naturally to you. Students like to be successful. Chunking the hard stuff into smaller pieces to avoid cognitive overload allows students to experience small victories as they move toward more challenging material.

For long-term retention, it is more effective to practice in five- to ten-minute sessions spread out and reviewed over days and weeks rather than an hour of the same monotonous stuff assigned in one mass practice session. One mass practice session (cramming) works great short term—but short-term learning isn't the goal. Once students start to forget, they have to work harder to jog their memory. Extra effort interrupts forgetting and strengthens the learning, which makes it easier to remember and use the information in the long term.[22] Long-term retention of information and skills primes students for more independence in their learning and sets them up nicely for student-directed learning. Students will not know how to successfully build a bridge if they don't first have a solid understanding of Newton's laws and how vertical and horizontal forces work.

## Key Ideas of This Chapter

- *Biologically primary material*—that is, "easy stuff"—involves information our brains are naturally wired to learn. This includes abilities like recognizing faces and learning how to speak a native language.

- *Biologically secondary material* involves the "hard stuff" such as math and reading. To learn these types of materials, our brains must rewire in ways they have not had to do in the previous eras of human evolution.
- In *direct instruction* the teacher chunks the presentation of new content into small segments followed by active retrieval or practice. Lecture and direct instruction are not the same. While lecture is often passive, direct instruction embeds active learning throughout the lesson.
- Secondary material is challenging to learn because students' working memories are limited. Evidence indicates that direct instruction is more suitable for teaching biologically secondary materials because direct instruction offers the guided, scaffolded, and active learning that students need to master more difficult concepts.
- When students have demonstrated proficiency on their own (*learn it*), the material is in the neocortex, even if it's not quite stable yet. At this point, students are ready to *link it*—they can strengthen and extend their neural links independently through student-directed experiences.

# 6

# Active Learning:

## The Procedural Pathway

It's a beautiful late spring Friday, and you've just trooped across the parking lot with a packet of papers to grade this weekend. As you pull out of the lot, you spot a hand wave from a young woman with a baby bump. It's Bella, your school's newest teacher. Suddenly you remember that Bella's baby shower is tomorrow. Agh! Not only did you forget about attending the shower—you haven't gotten her anything!

Your focus falls immediately on what to get Bella for a gift—let's see, was she into skiing? But is something ski-related appropriate for a baby? Oh yes, and you have to rearrange tomorrow's plans to watch your daughter's softball game with your spouse.

Twenty minutes later, still preoccupied with thoughts of Bella and the baby shower, you're home. You don't remember anything about the drive.

How did you get home?

When you consciously think of it, you can easily imagine your route home—left at the first light, then the long stretch of freeway before exit 24, and the last few familiar turns before pulling into your driveway. But when you were driving, you were aware of none of this. Does this type of unconscious thinking have anything to do with learning?

Yes, it does! In this chapter, we'll be exploring the often-neglected area of largely nonconscious* procedural learning. To begin discussing procedural learning, we will first compare it to declarative learning, which we discussed in chapter 3.

## Declarative Versus Procedural Memory Pathways

There are two major routes in the neocortex that information travels into and out of to get to long-term memory. Each pathway makes up a separate learning system—the *declarative* and the *procedural*.

We explored the declarative learning system in chapter 3. There, we saw how declarative thoughts move from our working memory to the hippocampus and on into long-term memory in the neocortex. When we show or tell students, step by step, what to do, or we explain facts or relationships, we are teaching them the information through their declarative memory systems. The declarative system is the learning system where students are (mostly*) conscious of what they're thinking about and learning.[1]

But the brain is a little like a rocket ship that has redundant systems for essential tasks. It has a second way of getting information to long-term memory—a backup system we don't even have to think about consciously. With this latter, *procedural* learning system, information is sifted and shifted from what we see, hear, or feel into long-term memory through the basal ganglia and their associated structures.*[2]

The procedural system is the basis of habitual actions. This type of learning has often been thought of as very different from the type of material learned in school. In fact, beginning with the cognitive revolution in the 1960s, the importance of habit-related procedural learning basically fell out of fashion. It is only recently that the study of procedural learning has been making a comeback.[3] A comeback, that is, except in education. This chapter is meant to help rectify that.

The basal ganglia receive input from the entire neocortex and project back to the neocortex,[*] forming a giant loop. It takes 100 milliseconds to go around the loop. This loop enables you to learn sequences of actions and thoughts that you deposit as sets of neural links in long-term memory. These links in turn create brain states and actions related to thinking, language, and song. For example, if you reach out to touch a hot stove, the feedback you get is “That hurts!” So you learn not to touch a hot stove. Or you taste a sweet berry, and your dopamine-based reinforcement learning system (we’ll learn more about that in chapter 8) helps rewire your brain so you keep an eye out for those delicious berries.

Working memory doesn’t create procedural sets of links.[4] But it *can* grab them once they’re created. Once working memory grabs the procedural links, you can become conscious of them, or at least the essential aspects of them, if not the tiny details (for example, you can consciously turn right on your bicycle, but you’re not thinking of the muscle detail of turning right on the bicycle). Becoming more consciously aware through working memory, it seems, moves you toward the declarative system. Perhaps this is why when you become consciously aware of the motion of your free throw in basketball, or of your golf swing, or the aim of an arrow you are shooting with a bow, it can throw off your aim. “Be one with the arrow” may be a simple call to stay with the procedural rather than the declarative system so your thoughts can flow more swiftly and smoothly.

It’s similar with speeches. When coauthor Beth coached the speech team, her students delivered their speeches so many times that they didn’t have to even think about what they were saying. But if something distracted them and pulled them out of their “trance,” they were completely thrown off. Beth could almost see them switch neural pathways from the procedural system, where words flowed mindlessly, to the declarative, where they were stumbling around trying to figure out where they were in the speech and what they needed to say to pick it back up again.

An advantage for experienced teachers, however, is that they can become so versed with what they are teaching that their mouths can be going on automatic, procedural mode while their declarative working memory races ahead to read students' faces and anticipate questions (and to see how Madison seems to be getting into a bit of mischief in the back corner). It seems to become easier not only to switch between modes but to use both modes at the same time. This, indeed, is why a novice knitter or crocheter is focused declaratively on learning to handle the yarn, while an expert knitter can chat happily away while knitting.

This procedural system is so far under the radar that it doesn't even use working memory or the hippocampus—at least, not mostly. Instead, procedural learning occurs gradually, day by day, mainly within the networks of neurons in the loop between the cortex neural pathways and the basal ganglia.

Teaching through the procedural system means giving students plenty of practice. Practice takes time—that's why procedural is slower than declarative learning. But as we'll see, once something's been learned through the procedural system, it can be processed and performed more rapidly and automatically than knowledge formed by the declarative system.

### THE VALUE OF AUTOMATICITY AND PROCEDURAL LEARNING

**A typical** twenty-minute TED talk is said to require seventy hours of practice. So Barb dutifully practiced for weeks for her upcoming TED talk. The result? Although Barb was a bundle of nerves, the words flowed out smoothly and automatically. You could have hung her upside down and she would still have talked away just as fluently. During her speech, Barb was consciously aware of her mouth moving. But she didn't have to think about what she was saying, which was just as well, because she was too nervous to think!

Nowadays, Barb is so experienced in front of the cameras and audiences that it's easy for her to speak of one familiar topic while also tossing in new but relevant insights or jokes. (Her real challenge is in answering two-part questions. So many ideas fly into her head related to answering the first question that, with her limited working memory, she often has to ask for the second question to be repeated.)

Even a twelve-hour time-zone change, or the inevitable speaker nightmare situations (like having to give a three-hour presentation to a large, masked, socially distanced audience in the dark with no slides due to a sudden statewide power outage) can still find Barb on her game. She seems fast on her feet, but it is only because plenty of previous practice has enabled her to think so quickly in relation to the topic that the outside world seems to slow, giving her plenty of time to think or react. This may be surprisingly akin to the quick reaction times of expert tennis, baseball, and cricket players. What a far cry from her previous nervousness in front of even the smallest of audiences, where she found herself struggling to even breathe, much less speak!

Interestingly, this procedurally-based comfort with the material allows Barb to relax in front of an audience. This is foundationally important, because it's audience questions that can provide the most powerful and creative impetus for Barb and her coauthor's work in this area. For example, a question from the audience at Novartis in Basel, Switzerland, about how learning sports ties into learning academic subjects helped spark the curiosity leading to the "aha!" of discovering Michael Ullman's important body of research. (More on Michael Ullman—and curiosity—ahead!) Learning, as we already know, is not just a one-way street. Both presenter and audience can learn from each other.

In any event, rest assured, during her convivial department meetings at Oakland University, meeting online with coauthor Terry's masterful classes on neuroscience, or at home, in the delightful chaos of the Oakley household, Barb still has to stop and think about what she's trying to say.

As we mentioned, it may be that race-car learners—those with prior knowledge or skills in the new area of study—can rely more on their fast-to-learn declarative learning system. On the other hand, hikers, who are new to the topic or have limited working memory capacity, instead rely more on their slower-to-learn (but faster to use!) procedural learning system.

The choice of systems isn't conscious. It seems, for example, that disorders such as ADHD and dyslexia can predispose students toward relying mainly on their declarative system, while having a lesser-capacity working memory can predispose students toward relying more on their procedural system.[5] The real challenge in these situations is in coaxing students, to the extent possible, toward using both systems.

### Dyslexia and the Procedural System

Dyslexia provides a potent example of what can happen when the procedural system does not work the usual way. Dyslexia, it seems, is not just a reading problem. It arises from a much more foundational problem with automatizing skills, which is the job of the procedural system.[6] Young children with dyslexia, for example, often have trouble learning to tie their shoes and have atrocious handwriting. Some children with dyslexia compensate for their problematic procedural learning system by developing exceptional declarative memory skills.

Both the procedural and the declarative systems work together to underpin learning in most children. Reading or doing math, for example, generally involves using both declarative and procedural systems at the same time. When one or the other system falters during the learning process, or when teachers emphasize only one system of learning, it can make it more difficult for a student to be a successful overall learner.

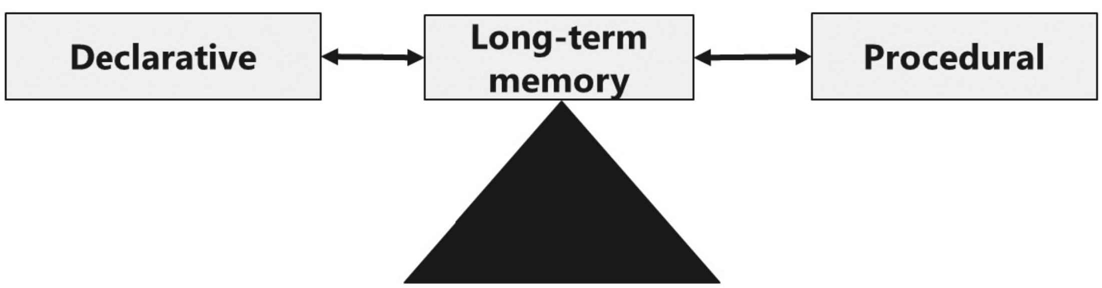
## Both Declarative and Procedural Learning of the *Same* Information Is Important!

The procedural system is no mental slouch. One reason humans are so smart is that they have unique genes that allow them to use their procedural system more easily than, say, a mouse can.[7] Although procedural learning takes time, once people have learned information with their procedural system, it can be used quick as a wink.

Neuroscientist Michael Ullman of Georgetown University, developer of the groundbreaking declarative-procedural theory of language learning, observes that it's important to realize that each learning system has types of information it's particularly good at acquiring. But *both learning systems can and often do learn information related to the same topic*. The upcoming table on this page describes the many different characteristics and implications of these two different systems. The bottom line: Unless there is a challenge with a particular pathway, students can use both declarative and procedural systems to acquire information. Information learned declaratively is flexible but slower to bring to mind. Information learned procedurally can flow into use with almost uncanny swiftness but be inflexible. (Think of how tough it would be to relearn how to type on a keyboard with a different configuration of keys.)

In a related vein, "unlearning" knowledge built from personal observation and "common knowledge" is perhaps one of the most challenging aspects of learning in many different fields, including physics, psychology, law, and business. The difficulty may well be because the unlearning involves (mis)information that has been learned procedurally. The common approach recommended for unlearning is plenty of practice with the new ideas—and practice, of course, is a foundation of procedural learning.

You can think of the two memory systems as a sort of seesaw. Emphasizing one system de-emphasizes the other.[8] But once *each* system learns the information, this knowledge becomes complementary: each way of knowing enhances your overall understanding of and ability to work with the material.




You can think of declarative and procedural learning as being like a seesaw. When one system is being used to learn, the other system is on standby. But ultimately, information learned with both systems forms the most powerful, flexible learning.

Often, teachers initially explain a concept with step-by-step explanations. This is exactly how students' declarative systems learn best.* So as students learn from their teacher, or from each other in more student-directed approaches, they deposit links in long-term memory through their declarative pathways. Those declarative links can be enhanced through retrieval practice. But how do you get students to *also* start building their procedural sets of links? Quite often, *practice* is the best bet for building both procedural and declarative links. (Unfortunately, there is no magic button that can turn the declarative or procedural systems on or off.)

Generally, textbook chapters convey declarative knowledge. The problems at the end of the chapters, on the other hand, are meant to also invoke the procedural system. Both explanations and problems are essential in helping a student master the material.

When Terry was a college physics major learning electricity and magnetism, he memorized Maxwell's equations, which were derived from many experiments with batteries and magnets. Did he understand electricity and magnetism? No, because it was not until he had to apply the equations to a problem, like designing a radio antenna, that he learned their consequences. By using procedural learning to solve many different problems in electricity and magnetism, Terry formed intuitions about what the equations really meant, how to use Maxwell's equations, and how to solve new problems quickly.

Let's give another example. In biology class, a teacher introduces students to a microscope. The students may draw a diagram of a microscope and take notes on the parts and how to use it; this information takes the declarative pathway to the neocortex. But once students have spent time examining cells and cultures under the microscope, the steps for handling one and referring to its parts by name become second nature (procedural)—students don't even have to think about it. When a teacher adds more specimens for students to work with, and provides explanations, students are back on the declarative path.

It's easier to understand declarative learning because we're aware of it, at least in part. But we're mostly *not* conscious of the procedural system, which may be why research involving this type of learning is not as advanced as research to do with declarative learning. It can be a little tough to grapple with understanding a system when you're hardly aware it's there!*

Early on, researchers determined that the procedural system involved motor skills like learning to hit a baseball or to handle a handsaw. The procedural system was also seen as key to the formation of habits—for example, when you automatically wave back at someone who waves to you. In short, the procedural pathway seemed only to involve simple, routine tasks.

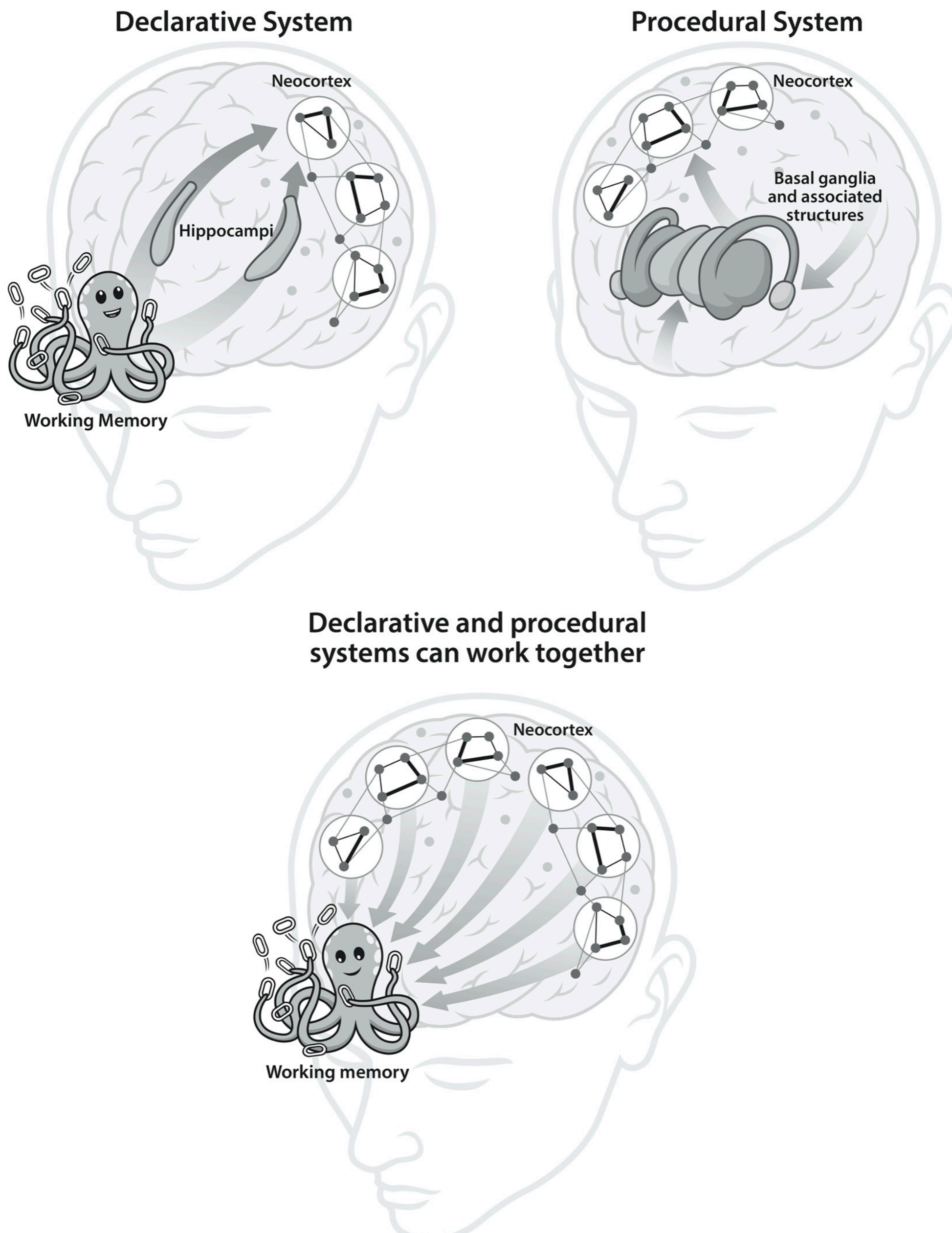
But recent research has revealed that the procedural system can be critically important when it comes to learning even staggeringly complex ideas and activities—everything from tying your shoelaces to grasping complex patterns in math to being able to speak an entire language quickly and naturally. The procedural system watches and learns from what you are doing, seeing, and hearing in order to assimilate and internalize patterns—like the shapes of letter formations when you are young. Or the inherent mathematical patterns you unconsciously access when you learn how to quickly solve Rubik's Cubes. Since the information you've learned doesn't need to go through your working memory (which is why you're not conscious of this type of thinking), you can solve the cube more quickly.[9] But it can also mean that even though you know how to solve the cube (which you do procedurally), you can't easily explain it (which you would have to do declaratively).

Here's what we mean. Let's say you are riding a bicycle, and you suddenly see a rock on the trail. Before you're consciously even aware, you've shifted the handlebars and glided around the stone.

You didn't become consciously aware of what's going on until *after* you passed the rock. The delay in awareness is because information came into your visual centers in the back of the brain, was processed by several smart layers of neurons surrounding the basal ganglia, and then went straight to the long-term memory links in the neocortex. Nothing went through the much-slower-to-process working memory. Your body reacted without your having to tell it what to do!

Here's an even neater trick. As you become better at riding your bike, your thinking processes don't even need to send signals through the basal ganglia. Instead, you can send signals from your vision centers directly to motor cortex neurons that activate your motion.[10] With enough expertise, you can react with uncanny swiftness to rocks, potholes, ruts, and roots that might suddenly appear before you as you ride down a mountain trail in the woods. As you can imagine, you can't explain the complicated instructions your brain is sending your body during the ride, other than in the roughest sense. But even if you can't explain how you did it, you did it. In other areas in your life where you react and do without thinking, you're most likely using your procedural pathway. (As we'll discuss later, anomalies in the procedural pathway may lie behind some impulsive adolescent behavior.)

Let's go back to your trip home in the car, which you accomplished mindlessly. Were you able to do that in the first few weeks after you moved into your home? No. You could get home, but you had to pay attention to what you were doing because you were using your conscious, declarative system. Only after you'd driven home many times did your procedural learning system master the information. Once it did, though, you could drive home without being consciously aware of it.[11] But if the car in front of you suddenly comes to an unexpected stop, your procedural system will quickly stop your own car while simultaneously signaling working memory to shift its attention to your surroundings so you can consciously figure out what to do next.




**Top left:** The *declarative system* goes primarily from your working memory through your hippocampus into long-term memory in the neocortex.

**Top right:** The *procedural system* of the basal ganglia takes input from the entire cortex, including the sensory input areas (the habitual part of the procedural system that begins with, for example, your visual or auditory systems toward the back of the brain) and the prefrontal cortex (the goal-directed part of the procedural system), through the basal ganglia and associated structures, to finally create a set of links in long-term memory.[12] Working memory can access links deposited by the procedural system.

**Bottom:** Working memory can grab well-established sets of links that have been created by either the declarative or procedural systems.

The declarative system, with its speedy way of learning, is often the first system to acquire information. The procedural system follows slowly behind, learning the material, but learning very differently—through practice. (Yes, this is an important reason behind why active learning exercises are so valuable.) The magic of the procedural system is not how quickly it learns (it's often pathetically slow!) but how quickly it can put that information to use once it's been mastered. Whether you are navigating a bike around a pothole, seeing instantly that 10/5 simplifies to 2, intuitively identifying that a shape is the letter *d,* or correctly using the past tense of a verb in your native language, your procedural learning system helps you do it effortlessly. With practice, you (and your students!) use fewer of the neural links that were deposited by the declarative system, and instead use more of the neural links that were stored by the procedural system. But this switch to the procedural system doesn't delete the information that still rests in the declarative memory system.

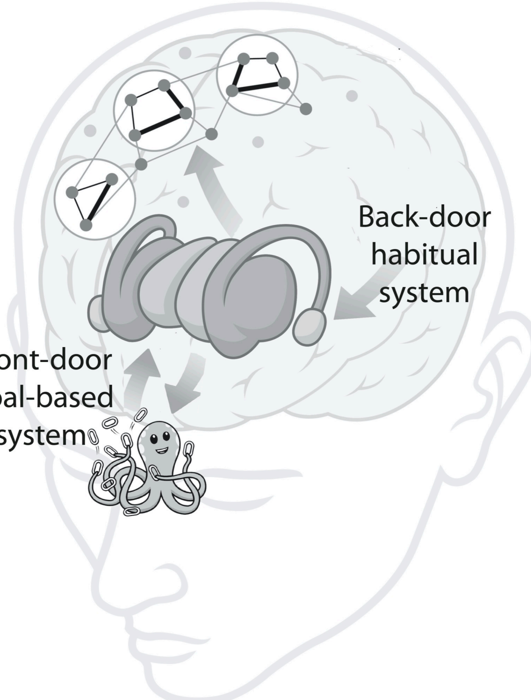
When students learn alternately through their declarative and their procedural systems, it means that the information nestles into two different places in long-term memory in the neocortex.[13] It's a little like having two legs. If you have just one leg, you can stand. But with two legs, not only are you more stable when you're standing, but it's easier to move forward.

Declarative learning gets students off the ground faster but with poorer overall performance. Learning declaratively *and* procedurally means that students can be fast and flexible with their knowledge. Explicit instruction, with its series of sequential, clear, step-by-step actions, increases learning in declarative memory. *Lack* of explicit instruction can enhance learning through procedural memory. For example, a child can learn his native language procedurally without explicit, formal instruction.[14]

It may be that some constructivist approaches[*] to instruction encourage procedural learning by allowing students to pick up the patterns by themselves. This type of "immersion learning" is a laudable goal and, with care, can work well when children are young and have stronger procedural systems for learning. But as children grow older, their declarative systems generally improve while their procedural systems recede. Where a toddler can grapple with the complex grammar of her native language without even thinking about it (almost literally!), a teacher can help a teenager learn a new language faster through declarative instruction coupled with procedural practice—that is, via active exercises.

## LEARNING MORE ABOUT THE PROCEDURAL SYSTEM

**Suppose a** strange dog wanders in front of you. You may have a gut feeling about this dog—a conscious feeling of happiness, or of apprehension or fear. These feelings emerge as a result of your past experiences with dogs. Your brain has learned what is typical of friendly dogs, as opposed to aggressive or dangerous dogs. You may not be able to put into words exactly why the dog might make you happy or nervous. You may not even remember what past experiences have led to your current feelings. Occasionally, however, a vivid memory may come to mind if you try to be specific about why you feel a certain way about the dog. Strangely enough, however, that recollection could also be a rationalization rather than a reflection of what your brain really was up to. Why is that? It's because of the mysterious "black box" of the procedural system. We don't know what's inside the box, but it underpins a surprising amount of our thinking.




The procedural memory system has a front door, which is for goal-directed activities, and a back door, for habitual actions.

The procedural system can be thought of as having a front door, which is for goal-directed activities, and a back door, which is for habitual actions. The front pathway takes its orders mostly from working memory in the front of the brain. For example, when you might tell yourself to *flow through a yoga sun salutation,* your intention flows into the basal ganglia from working memory in the front of the brain. Next, the information is processed by the basal ganglia, and finally, it is sent on to the cortex. The result? You find yourself moving into the pose.

The goal-directed procedural system also comes into play when you are speaking your native language or a very well-learned additional language. For example, if you want potato soup, your procedural system will help you blurt *potato soup* to your English-speaking friends without even having to think twice about it; if you're with your friends in Hungary however, using your well-versed Hungarian, that same desire for potato soup would have you blurting *krumpli leves*.

Jim Knight, who runs a superb instructional coaching program for teachers, notes that his coaches are most effective when they choose a goal a teacher wants to work toward related to their teaching. He observes:

> *We have found that people sustain their use of strategies after they apply them to real life work. A teacher can go to a thousand workshops and hear a thousand ideas, but it really isn't until they start to apply the ideas in a real*

*way to their classroom that they start to internalize and remember what they're learning.*

*One thing is, we don't try to get teachers to do anything. Our coaching is guided by the teacher's goals, and we have found student-focused goals are the best. If a teacher sets a goal that at least 90 percent of her students will be able to write well-organized and correct sentences, for example, and then the teacher starts to learn new strategies that help her reach that goal, then we have a teacher who will internalize what they're learning and remember it. So that is what we try to set up with coaching. But for the goal to matter, it has to be chosen by the teacher. In our experience, people aren't motivated by other people's goals.*

Jim's coaching system may be so effective because, by co-opting the teacher's own goals, it is also able to enlist the teacher's procedural system.

The back-door habitual entrance, like many back doors, is sneakier. It is used for unthinking sensorimotor learning and activities, for example, riding a bike, putting your feet up on a footstool as you relax, writing letters, or shrugging to indicate you just don't know. The habitual entranceway links sensory inputs with motor outputs, called *conditioned responses*. The back-door entrance originates in the back of the brain (natch) with information about what you see, hear, or otherwise sense. That information then flows into the rear of the basal ganglia and returns to the cortex.

As you might guess, the basal ganglia are part of the switching system between habitual (unthinking) or goal-directed (consciously initiated) procedural activities. We can see this most clearly if we switch the hand we're used to writing with. If, for example, we are right-handed, we can use the habitual part of our brain to write without even thinking about it. But if we're right-handed and try to write with our *left* hand, watch out! Suddenly we can't use the habitual entrance to the procedural system, and must instead make use of the *goal-directed*, front-door entrance, which is primed by our conscious (declarative) thoughts. Our procedural system hasn't really learned how to write with the left hand yet, so our writing is very clumsy. We have to constantly keep our conscious thought on what we are trying to do.

The procedural goal-directed system is where the declarative and procedural systems can work together. The declarative system, which you are aware of, "primes" the black box of the procedural learning system. But what will come out of the black box is something of a mystery, at least as far as your declarative system is concerned. It's a little like randomly flipping switches to see which one turns on a light. Your history of mistakes and successes in whatever you are learning, whether it's writing, speaking, or yoga poses, shape your reflexes. You are perfectly conscious of your mistakes but not of how the procedural system learns from those mistakes to gradually be able to, for example, write smoothly and automatically. This explains why conscious control is so slow and inefficient. Slowly, with a lot of repetition, the procedural system learns and takes over from the declarative system, making your writing, or any other procedural action, fluid and automatic.

Incidentally, it's not as if the interactions between the declarative and procedural systems are a one-way street. The conscious goals of the declarative system can be driven non-consciously by the basal ganglia procedural system. Procedural learning works by using a value function that it has built over many years of experience in dealing with complex, uncertain conditions in the world. The value function helps the procedural system to maximize future rewards. Rewards are typically innate (like food and water) or involve distant payoffs (like earning an A for the marking period in U.S. history). If you ask someone why they made a decision, they can devise a story that has little to do with the procedural system's value function that the decision was actually based on. This is because the value function for procedural goal-based learning is as inaccessible to consciousness as the procedural habit-based value function is for bike riding. Put bluntly, the declarative system is clueless when it comes to the black box of the procedural system.

This is not only why a gut feeling about a dog can be hard to put into words but also why certain subjects (including those that are the cause of many a dinner table argument over the years) can be so fraught during conversation. Our thoughts are driven in part by nonconscious motivations arising from the procedural system. This means that conscious, declarative discussion sometimes—perhaps even quite often—cannot get at real motivations.

Both the procedural and the declarative systems work together to underpin learning in most children. Reading or doing math, for example, generally involve using both declarative and procedural systems at the same time. When one or the other system falters during the learning process, or when teachers emphasize only one system of learning, it can make it more difficult for a student to be a successful overall learner.

| COMPARING THE DECLARATIVE AND PROCEDURAL SYSTEMS | |
|---|---|
| *The declarative* and *procedural* learning systems form two dramatically different ways of learning that can combine their strengths and allow for student success.[15] This table provides a comparison of the two systems. *Note that each system can perform some tasks or functions of the other system.* | |
| **Declarative learning system** | **Procedural learning system** |
| Primarily uses working memory and the hippocampus to interface with long-term memory. | Primarily uses the frontal/basal ganglia circuits to interface with long-term memory. Also integrates with the cerebellum. |
| Mostly conscious. (You're explicitly aware of your thinking and learning, as when you pay attention to the instructions about how to fill out a form for your new job.) | Largely nonconscious. (You're only implicitly aware of your thinking and learning, as when you drive home without thinking about it.) |

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| Declarative learning system | Procedural learning system |
| Provides rapid linking and association of bits of knowledge from various domains and modalities including<br>• *Who* (e.g., a friend, a popular actor)<br>• *What* (e.g., facts, meanings)<br>• *Where* (e.g., landmarks)<br>• *When* (the time an event occurred) | Underlies nonconscious learning and processing by the perceptual motor and cognitive systems of<br>• *How* (e.g., skills, tasks, and functions)<br>• *Habits* (e.g., the way you nod your head to mean yes in your culture) |
| PRIMARILY UNDERLIES THE LEARNING, REPRESENTATION, AND USE OF KNOWLEDGE ABOUT | |
| • *Facts* (Also called *semantic memory*. For example, the abbreviation for copper is Cu.)<br>• *Events* (Also called *episodic memory*. These are the memories you personally experience, such as meeting with the principal after school yesterday.) | • *Intuiting rules without necessarily being explicitly told what they are*. (Examples include predicting where your bat is moving when you are hitting a baseball, or saying "an apple" rather than "a apple.")<br>• *Determining categories and their differences* (For example, living versus non-living organisms, or fractions versus decimals.) |
| THE TWO SYSTEMS CAN LEARN THE SAME INFORMATION DIFFERENTLY | |
| • The declarative system can allow you to navigate to a local coffee shop by using a landmark, such as a tall building.<br>• Students learning English as a second language may learn rules for conjugating a verb—e.g., *I walk, he walks*. When it comes time for a student to use one of these words, it may take a moment to recall which form is appropriate. But the student can explain why she is using that form.<br>• Students learning their times tables may say to themselves that 5 × 3 = 5 + | • The procedural system can allow you to navigate to a coffee shop you frequent by following a familiar route (turn left at the corner, then turn right)—even when you're not conscious of what you're doing.<br>• Students who speak English as their native language first acquire the language without being told the rules. A student can use those rules to speak quickly, without even thinking about it. But she may have difficulty explaining why she is using certain verb forms. |

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| Declarative learning system | Procedural learning system |
| 5 + 5 = 15. Or see a table of 3 columns of 5 beans each, that the filled-out table totals 15 beans. | • Students have calculated 5 × 3 = 15 so many times, in so many ways, that they can know instantly and intuitively that 5 × 3 = 15. |
| THE LEARNING CONTEXT CAN ALSO AFFECT WHICH SYSTEM STUDENTS WILL TEND TO RELY ON. DIFFERENT FORMS OF TEACHING CAN HELP A STUDENT INPUT INFORMATION INTO EACH SYSTEM. | |
| The declarative system is employed when a student is "instructed." For example, by<br>• Explicitly describing rules and facts, such as explaining the PEMDAS* acronym to remember the order of operations in math, or explaining spelling rules such as the difference between *there*, *their*, and *they're*.<br>• Telling students to look for a specific rule or pattern.<br>• Giving slow or no feedback. Slow or no feedback on practice exercises involving addition or the multiplication tables means the student has little opportunity to internalize those math facts procedurally. Students then resort to slower declarative memory or finger counting even for simple relationships such as 7 + 5 = 12. | The procedural system is employed when a student is "uninstructed." For example, when<br>• There is a lack of explicit instruction, as with immersion-type contexts in language learning.<br>• There is interference that reduces attention to the information (as when thinking about a new teacher's baby shower when trying to drive home!).<br>• The rules or patterns are complex, so they are not obvious, as with a Rubik's Cube.<br>• A student has plenty of opportunities to practice through active exercises, either with a physical skill (e.g., the piano or basketball) or a mental skill (e.g., mental math). Active learning in class can be powerful in part because it seems to jump-start procedural learning.<br>• A student receives rapid feedback on tasks involving prediction. For example, immersion with native German speakers allows a student to predict how to say a sentence properly in German. Her new German friends offer feedback after she says the sentence, which quickly confirms |

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| Declarative learning system | Procedural learning system |
| | or disconfirms her prediction. This is particularly beneficial for proceduralization and thus for eventual automatization of a new language. |
| GENERAL CHARACTERISTICS | |
| • *Rapid learning at first:* Learning with the declarative system is relatively quick. Learning after even a single exposure to the information is possible, although additional exposures strengthen memories.<br>• *Slower to use:* Although it's possible to learn more quickly using the declarative system, this system is slower when a student is using it. Beginning language learners sometimes struggle with speaking a new language because they have relied too heavily on their declarative systems, without enough procedural practice (not enough active retrieval exercises). Math students who have not gained automaticity can get bogged down because they do not readily see relations, such as $\frac{1}{1/k} = k$, that can dramatically simplify their work.<br>• *Flexible:* Once learned through the declarative system, knowledge can be generalized and used flexibly; transfer of ideas across domains is easier. (For example, science students who learn about the conduction of heat might think of cooking potatoes faster at | • *Slower learning at first:* Learning in the procedural system generally requires practice and thus is often slower than learning in declarative memory.<br>• *Faster to use:* The procedural system is ultimately faster to access and use than the declarative system. The procedural system allows for fluency and automaticity, such as the rapid, unthinking ability to speak a native language or a well-learned additional language, the unthinking ability to write sentences that start with a capital letter and end with an appropriate mark of punctuation, or the ability to convert a frequently encountered fraction like ¼ into the decimal 0.25.<br>• *Inflexible.* The procedural system is also involved in habits—the unthinking actions we take because we've learned them through repetition. Because we are often not conscious of the processes involved, it's harder to generalize or use flexibly the information gained in this system. Much like a brick wall, the information |

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| Declarative learning system | Procedural learning system |
| home by inserting a metal skewer through a potato.) | is solidly and reliably there but difficult to change! |
| Declarative memory improves through childhood, plateaus in late adolescence/early adulthood, and slowly declines with age. | The procedural system is well established in early life, which is why young children can learn a language, in particular its grammar (largely learned procedurally), so easily.* This system appears to decline as children mature.[16] |
| Declarative memory learning systems are generally stronger in those with larger-capacity working memory. | Procedural memory learning systems are stronger or may be used preferentially in those with lesser-capacity working memory. |
| Declarative learning is enhanced by the engagement of frontal control processes. Mindfulness training, which enhances prefrontal control processes, appears to enhance declarative learning.[17] | Prefrontal engagement (focused attention) does not benefit and in many cases hurts procedural learning. Mindfulness training appears to inhibit procedural learning by disengaging the basal ganglia and increasing effortful control in frontal areas of the brain.[18] |
| Higher estrogen levels are associated with improved declarative learning, as is left-handedness. Specific genes, which vary between individuals, can improve declarative learning. | Lower estrogen levels are associated with improved procedural learning. Some genes may accelerate transitions from declarative to procedural learning, while other genes may simply enhance procedural learning.[19] |
| The declarative system may help compensate or even be strengthened in those with:[20]<br><br>• Dyslexia<br>• ADHD<br>• Dyscalculia<br>• Developmental language disorder<br>• Articulation disorder and developmental stuttering | The procedural system may help compensate or even be strengthened in those with:[21]<br><br>• Autism spectrum disorders<br>• Tourette's syndrome |

**COMPARING THE DECLARATIVE AND PROCEDURAL SYSTEMS**

*The declarative* and *procedural* learning systems form two dramatically different ways of learning that can combine their strengths and allow for student success.[15] This table provides a comparison of the two systems. *Note that each system can perform some tasks or functions of the other system.*

| Declarative learning system | Procedural learning system |
|---|---|
| • Obsessive-compulsive disorder | |

Similarities between both learning systems are also important:

- Each system seems to perform consolidation processes that improve the memories.
- Sleep and exercise show similar effects in the two memory systems, improving learning in both.
- The dysfunction on one system may lead to an increased dependence on and enhanced functioning of the other system.
- Both systems often work together. For example, the idiom "get your act together" is learned through the declarative system. But what if the past tense is needed—for example, "you *got* your act together"? It turns out that these changes in verb form are swiftly and unthinkingly handled by the procedural system. Pronunciation and, eventually, writing and math can become easier because of the quick, ready access of the procedural system to fundamental bits of information that are also being used by the declarative system.
- What is learned by one system is *not* transferred or transformed into knowledge in the other system. *Each system gains its knowledge independently.* For example, as learners practice writing and receive feedback, they gradually rely less on grammar learned declaratively. Instead, they gradually shift to rely more on grammar learned procedurally. What is learned through one pathway is stored by that system in its own storage area in the neocortex. Even though the two systems have their own storage areas, the knowledge deposited by the procedural system may be used by the declarative system, as when reading a book, throwing a ball to a friend, backing up a car, or inserting a word newly learned by the declarative system (say, *neologism*) into a grammatically correct sentence structured by the procedural system. How the two systems work so seamlessly together is complicated and, at present, poorly understood.
- With time, both memory systems rely less on the "transit structures" (the hippocampus or basal ganglia) and instead rely directly on the long-term memories of the neocortex.

## Good Teachers Teach so That Students Learn with Both Their Declarative *and* Procedural Systems

Good teachers make sure that, wherever possible, students learn using each of the two different systems. For example, in math, students can be consciously aware of how to solve a problem through their declarative learning system. But they should also do plenty of practice problems—lots of active learning—to develop an unconscious sense of the patterns involved, which involves their procedural learning system.

It turns out that essential aspects of learning math—for example, topics like addition or subtraction—likely involve procedural memory. The areas of the brain that process arithmetic overlap considerably with the parts of the brain associated with procedural memory.[22] In the past, researchers thought that shifting from finger counting to a more instantaneous grasp that 2 + 3 = 5 was simply a rote memorization process. However, it's becoming clear that adding becomes faster because it becomes automatized through the procedural system. It seems children who have practiced with math facts can use those facts as quickly and efficiently as they do grammar in their native language because they are using some of the same systems for math as they do for language.[23]

In language learning, a student can be taught the formal rules for verb conjugation in Spanish through the declarative system while sitting in the classroom. But when she practices her Spanish grammar through verbal exercises, worksheets, or (best of all!) conversation with a native speaker, she is learning, at least in part, through her procedural system. Many students study a foreign language primarily through their declarative system, which is why they tend to freeze when put on the spot and asked to speak spontaneously. It's not that they haven't learned the material—they have. It's just that they've relied on learning the material declaratively. They haven't placed enough learning yet in the procedural parts of their memory.

Sometimes less instruction is more—as when you start learning your native language as an infant. Here, learning bypasses the declarative pathway and leans into the procedural system. Young children's strong procedural learning systems may be one reason why Montessori and Reggio Emilia schools, which offer more exploratory experiences for children, can be so highly effective for children at those earlier ages.

But that's not a reason to present students with an assignment sheet or problem and say, "You figure it out." It just doesn't work that way for advanced, biologically secondary material—or even for many seemingly simpler activities. For example, you can't just give a child a shoe and expect him to know how to tie the laces. Careful scaffolding of explanation mixed with active exercises—plenty of well-designed practice—are in order.

An interesting twist on scaffolding of more advanced material involves a teaching methodology called *concept attainment*.[24] In this approach, the teacher presents examples and non-examples of the concept. The students figure out the common attributes of the concept and generate a potential definition. The teacher provides further examples for students to test their hypothesis and solidify their definition. In this way, students develop their own understanding of the concept.

For example, if a teacher wanted to teach students the key characteristics of inorganic compounds, she would present students with a series of *yes* and *no* examples of the concept. *Yes* examples embody all of the characteristics of inorganic compounds, while the *no* examples might have some but not all of the characteristics of inorganic compounds. Students record their observations and generate a list of key attributes of the concept. Once students think they have a definition of inorganic compounds, the teacher then adds more challenging examples to test the students' definition. After students have a handle on the concept, the next step is for the student to apply their learning to a new task, such as coming up with more *yes* examples. Sometimes concept attainment is used at the start of a lesson to hook students prior to moving onto direct instruction.

### NOW YOU TRY!

#### TEACHING STUDENTS ABOUT TWO WAYS OF LEARNING

Sometimes students are not convinced they need to practice. You can almost hear them grumbling before you even assign a few more problems. They think that because they have answered a few questions or completed a few tasks on their own, they have mastered the concept or skill you are teaching. To curb their resistance, explain how learning occurs. Learning how to learn, after all, is a meta-skill that will last students all their lives.

Tell your students that they have an "explanation" (declarative) learning pathway that learns through explanations, and a "practice" (procedural) learning pathway that learns through practice. Both paths are essential for learning. The reason students need to practice on their own is to help them develop that second "practice" pathway.

## Strategies to Enhance Both Declarative and Procedural Memory

If students learn best when they learn through both the declarative and procedural systems, what's the best way to teach if you want to enhance their understanding via a particular system? Unsurprisingly, active practice lies at the heart of learning with either system. But subtle differences can support one system better than another.

The best approach to enhance declarative learning may seem obvious to you by now. It is, of course, retrieval practice. Retrieval practice helps students focus deliberately—that is, declaratively—on what they are trying to learn.

But when it comes to procedural learning, your best bet is to use either spaced repetition or interleaving. Let's start with interleaving.[25]

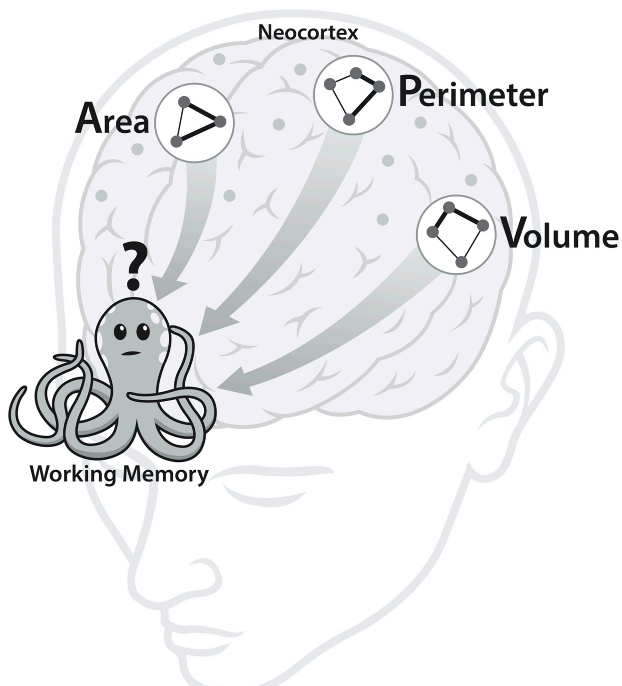
### Interleaving

Interleaving is when students mix up their practice of a topic, rather than merely repeating virtually identical materials and questions all in one block of time. For example, if you were studying impressionism, blocked practice would mean you are exposed to, say, five paintings by Monet, then five each by Degas, Renoir, and Pissarro, a little like this: MMMMMDDDDDRRRRRPPPPP. But interleaved practice would mean you'd mix up the different artists as you were studying, so your studies might look more like MMDDRRPPMDRPMDRPMDRP.

Or let's say that you are teaching Spanish. It's easy to practice the present, preterite, imperfect, and conditional tenses in separate blocks. After studying, students feel they have learned each tense well. But it's when the tenses are mixed up—interleaved—during practice, that students begin to understand the real differences in usage.[26]

If you are teaching English literature, you may try interleaving literacy devices such as similes, metaphors, hyperbole, personification, onomatopoeia, and alliteration. Coauthor Beth, for example, used direct instruction to teach students how to recognize each of these devices in literature. After being presented with the definition of each device and examples (*I do*), she had students create their own examples to share with the whole class and elicit feedback (*We do*). She found that students could easily recite definitions and give examples when it came time for the test (*You do*)—but they often didn't demonstrate true conceptual understanding. That is, students weren't able to generate original examples of the devices on the spot when the terms were presented to them randomly. They also couldn't locate examples scattered throughout a text—even when the examples were strikingly obvious. Students needed more practice—not simply declarative-style memorization of definitions, which can have little to do with whether students truly understand material. To give her students more of a challenge, increase their effort, and make learning stick, Beth had students perform a scavenger hunt for literary devices each time they read a new piece of literature. The devices were interleaved throughout the literature, making the learning slow going at first. (More than one student grumbled.) But as students made strides in their understanding, they became speedier at spotting the devices in context, and were more often correct than not. Beth could intuit her students had internalized the devices through their procedural pathway when they began bringing in examples they had found in pieces of literature they were reading on their own. She saw onomatopoeia, personification, metaphors, and the like used masterfully in her students' own writing months later. Her students were even able to explain how and why they purposefully used each device.

If you're teaching math, you may wish to interleave, for example, calculations involving area, perimeter, and volume randomly. In this way, students don't get so used to doing one type of formula that it becomes the first and perhaps only formula that comes to mind when they must solve a problem.[27]



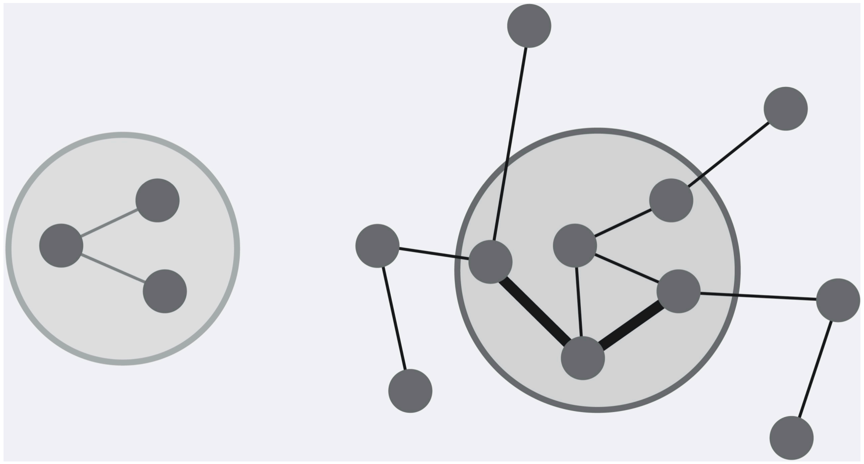

Interleaving: Recall that each round "dot" represents a neuron. Calculating area, perimeter, or volume each involves different sets of neural links. Interleaving helps students recognize the subtle differences between these sets of links, so they know which set of neural links to call into play for a particular problem. Interleaved practice would look more like APVPAPVAVPA.

As we've mentioned, drill can be a very good thing—but *not* when it's conducted as blocked practice. Once a student gets the basic idea, she is still forced to go through a sludge pile of additional virtually identical problems.

Students pay less attention when they are at the latter part of the block of exercises—they're just going through the motions. Blocked practice wastes valuable instructional time without doing much to improve learning. Students seem to learn more quickly through blocked practice, but they don't retain the information as long as they do when they've learned through interleaving.[28] As Peter Brown and his coauthors note in the insightful *Make It Stick*: "Massed practice gives us the warm sensation of mastery because we're looping information through short-term memory without having to reconstruct the learning from long-term memory."

Interleaving helps students learn virtually any subject, including sports, math, music, art, and language. Even seemingly simple concepts, such as learning to write different letters (*a*, *h*, *y*), can benefit from interleaved rather than blocked practice.[29] (Incidentally, if you think that concept attainment is related to interleaving, you're right.)

Interleaving may boost procedural memory because it gives students practice in picking up on *patterns*—that is, detecting the subtle difference between somewhat similar items or techniques. Detecting and intuitively mastering patterns after seeing, hearing, and doing something many, many times is precisely the kind of thing that procedural memory is good at, which means that somewhat similar categories like seals versus sea lions, or preterite versus imperfect tenses in Spanish, are perfect fodder for interleaving.[30] However, differentiating between more obvious categories like dogs and cats, or teaching when to use a statistical technique in math as opposed to when to use a painting technique in art, doesn't benefit from interleaving. The differences between those categories are so apparent that there's no need to spend time practicing to learn them.



The term *desirable difficulties* means the mental effort of building a strong set of neural links to understand and remember a concept.[31] Building a strong set of neural links can be hard work compared to just scanning the information! For example, if a student is trying to learn the character 人 (rén), which means *person* in Chinese, she might take a few seconds to glance at the character. At best, this creates a weak set of connections, as shown at the left. These weak connections can disappear by the time she next tries to retrieve the word and character.

But if she takes the time to imagine that 人 is a person with two legs, "running" (*rén*), and she even moves her fingers (or her own legs), then she's encoded the new word more strongly into what she already knows. This greater conceptual elaboration, which takes time and effort, is more likely to create a strong set of links that will stick. You can think of it as a building a larger spider web that catches more flies. (Later consolidation processes tighten things up.) Of course, desirable difficulties apply as well to far more complex concepts. Successful students frequently develop their own desirably difficult approaches to study.

Incidentally, making meaningful gestures while learning a new foreign word seems to be particularly helpful for students in allowing them to remember that word and lock in its meaning.[32] For example, while trying to remember the word for *high* in a foreign language, the teacher (and the students) can raise their right hands up high while saying the word. To remember the word *bond*, the students can "join" the fingers of each hand so they just touch. New written or spoken words in a foreign language activate little neural activity in a foreign language learner. Pictures accompanying those new words activate more neural activity. But meaningful gestures accompanying the word result in the most neural activity, and tellingly, much of this activity has to do with the word's meaning. In other words, meaningful gestures lead to deeper encoding (stronger, better neural connections) of the new word, whereas just reading or hearing the word leads to shallower encoding (weaker connections).

Oddly enough, students think they aren't learning as well when they are interleaving because the learning is more laborious. The answers don't flow out as easily as when the same old thing is repeated over and over again, with only slight tweaks. But laborious learning such as interleaving is, as psychologist Robert Bjork has found, a "desirable difficulty."[33]

Let's take soccer, for example. Soccer players—even world-class ones—can end up practicing more with the stronger than with the weaker leg, because it can be so gratifying to get better hits with the stronger leg. This so-called peg leg[*] syndrome, where the weaker leg doesn't get the practice it needs, can mean lost games because players need to be expert with both legs during a game. The harder learning creates a desirable difficulty and makes for enduring learning.

Using a teaching approach that requires more time, care, and effort from the students pays off in better learning. The challenge is convincing students that the more straightforward, blocked instruction most of them are used to isn't as good as interleaved instruction—especially when blocked instruction looks like it produces good results fast. Using counterintuitive approaches like interleaving and desirable difficulties is why uncommon sense teachers can make a difference![34]

The bright side of learning is that, with appropriate teaching, humans can get better at almost anything. But there's a dark side of learning as well—the improvements usually involve only *precisely* what the student has learned. There are little to no gains in tasks that might seem nearly identical. This phenomenon is known as the curse of specificity.[35]

What's the cure? Training on a *large* set of *varied* samples.[36] So interleaving also may assist with transfer—a student's ability to apply learning from one situation to another.[37]

Interleaved practice, incidentally, is similar to the conditions students will encounter on tests—unlike the blocked practice materials provided in most textbooks. Here's an example. When you assign students a series of problems to solve using the Pythagorean Theorem for their homework, they already have a leg up on the solution—they know which procedure to use.

On the final test in the class—and in real life—there will be many different types of problems, often without any clue about what technique the student needs to use. Practice on which set of neural links to pick out is invaluable.

On a side note, efforts by schools and universities to make shortened, condensed, intense study courses may be counterproductive for students, because it leaves less time for spaced repetition and consolidation processes.[38]

### The Value of Handwriting Over Typing

This is also a good place to mention the importance of handwriting over typing for learning in the classroom, at least during the early years. As professor of developmental neuropsychology Audrey van der Meer has noted:

> *The use of pen and paper gives the brain more "hooks" to hang your memories on. Writing by hand creates much more activity in the sensorimotor parts of the brain. A lot of senses are activated by pressing the pen on paper, seeing the letters you write and hearing the sound you make while writing. These sense experiences create contact between different parts of the brain and open the brain up for learning. We both learn better and remember better, so it's important for children to go through the tiring phase of learning to write by hand, even though it can take longer.*[39]

### Caution with Regard to Interleaving and Desirable Difficulties

There can be a natural tendency to think "the more, the merrier," when it comes to both interleaving and desirable difficulties. But as Daisy Christodoulou, author of *Seven Myths About Education*, astutely notes: "A colleague of mine who works with a lot of science teachers recently told me that he is very worried by the recent popularity of interleaving in English classrooms. He says he sees lots of lessons where students are being bombarded with lots of different questions about concepts they don't fully understand, and when he asks the teacher what they are trying to accomplish, they say 'interleaving.'"[40]

Naturally, any technique can be misused, but the challenge is knowing when a difficulty is desirable. Unlike infants, who learn well by relying on their procedural pathway, older children and adults tend to rely more for initial learning on their declarative systems. They often need information explained and procedures demonstrated before being able to retrieve and use them. A certain amount of blocked practice is thus often necessary to get the basic declarative links in place before embarking on interleaving. The limitations of working memory can mean that if too much is thrown at a student at once, links can't make their way into the declarative system. This means nothing has been internalized for the procedural system to monitor and learn from, which can considerably slow the learning progress.

### NOW YOU TRY!

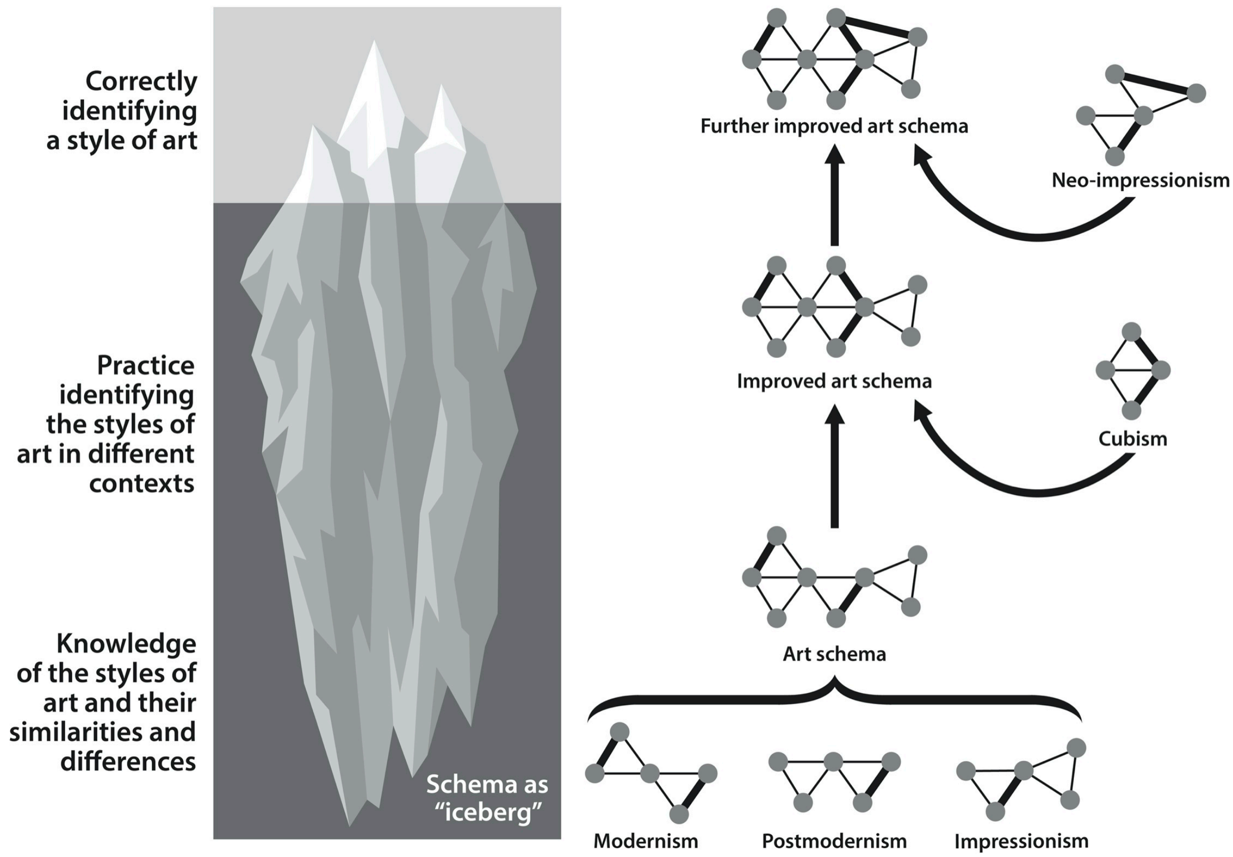
#### INTERLEAVING

**Teachers often** wonder how specifically to apply interleaving to their subject. Teaching is so broad that there is no one recipe. One way to get started is to begin with the end in mind. Think about the final test you will give your students after a unit of study. What are the topics that students frequently confuse? Do they use fractions when they should be using decimals? Do they mix up verb tenses in foreign language study? Do they keep the basketball instead of passing? All of these are areas you can tackle as a teacher or coach by using interleaved practice, whether you are doing in-class problem-solving, running active practice sessions, or assigning homework. You don't want just to teach your students *how* to do something. You also want to teach them *when* to do it.

## Building Schemas

Since we're talking about sets of neural links, this is an excellent time to step back and talk about schemas.[41] You can think of a schema as a sort of über neural pattern—a set of neural shelves that students can easily set new ideas on. Why so easily? Because students have practiced enough with the material that their minds have begun to integrate common patterns.

Schemas tie together the different concepts that a student is studying, including both procedural and declarative components. Schemas are the quintessential form of prior knowledge, and are intimately related to narratives and main ideas, concepts and categories, and knowledge of statistical regularities.[42]




Schemas: Students gradually develop schemas regarding what they are learning. In this example, a student is gradually improving her "art styles" schema. You can think of the individual sets of links, for example, involving modernism, postmodernism, and impressionism in the bottom row, as mini-schemas that arise as students practice with the concepts (interleaving between the different styles helps speed the practice development of the mini-schemas). Learning these three styles helps students to develop a simple art schema. This simple schema allows the student to move on to learn about the key concepts of cubism slightly more easily. In other words, the student has a neural structure that allows cubism to tuck more readily in beside the other, previously learned mini-schemas. Likewise, having the preexisting schema allows the student to tuck the new style of neo-impressionism into place. Each new style slides into place slightly more easily as a schema gets bigger and stronger with more practice and learning.

This illustration shows the development of a schema related to art, but the illustration could just as easily be applied to doing various mathematical operations, such as addition, subtraction, multiplication, and division. Or it could relate to fundamental concepts in chemistry, playing a musical instrument, geology, dance, fashion design, basketball, or language learning—you name it.

There’s plenty of evidence that schemas settle into the neocortex, as opposed to the hippocampus. (This makes sense, given that Hip is into only the more superficial, indexing aspects of the material.) In fact, the stronger the schema, the less likely the hippocampus is involved. Interestingly, schemas shape our thoughts about what we are learning. This can be both positive and negative as far as our ability to break down and reshape material to see it in fresh ways, or to overcome preexisting biases and prejudices. Part of why interleaving is so valuable is because it helps students to create schemas.

Schemas are important because, as shown in the illustration above, they allow new learning to be more easily placed in with other, previously learned material. In other words, the neocortex can learn more rapidly.[43] A chess expert, for example, has a fantastic repertoire of chess-related schemas. These schemas of expertise allow the chess expert to quickly master new chess patterns. It’s this way with whatever a student is learning. Schemas are frameworks for learning—and the bigger they are, the easier it becomes to make them even bigger. Ultimately, as we’ll discover in the next chapter, schemas can also help improve student motivation.

A common misconception is that specialized vocabulary is synonymous with a student’s schema for a subject. Vocabulary is *part* of the schema, but it’s certainly not everything. For example, a student may learn all the terms for different types of triangles (isosceles, equilateral, scalene), but a student needs to know (among many other things) how to do calculations related to those triangles in order to develop a robust geometry schema or set of schemas. Or students may learn specialized vocabulary related to the study of art (impressionism, postimpressionism, cubism, art deco), but they also need the ability to understand and use the vocabulary successfully in a variety of contexts to build a sturdy schema. Chess masters might develop a specialized vocabulary about chess (the names of the pieces and names of typical moves), but they also need to have in their schemas what the best moves are in a given situation. They even need skills related to psyching out their opponents at critical junctures. Specialized vocabulary is often just the tip of the iceberg of an underlying schema.

One goal of learning is that students should eventually be able to transfer the new material or skill we have taught them to novel situations. This is doable to a point—the more dissimilar the new material, the harder it is to transfer.[44] But you can extend students' ability to transfer by introducing your students to as many different uses of the content as you can—that is, enlarging their schemas.[45] And encourage your students to explore on their own. Surprisingly, retrieval practice may also assist with transfer—even far transfer to quite different domains.[46] Don't be too harsh with your students if they aren't able to easily transfer their new knowledge to a variety of areas and scenarios. Even experts can struggle with transfer, as when master teachers were put to the test during the COVID pandemic and asked to transfer their face-to-face teaching skills overnight to online instruction.

Incidentally, the development of schemas may well underpin the higher order levels of Bloom's taxonomy and Webb's Depth of Knowledge.[47] Schemas make clear that higher orders of conceptual understanding grow organically from mastery of lesser, simpler levels. It's not possible, in other words, to just jump to the top of the mountain and focus on higher-level understanding alone. We look forward to the day when a new taxonomy of learning will be developed that is based on neurobiological considerations.[48]

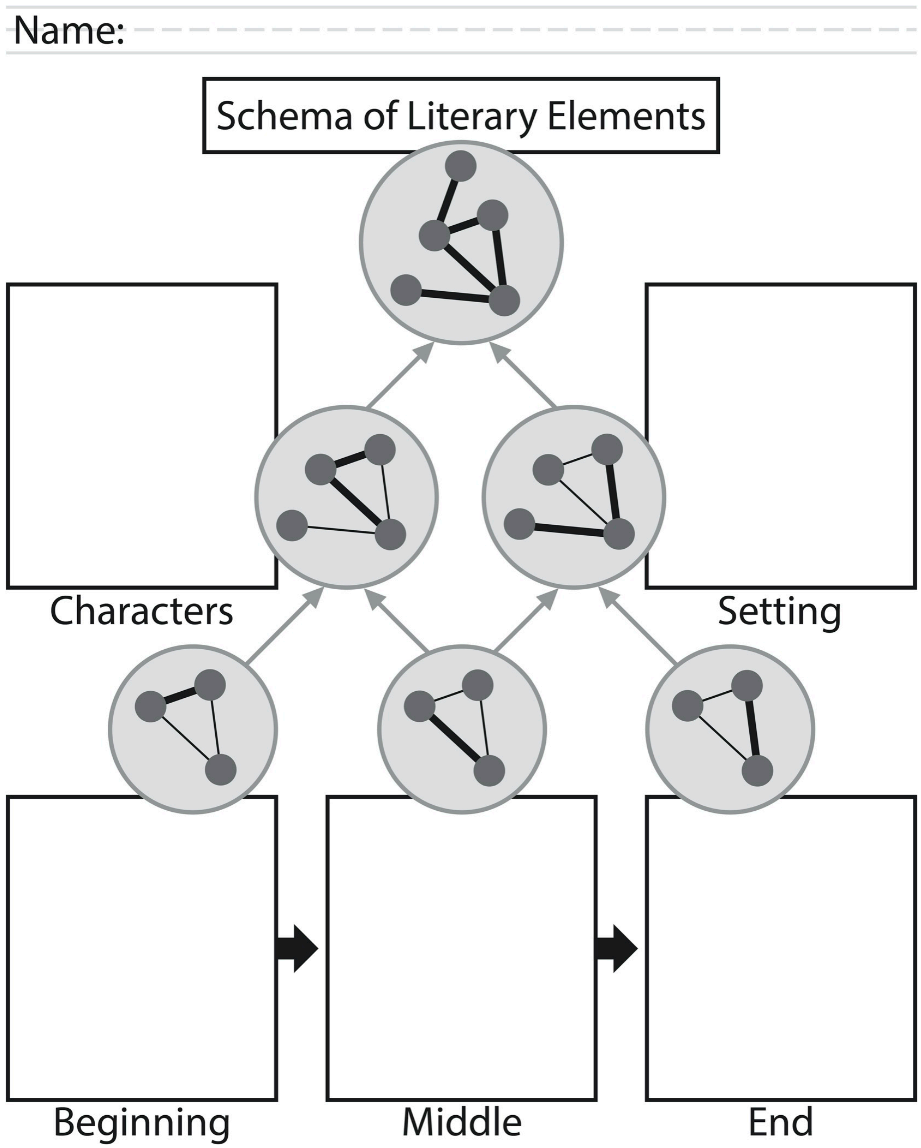
## NOW YOU TRY!

### USING GRAPHIC ORGANIZERS TO BUILD STUDENTS' SCHEMAS

**A teacher,** a neuroscientist, and an engineer got together to write a book. The teacher saw a graphic organizer. The neuroscientist saw interlinking neurons. The engineer saw an Excel spreadsheet.* Each had different schema about the book-writing process based in large part on—you guessed it—their prior knowledge and experience, which serve as the framework for their schema.

You can build your students' internal schemas through graphic organizers. Graphic organizers are visual representations of content—showing, for example, similarities and differences, key attributes, and hierarchical structures of concepts. Unlike concept maps that have a fluid, spur-of-the-moment structure, graphic organizers take the form of clearly labeled tables, diagrams, and charts where students show how categories and concepts not only connect but contrast. Such organizers allow students to go deeper into the content—to lay out key ideas and then compare them with one another to develop a sense of underlying patterns and influences. Research shows that graphic organizers can be even better than note-taking. Note-taking, after all, is a purely sequential activity. Creating a graphic organizer, on the other hand, is a generative activity that helps students mentally reorganize materials into a coherent structure.[49] Graphic organizers can solidify and add to students' schemas.

For example, in English language arts, first graders build their schema for literary elements when they complete story maps describing the main characters, setting, and sequence of events after listening to a story, as shown in the graphic organizer figure below. They do this for several stories, filling out several graphic organizers, so they begin to get a sense of how the stories' elements are similar between stories. They begin to see, story by story, how each part works together to form a whole. By middle and high school, students can extend their schema for literary elements. They have moved beyond identifying the beginning, middle, and end of a story to explaining the rising action, conflict, climax, falling action, and resolution. They not only can describe the main characters but can also explain how the actions of the protagonist affect the story's climax.




**Graphic organizers**, where the key characteristics of a schema are laid out on paper, can help students develop their internal schemas. The story map above helps students identify and visualize the key literary elements of a short story. This graphic organizer helps students to build their internal schemas as they practice with many stories.

Tips to capitalize on the power of graphic organizers to build students' schemas:[50]

1. Provide students with a surface-level understanding of the concept before you introduce a graphic organizer. Students can't transform knowledge they don't understand.

2. Next, provide students with a graphic organizer template, but require them to fill it in on their own. This can serve as a scaffold toward students' construction of their own internal schemas.

3. For students who already have a sense of the material, and are looking to enhance their existing schemas, allow them to create their own graphic organizer. To do this, teach students a variety of organizers that work for the types of concepts they are learning. Students can create their own diagrams to compare and contrast, timelines to sequence events, and charts to organize cause-and-effect relationships.

4. Finally, have students *use* their organizers in subsequent activities—in debates, writing reports, and research—to cement and extend their learning.

For this exercise, we challenge you to develop (or find) a graphic organizer for your subject that will help students pick out and compare key parameters in what they are learning. Or enlist your students in developing a graphic organizer, either for your class or for themselves. Have fun!

## Spaced Repetition

We've arrived at last at the other "desirable difficulties" approach to teaching and creating neural links in long-term memory: *spaced repetition*. Spaced repetition, like the closely related technique of retrieval practice, may assist not only with declarative but also with procedural learning.

When you first learn a concept, your brain is struggling to make the connections. It makes those connections any way it can. Often, the connections aren't necessarily the best configuration of neurons to capture the essence of what you're learning.

The best way to allow those connections to rearrange themselves and make simpler, better, deeper, stronger connections is to take a break. Then return repeatedly to the concept. Returning over time is the essence of spaced repetition, and underlies the brain's ability to consolidate the information, as we saw in the image back on this page. This revisiting may even allow links created by the procedural system and other links created by the declarative system to find ways to connect if they relate to the same concept.[51]

How long should the spacing between repetitions be—minutes, hours, days, weeks, or months? Sadly, there are no easy answers—except that we know sleep and moments of mental relaxation, along with the simple passage of time, can help.[52] If students wish to remember the material for an upcoming test a week away, they should review it every day in the preceding week. If you want students to retain the content because you'd like them to know it in a year, it's a good idea to review once every three weeks.[53]

But everyone is different. Information sticks better with some students than with others. This is a function of both their previous experience with the material (their preexisting schemas) and the facility with which their brains create mental links, which includes their internal motivation. Incidentally, interleaving itself appears to be a form of spaced repetition, which may partly explain its ability to help students retain the information.

### The Value of Judicious Homework

Excessive homework—three to four hours a night—has become a contentious issue, causing some schools to eliminate homework altogether. Sadly, this throws the baby out with the bathwater. Judicious amounts of homework allow students to reinforce their declarative understanding of the material and to develop their self-regulatory skills. Perhaps most important, however, homework can be one of the best approaches to enable students to develop their procedural understanding of the material, as it allows for both spaced repetition and interleaving.

When it comes to homework, less is more. It's about the quality of your assignments, not necessarily the quantity. If students are required to spend too much time on homework, they are bound to grow bored and be resistant to completing it. Instead of assigning forty homework problems, try seven. To incorporate interleaving and spaced repetition, assign (for example) two problems from today's lesson, three problems from the previous lesson, and two problems from the distant past.

Is there a sweet spot for the time students at different ages should spend on homework for specific subjects? Unfortunately, not that research has so far revealed. We may never have a precise answer to the "optimal homework" question for each individual. The truth is, it all goes back to the quality of the assignment and the students' motivation. A reasonable guideline is that biologically secondary material like math, reading, and writing, with their need for dramatic neural rewiring, would probably benefit the most from homework practice. Short daily practice helps much more than longer sessions scheduled days apart.

While guidelines for the length of time spent on homework are useful, they are just a start. Other recommendations to consider include:[54]

1. Always wait until the end of class to assign homework. When homework is written on the board at the start of class, the students may be tempted to start working on it during the lesson.
2. Have a plan to use key ideas from homework the next day during class.
3. Make homework count toward the course grade by at least a small amount.
4. Have students start working on the homework a few minutes before the end of class. Students are more likely to finish what they have already started. Plus, these few minutes allow you to assist those students who may have additional questions.
5. Never use homework as discipline.

The parents' attitude toward homework is critical. Students must be allowed to struggle and receive only judicious guidance and hints, rather than for parents to hover continually, control, and correct. In this sense, parents of limited educational backgrounds but positive attitudes toward learning and homework can be beneficial for students in developing their own metacognitive skills.[55]

Students often want to zip through homework as quickly as possible. When a task takes longer, they typically don't want to take the time to battle through it. They may say they tried and couldn't do it. The teacher then helps them out—which is, of course, classic enabling behavior. Your best strategy as you supply homework practice for your students is to give frequent short assignments based on an interleaved approach.

## Being Able to Explain a Concept Does Not Necessarily Prove Conceptual Understanding

Teachers often think that if students can explain the concept verbally, it indicates a true conceptual understanding of the material. But, sadly, that's not necessarily true. Students can simply regurgitate a verbal explanation they have memorized using their declarative system. For example, Kevin Dunbar and his colleagues have found that adults who explicitly state the correct pattern of Newtonian motion show the same brain activation patterns of adults who don't understand Newtonian motion. As David Geary notes: "'Deep' conceptual understanding and explicit statements of concepts are not the same thing."[56]

Some students may understand a concept through their procedural system—for example, involving a point of grammar or the simplification of fractions—but find it challenging to put their understanding into words.* Students with poor working memories, who often learn through their hiker-like procedural systems, can become frustrated and feel disenfranchised when a teacher might insist that declarative explanations are the only way to demonstrate knowledge. Repeatedly asking a student who, say, might have some aspect of autism spectrum disorder to put their understanding into words—that is, to explain by using their declarative system—can shut that student down when it comes to school and classroom learning. It may also be a surprising example of the expertise reversal effect. The student can truly understand the content but become demotivated by being forced to slowly limp through confusing verbal explanations of material they already grasp intuitively. Students are individuals, and sometimes good teaching means understanding that if a student knows how to get the right answer, and they're enjoying the material, that's enough.

## Blending Declarative and Procedural Learning

How you teach will elicit different ways of learning in your students. The brief explicit parts of direct instruction where you offer a sequence of explanations, or even just draw attention to rules or patterns, can increase learning through the declarative memory system. On the other hand, practice shifts the learning toward procedural systems.

When students first learn a fact through the declarative system, say, that $2 \times 3 = 6$, they store that information in one set of neural links. When they practice $2 \times 3 = 6$, they are storing the learning in a different set of links. Learning simple additive and subtractive facts and the multiplication tables enables students to develop a procedural, intuitive understanding of the relationships between numbers through practice.

Similarly, when students learn the essential facts of the color wheel, such as that blue and yellow colors mix to become green, they are learning through their declarative system. When students *practice* mixing paint colors, however, they develop an understanding of the relationship between colors through their procedural system. It is declarative and procedural systems working together that result in fine art. What students learn declaratively, they can put into words. This is not necessarily true of what students learn procedurally, even though both are essential to learning.

### NOW YOU TRY!

#### USING INTERLEAVING AND SPACED REPETITION TO STRENGTHEN YOUR STUDENTS' DECLARATIVE AND PROCEDURAL PATHWAYS

Short, frequent in-school and homework problem sets are excellent tools to build students' procedural and declarative memories. These sets should always involve a few starter problems to focus students on the central concept they are learning.

They should then move on to interleaved problems with the concepts students most often confuse, along with a few problems from some time in the past (spaced repetition). Of course, for language study, the closer the student can get to immersion-style learning, with its rapid feedback and natural interleaving, the better it is for building information via the procedural system.

Students like success, so they may resist tackling the more challenging problems and instead simply wait for you to provide the answers. An essential aspect of good teaching is to help your students become aware of good learning practices so they can become better independent learners. To do so, explain to them that in sports there can be a tendency to rely on whatever you're best at—like the tendency of some soccer players to rely only on their strong leg—and why that's a poor strategy for learning. Explain that in learning, it can be desirable to *lean in* to the more challenging information rather than avoid it. Students should alternate between their "strong leg" (the material they already think they know) and their "weak leg" (the newest material they are learning).

Further explain that when you give problem sets that interleave slightly different concepts, what you are doing is teaching your students to be strong in *both* (or all!) of their "learning legs," not just in the leg that was already strong.

Finally, ask the students to pair up to explain what you have just taught them about why they need to lean in to the more challenging aspects of their learning. You may also ask them to share an example from their own life where leaning in to challenges allowed them to achieve more than they thought they could.

## Key Ideas of This Chapter

- There are two major pathways the brain uses to store information in long-term memory: *declarative* and *procedural*. Each pathway stores its information separately in long-term memory in the neocortex.
- The declarative pathway is (mostly) conscious and fast to learn and store information. The procedural pathway is nonconscious and slow to learn and store information.
- Once information is learned, the procedural system can put it to use much more rapidly than the declarative system. But procedural learning is much less flexible. Change a few keys on a keyboard, and you're suddenly not such a fast typist!

- It’s important, wherever possible, to ensure that students are acquiring information through both the declarative and the procedural systems. This makes them flexible, adaptable, and fast problem solvers.
- The explanations and demonstrations teachers provide to students during the “I do” stage of direct instruction enhance their declarative learning. When that instruction is followed up with practice (“We do”), students begin to activate their procedural pathway—which helps (eventually, with lots of practice!) to automatize the learning.
- The procedural system is strong in infancy and early childhood but then weakens. The declarative system is weak in childhood and gradually strengthens as the child matures.
- *Interleaving* is when a teacher mixes up their students’ practice by including confusingly similar aspects of a topic, rather than blocking their practice into specific, nearly identical repetitions of the same topic.
- *Desirable difficulties* involve the intense mental effort of building a strong set of neural links to understand and remember a concept.
- A *schema* is a set of “neural shelves” that holds together the different sets of links that a student is learning about a subject. Preexisting schemas allow students to learn new material about a subject more easily.
- *Spaced repetition* is when retrieval practice of the material is stretched out over days or months.
- Both interleaving and spaced repetition are the best methods researchers know of to build learning through the procedural system.
- It is more important that students demonstrate that they know how to apply a concept than that they demonstrate their ability to articulate it. Being able to explain a concept does not necessarily prove conceptual understanding.

# 7

# Building Community Through Habits

The bell rings for third period to begin. Ms. Duwell's students sit quietly writing in their notebooks to do the bell ringer—a short task written on the board that students complete upon entering the classroom. Today's bell ringer is a response to yesterday's reading. Every group of four students has a basket of materials placed in the center of their collaborative workspace. As students finish the bell ringer, they reach into their basket to get the materials needed for class. Ms. Duwell has stocked the baskets with plot maps and different-colored Post-it Notes for today's lesson on short stories.

Across the hall in Ms. Guided's room, a few stragglers are making their way to the door as the bell rings. A line is forming at the pencil sharpener. As Charlie makes his way to his seat, he knocks Jake's book onto the floor. The boys glare menacingly at each other. On the opposite side of the room, Ms. Guided looks up in exasperation as two students ask, "Are we doing anything today?" While she finishes gathering supplies for the lesson, she tells her students to sit down and get their notebooks out. Hands dart in the air—half the class needs to go to their lockers to get their notebooks.

The upshot: Both teachers are sincerely doing their best. But the classrooms of master teachers like Ms. Duwell run like clockwork—making every second of instructional time count. Ms. Guided was defeated before she even began.

What went wrong? In this chapter, we're going to put together some of our previously learned neuroscience so you can see how tweaks in your teaching can make an enormous difference in how your class unfolds. Hint: It all goes back to procedural learning.

## The Habit-Forming Power of Procedures

Think back to the imagined scenario that began our last chapter. You were able to drive while pondering the baby shower instead of paying attention to the route on your drive home. How? You first learned to get home by using long-term memory links laid by your *declarative* system. But gradually, as you practiced by repeatedly driving home, your *procedural* system laid down its own sets of links. Your mind and body began to know what to do without you consciously thinking about it. You have become so used to going home by your habitual route that if you ever had to turn off that route to do something out of the ordinary, you would likely find yourself missing the turn and continuing home as usual!

That's the power of procedural memory: routines foster habits. You can use that power to create a smooth-running classroom. Once you've got the links laid down in long-term memory, procedural memory is *fast*—the magic "leapfrogging" of the basal ganglia allows the habitual action to be performed quickly and automatically. By using the procedural system, you can help students develop habits that will make your classroom a positive experience for *all* of your students.

But good habits rarely happen by chance. We may think it's common sense to know how to get supplies efficiently or to seek the teacher's attention respectfully, but as we have shown throughout this book, common sense isn't necessarily so common.

We teachers can easily visualize our students entering the classroom with purpose, working cooperatively, and walking to another location without disruption. What our students should be doing can be so apparent to us teachers that we can become frustrated when they don't do it. But here's the problem: *Your students can't see what is in your mind.* This inability to know what you're thinking means that in the first few days of teaching, you need to make sure students have a clear understanding of what you are envisioning. This will help support them in developing the right habits.

## Laying the Foundation for a Productive Classroom Environment

Even before the first day of school, you can begin establishing a welcoming and productive classroom climate. When students have an idea of what to expect, it reduces *dis*tress (the bad part of stress).[1] It allows for *eu*stress—the healthy anticipatory stress of an exciting new experience or accomplishment.[2] (More on stress in the next chapter.)

### Before the First Day

Plan to send a message to students and parents introducing yourself and letting students know what to anticipate on the first day. Your message should also contain intriguing descriptions of what is to come. (Think of it as the blurb for a much-anticipated thriller. This isn't the time for a boring description or a set of objectives.) Your letter should ease students' anxieties and give them a heads-up on any supplies needed. (No parent wants to head to the store for three-ring binders the evening after school begins!)

### The First Day

When the first day of school finally arrives, your students bid farewell to the relative freedom of their summer schedule. In some cases, they wake up before dawn, arriving at school to find themselves being shuffled from room to room for seven hours. Even trips to the bathroom require express permission. Your best bet to help students manage the transition is to emulate master teachers and have a plan for the first days of school. Harry and Rosemary Wong, for example, authors of the bestselling *The First Days of School,* anticipate students' first-day questions and develop a plan for addressing each one. This plan aids students' transition from the unscripted days of summer to the rigidity of the school calendar.

Here is a checklist of common first-day questions and answers to guide you in your preparations:[3]

- ☐ **Am I in the right room?** (This applies to virtual rooms, too!)
  We all know the panic students feel on the first day of school as they rush between classes to find their next room—especially when they have enrolled in a new school and are not familiar with the building's layout. Having your name, grade, and subject (if applicable) near your door and board serves as a visual indication. Our heart goes out to the student who walks in ten minutes late and has the whole class staring at him. We know he was sitting in the wrong class and has suffered

embarrassment twice—once with his noticeable exit from the other class and then again with his entrance to yours.

### ☐ Where do I sit?

Plan seating arrangements in advance. Students who are popular and have class with their buddies want to sit by their friends. They try to convince you that they will not distract one another. Don't believe them. Allowing students to sit next to their friends means they can easily whisper and reinforce one another in off-task, distracting behaviors. Power lies in groups—friends sitting together can end up commandeering the class's attention. Seating students by those they don't know keeps this kind of behavior at a minimum during the first few critical days of class. It also allows new friendships to begin developing.

Having a method for assigning seats decreases the stress levels of shy and insecure students. Humans are hardwired for a sense of belonging; no one wants to be excluded when they attempt to sit down. Younger people have a particularly heightened neural response to social exclusion as compared to adults.[4] A seating system prevents disheartening feelings of rejection.

On the first day of school, coauthor Beth greeted her students at the door to welcome them and individually hand each student a card. The card was in the shape and color of one of the nine different Lucky Charms that hung from her ceiling (playing cards work great as well). After giving each student a card, she instructed students to look at the ceiling to find their seat. Groups of four desks were arranged by charms. Students sat in the group that matched the charm they received. By narrowing their options from any desk to one desk in a group of four, her system allows students to have some say in where they sit. One master teacher trick: Students typically walk into class with their friends. Mix up friend groups by strategically handing out different-colored cards. Assigning students to a group they sit with on the first day of class automatically solves the problem of assignment to the collaborative teams we describe in the next chapter.

### ☐ Who is my teacher?

Introduce yourself. You will spend 180 days with your students. Share a bit of personal information with them. Students are interested in your pets, your favorite sports team, and your hobbies. Relate to your students. Let them know what it was like when you were in their grade. What were your worries and goals? What life events at that age added a few twists to your narrative?

Without going into elaborate detail, when you share such information with your students, you start to make personal connections with them. Many will begin to tell you about their pets, what sports they play, and what they like to do outside school. As they begin to trust you, they will share their struggles and fears. Relationships are crucial to teaching. The popular adage holds: "Students don't care how much you know until they know how much you care."

### ☐ What will we be doing?

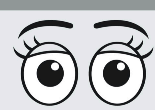
Spark your students' interest in what you'll be teaching. The content of your course is important, but don't start day one by diving deep into the curriculum. The first day should be a teaser. If you teach chemistry, for example, wow them with a simple experiment turning a liquid into a gas. They will surely want to know how you made that happen. *Just don't tell.* Remember, you are hooking them so they will be excited to come back for more. If you give the answer, it provides a sense of closure that kills anticipatory curiosity.

If you teach English, engage students with the dramatic personalities of the characters and conflicts found in the stories they will be reading throughout the year. You might even act out a brief scene from one of the stories with a few "characters" from your audience. Students are never too old for this kind of thing. Coauthor Barb has her college students act out the parts of a refrigerator, which gets them to wondering about condensers, compressors, and evaporators (not to mention their professor!) from the very first day of class. Remember, the first day is meant to excite their curiosity and enthusiasm, so they will be excited to come back for more.

### ☐ What are the expectations?

Let students know acceptable behaviors in your classroom by *teaching* behavioral expectations and procedures (more on procedures to come). When students know your rules have a reason, they are more likely to buy into following them.

An overarching expectation (for example, "Nice or Neutral—No Nasties") can work well for elementary and middle school students. Coauthor Beth uses this general rule to cover a lot of territory. On the first day or two of class, it can be a real turnoff to present students with a laundry list of everything they *can't* do. So instead of focusing on the negative, have fun! Ask student groups to brainstorm examples of what nice and nasty *looks like* and *sounds like*. When students can chitchat about specific behaviors, they loosen up, especially when the inevitable mention of farting arises.

| NICE | |
|---|---|
|  |  |
| Participating in activities | Speaking clearly and with appropriate volume and tone |
| Sitting upright | Answering questions when asked |
| Providing eye contact to the speaker | Listening quietly to the speaker |
| Cleaning up after yourself | Saying "Please" and "Thank you" |
| Raising your hand to speak | |
| Having materials on your desk | |

| NASTY | |
|---|---|
| Having side conversations | Interrupting others |
| Leaving someone out | Calling someone names |
| Using a device, app, or tool without permission | Complaining |
| Leaving materials in your locker | Making snide comments |

Bring the conversation back to the whole class and create charts (graphic organizers!) to generate consensus on acceptable behaviors. Use a separate piece of chart paper for each adjective—in this case, *nice* and *nasty*. On one side of the chart, draw a set of eyes, and on the other side, an ear. Be sure to steer the discussions to cover important behaviors that students may miss—for example, raising your hand before speaking and not interrupting others.

Often the expectations you are establishing in your classroom involve compliance behaviors. You can use your discussions of compliance to broaden your teaching by reinforcing the social emotional aspects of those behaviors.[5] Point out the important life skills students are learning and practicing. For example, when students take turns speaking, others will feel comfortable participating because they know everyone will have an opportunity to be heard. Through these discussions and charts, students build a clear picture of behavioral expectations. The chart is then hung in the classroom so students can easily refer to it. Additional behaviors can be added as the school year progresses. Because students have defined the rules, they have a voice and buy-in.

## The First Week: Establishing Procedures

A procedure is an established way of doing something. It provides a sort of safety net that protects your students and gives you a framework for learning. How does this play out? As you plot your lesson, think through how you want your students to interact with the material. Will they be taking notes in their notebooks? Will they be using their laptops? What supplies do they need? How will they get the supplies? Will they be sharing with a partner or working in a small group? How will partners or groups be assigned? How much time do they need? The answers to each of these questions lend themselves to procedures, which in turn prevent mishaps and chaos. In safe classrooms where procedures have been taught and reinforced, students are focused and on-task, materials are prepared and organized, and a positive classroom environment prevails.

To teach procedures, use direct instruction to get the information into your students' declarative memory systems. *Tell* your students what you expect them to be able to do—for example, how to properly enter the classroom. Break the procedure into steps and *show* students how you expect them to complete each step. Finally, have your students *practice* under your watchful eye until they master each procedure. When students are first learning the procedure, reinforcement with praise directed at specific actions should be frequent and timely. Then capitalize on the procedural pathway by rehearsing the skills and reinforcing them until they become habits. When students forget, you reteach. The magic of the procedural system will have your students doing what you want and expect without you having to remind them. (Mostly!)

Common Procedures to Teach Students[6]

- Entering the classroom
- Taking attendance
- Participating in class discussions
- Asking for help
- Using technology

- Putting a header (name, date, assignment) on papers
- Making up missed work
- Using hand signals to communicate needs (e.g., to use the bathroom or the pencil sharpener)
- Using free time
- Leaving the classroom for lunch or the bus

Establishing procedures also communicates your positive expectations for your students.[7] When students are in their seats working on the bell ringer at the start of class, remark on this behavior. Tell them that you have high expectations, and you appreciate that they are meeting them. Recognizing and reinforcing specific on-task behaviors motivates your students. It also cues the dawdlers as to what they should be doing. A bonus: When students have internalized what to do, they will often lend a hand to other students who may be having difficulties. In this way, habits build classroom community.

## NOW YOU TRY!

### TEACHING AND UTILIZING A CLASSROOM PROCEDURE: LINING UP BY NUMBER

Collecting and passing back papers; lining up to walk to the cafeteria, library, or auditorium; and regrouping outside for a fire drill are routines that drain your instructional time and can be a breeding ground for student misbehavior. One way to efficiently organize students and their materials is to assign each student a number for the entire school year. The number should correspond with the order in the teacher's grade book. To aid students' memory, have them write their number in a conspicuous place—for instance, on the cover of their notebook. (Of course, numbers are just to expedite matters—no student should ever be referred to as a number. You may wish to use a reverse alphabetical order for your numbering system. This gives students whose last names begin with letters toward the end of the alphabet the opportunity to start at the beginning of the line!)

To teach the procedure for lining up to return or collect assignments:

1. Indicate where in the classroom the line should begin and end. In tight classrooms, explain how it should flow.
2. Stand at the start of the line.

3. Give students a specific amount of time to get into the lineup. A class of twenty-five can be coached to line up in less than thirty seconds. Don't be alarmed, however, if it takes them two minutes or more to line up on their first attempt. With a few tries, the time is drastically reduced.
4. Direct students to line up in numerical order. The first few times they practice this procedure, remind students to look in their notebooks for their number if they can't remember.
5. Have students notice who is supposed to stand in front of and behind them. It helps students form the line quickly when they know the person they need to be on the lookout for.
6. Count down the seconds remaining if students are dawdling. Keeping them on the clock keeps them moving.
7. As you stand at the head of the line, have the first student in line hand in or receive their paper and then take their seat. Subsequent students do the same. By having students move forward in the line toward you, you save your energy and let the students get the exercise.

When initially teaching the procedure for lining up, have students practice a few times to build their procedural memory. When a student later struggles to find his place in line, he may think, "Emily isn't here. Where do I stand? Oh, Liam is here. I stand in front of him."

A lineup saves time—especially when you consider how long it takes to hand back or collect papers and to sort the papers to enter in your grade book. Plus, it gets students out of their seats and moving with purpose. A bonus: Physical movement is often a part of forming a habit in procedural memory and is a desirable part of any student's day. That's why building in routines that get students out of their seats in an organized, purposeful manner can be so beneficial.

## Consistency Is Paramount

Ms. Guided may have taught her students procedures at the beginning of the school year, but it is unlikely she consistently enforced them or followed them herself. Instead, all we notice in our glimpse into her classroom is the chaos and the enormous amount of lost instructional time. Preventing problems before they start can go a long way in creating a safe and productive classroom environment. A brief visit to Ms. Duwell's classroom piques our curiosity. What reading are the students responding to? Are the baskets on students' desks every day? What do the students do with the color-coded Post-its? Doug Lemov, author of the superlative *Teach Like a Champion 2.0,* explains the difference between these two classroom cultures:

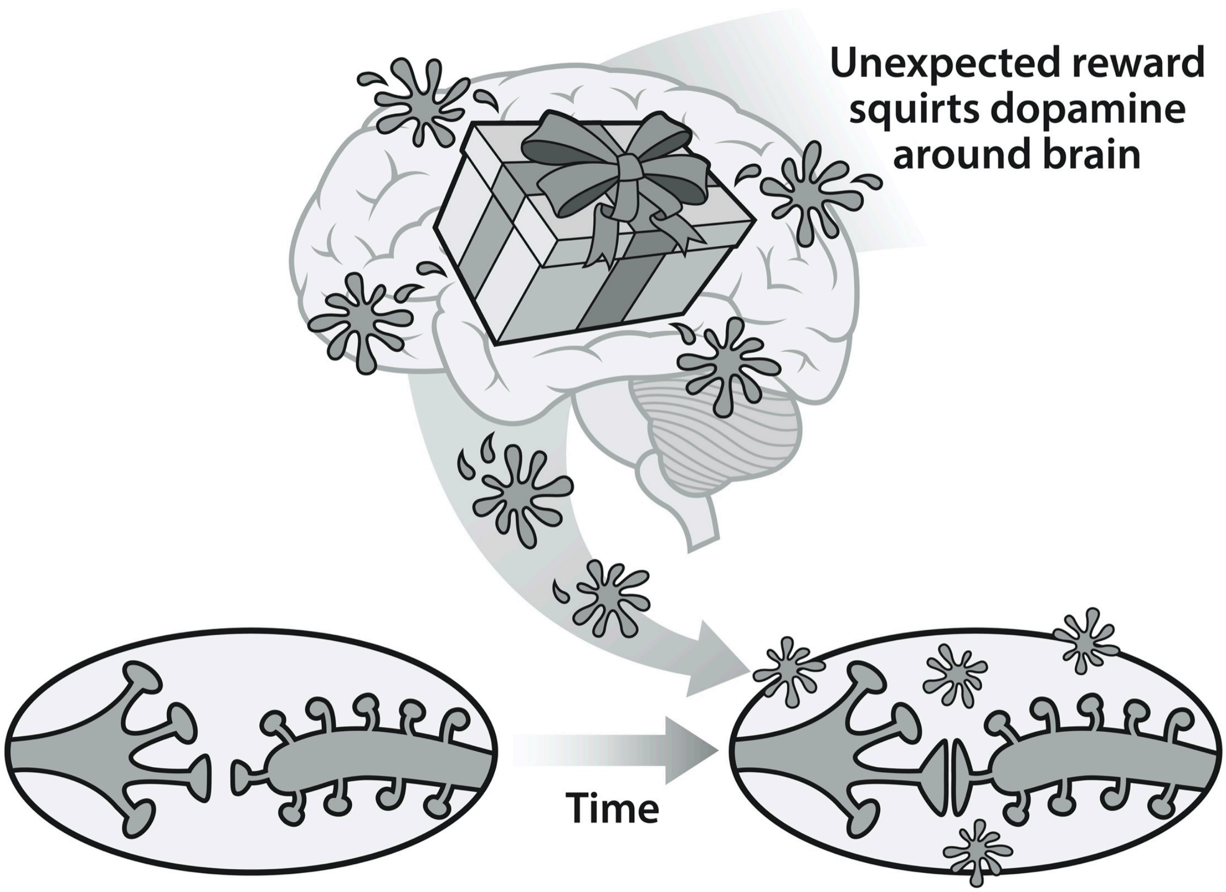
> *Because effective classroom culture is nearly invisible for stretches of time, some people will not see the work that goes into it; they see teachers who don't talk to their students much about behavior, and believe that the answer is not to talk about behavior much with your students. The result is paradoxical: if you try to ignore behavior, you will end up talking about little else, whereas if you are intentional and consistent about behavioral culture to start, distractions will ultimately fade into the background as you talk about history, art, literature, math, and science.*[8]

## Rewards Are Valuable for Learning and Motivation—Except When They Aren't

In our journey together through this book, we've discovered how important the rewiring process is for learning. Creating new sets of neural links isn't easy. It involves getting axons to turn and hook into dendritic spines, and strengthening new neural links through plenty of practice in a variety of circumstances. But it turns out that there is an almost magical chemical that makes that rewiring a lot easier—dopamine. This tantalizing neurochemical is important for both declarative and procedural learning. If we can just figure out how to bathe certain parts of our students' brains with dopamine, learning can take place more quickly. Why?

### The Special Value of Unexpected Rewards

Students' brains estimate, moment by moment, what kind of reward might be in the offing. (A reward is something a person perceives as positive, whether it's an object, an action, or an internal feeling.[9]) Most of the time, life just moves along for students as a predictable routine. So unless something like a chocolate bar or a roller coaster magically appears, students' brains just sit around, doing usual brain stuff. But if an *unexpected* reward appears, dopamine squirts into many of the areas of the brain involved in learning. This dopamine not only makes students feel good but also allows connections between neurons to strengthen more easily.[10] And remember that competitive, seesaw behavior between the declarative and procedural systems? It turns out that dopamine temporarily puts a halt to the competition and instead enables the two systems to work together.[11]




When an unexpected reward arrives, it triggers sprays of dopamine in areas of the brain where the new links of learning are being formed across the synapses (the gaps between the neurons). This dopamine assists in strengthening the links that were developing before, during, and after the unexpected reward.[*]

In other words, dopamine from unexpected rewards helps students learn![*12]

Dopamine reinforces actions that lead to desirable results. Here's how it can play out. If fourth-grade students are sitting at their desks while their teacher is shuffling papers, there's little expectation of a reward coming any time soon (the end of the school day may seem eons away). If the teacher asks all the students to line up according to their number, well, no big deal. The students begin to line up.

But if, as all the students begin to line up, the teacher provides positive reinforcement, saying, "Isn't it great to get out of our seats and get our blood flowing? Let's add a stretch to the sky or give yourself a hug," with an infectiously upbeat, encouraging voice—*this* is unexpected. And the teacher's cheerful voice, along with the ability to get out of their seats, is rewarding! The unexpected positive reward doesn't just hit the brain's pleasure centers. Dopamine also surges in many areas of the brain involved in learning. In addition, dopamine can make a dramatic improvement in working memory.[13] Students learn that lining up feels good—*and they also more easily learn to line up.*

Let's contrast this with Ms. Guided's handling of her students when she is teaching them to line up. She expects them to be able to line up—after all, she sees it already in her mind, and it's quite simple. But when students don't line up the way she wants the first time (it's confusing for kids, after all), she begins yelling at them. Suddenly, the kids' expectations plunge from ho-hum to negative. Dopamine levels unexpectedly plunge, too, as dopamine neurons quit pumping it out. Kids' abilities to learn decline right along with the decline in dopamine levels. Students' brains react in an "unlearning" way—the sudden lowering of dopamine signals neurons to *disconnect* rather than *connect*.[14]

The result? Ms. Guided is even less satisfied with her seemingly difficult students, who don't seem to be able to learn even something simple, like how to line up. But the students *have* learned something—that Ms. Guided is associated with negative feelings. Lining up also becomes affiliated with negative emotions, so kids drag their feet even more. Ms. Guided becomes even more upset. She wonders why she got such bad students again this year, while Ms. Duwell's students always seem so much smarter and more well-behaved. (In an important sense, Ms. Duwell's students *are* smarter simply because of the environment she has created. Frequent dopamine boosts keep her students' synapses snappily connecting with their new learning.)

Here's another example. Few students ever walk into coauthor Beth's classes thinking, *I can't wait to write an essay!* So Beth enthusiastically sells them on the idea that writing is the best and easiest thing ever, by breaking the writing process into small steps. With students who find writing to be a particular struggle, Beth catches something to praise, which she announces joyfully to the class.[*]

Those bits of praise are perfect examples of providing unexpected rewards that support the neural linking of *learning*. Beth's sporadic positive boosts help her students more easily learn what she is teaching about writing. Of course, as the writing becomes more manageable with the gradual development of the schemas that ease learning, students become more receptive to improving their writing and their dispositions toward the subject change.

The critical point here is that rewards must be *unexpected* if they are to promote the neural rewiring of learning. An *expected* reward, such as time with a video game after finishing a homework assignment, may assist with *motivation,* but not with learning. Dopamine, it seems, is not released following an expected reward because there is no need for rewiring the synapses. After all, the brain is already correctly predicting the reward.[15] An odd side effect of all of this is that being too positive all the time means your positive comments become expected—which means your positivity doesn't work as well as you might like to enhance your students' learning.

This brings us to another important related point. Students often develop a dislike of a subject simply because they have not yet had enough practice. Practice helps with the development of schemas, and schemas make learning easier. As brain scientists Szu-Han Wang and Richard Morris point out, "Once built, relevant new information can be assimilated into schema very rapidly. We rapidly remember what interests us, but what interests us takes time to develop."[16]

## The Role of Expected Rewards in Motivation

Expected rewards do provide motivation—sometimes powerfully so, as with the rewarding break at the end of a Pomodoro session.[17] Or sometimes less powerfully, as when the reward is in the distant future. The brain's ability to discount the motivation of a reward that is delayed in time is called *temporal discounting*. Steeper rates of temporal discounting have been associated with impulsive and ill-advised behaviors in teenagers. It seems that these tendencies toward "smaller sooner" rather than "larger later" rewards may be related to quirky behavior in a part of the basal ganglia known as the striatum.[18] Of course, the basal ganglia is also prime neural territory supporting the fast, no-conscious-thinking-involved actions of the procedural system.

A challenge with an expected reward is that it is sometimes not what you think it is. Students' need for social acceptance by their peers, for example, can be far more rewarding than understanding what's being taught, pleasing their parents by getting a good grade, or receiving a trinket like a novelty pencil or sticker. If students want to feel accepted (and thus rewarded) by fellow students in social groups that disparage learning, they may deliberately choose to avoid their schoolwork.

Some students are naturally motivated to succeed in traditional schooling. Others may be discouraged in their learning because they find it to be more difficult or their real rewards come from their peers, not their studies. As the old saying goes, when you are trying to flush out a source of corruption, follow the money. Similarly, in teaching, if you are trying to understand why a student has no motivation for learning, it's best to "follow the reward" and to deduce what that student is truly seeking. Few of us teachers have the chops to become professional counselors or therapists, but sometimes it can help us to realize that the subject matter we cherish is not necessarily the be-all and end-all for our students.

## TEACHING TIP:

### Working with Impostors and the Overly Cocky

Students can sometimes begin to feel as if they are impostors—that there is simply no way they are as good as the other students in the class. These feelings can be especially common in better students.[19] Engineering professor Richard Felder describes the subliminal message that plays endlessly in impostors' heads:

> *"I don't belong here . . . I'm clever and hard-working enough to have faked them out all these years, and they all think I'm great, but I know better . . . and one of these days they're going to catch on . . . they'll ask the right question and find out that I really don't understand . . . and then . . . and then . . ."*

When a student feels inadequate, sometimes all it takes is the tiniest push—a below-average grade on a test, for example—for the student to think that that subject isn't for them. This seems particularly common in STEM subjects.

A good way of addressing these feelings is to discuss the impostor syndrome openly. As Professor Felder notes: "There is security in numbers: students will be relieved to learn that those around them—including that hotshot in the first row with the straight-A average—have the same self-doubts." You might also let them know that feelings of being an impostor aren't *all* bad—they can actually help to keep them from becoming overly cocky.

In our experience, some of the most significant teaching challenges come from high self-esteem but (current) low-ability students who are confident in their abilities when they shouldn't be, or simply satisfied with their lack of ability.[20] It's not that such students can't change or that they aren't trying to change—it's that their limited efforts can be far from what's needed. Even great teachers can become frustrated when they realize that after all their teaching efforts, a student remains mainly oblivious to feedback. In these cases, small, unexpected rewards such as praise can backfire. They can stoke a student's already inflated or misaligned self-image and make them even less likely to pay attention to much-needed learning and growth. It is possible for such students to change, however. For example, a stint at a terrible job or a scathing talent show evaluation can provide the impetus for students to reframe their understanding of the need for and value of learning.[*]

## What Happens When Students Don't Meet Expectations or Follow Procedures?

We all have bad days. Life is not easy for our students. It is not out of the norm for a tragic life event to occur the night before your student is sitting in your class. On any given day, any of our students may experience community violence, sexual and physical abuse, peer pressure, cyberbullying, divorce, breakups, and abandonment. Or it could just be that they overslept and missed breakfast, had a fight with their bestie, or got a bad grade in their previous class. Because we know our students' worlds are constantly changing and anxiety-provoking, part of our job as teachers is to provide them with a safe, orderly classroom where they know what to expect and how to meet our expectations. Even so, students' bad days may trigger resistance.

### Proactive Measures to Prevent Student Resistance

- Provide specific praise to individual students, groups, or the whole class as warranted. When you sprinkle in specific praiseworthy feedback, you build trust and rapport, and students are more open to learning from their mistakes.
- Reassure students, even when their responses are incorrect, to help establish trust and encourage students' future participation.
- Teach students the benefits of failure (FAIL is the First Attempt in Learning) to normalize making errors and learning through mistakes. After all, we would be out of a job as teachers if students knew everything!
- Set students up for success by making sure they have the correct answer before calling on them in front of their peers. Circulating the room makes it easy to notice students' responses prior to engaging the whole class.

Many other factors besides having a bad day can influence student resistance.[21] Parents, coaches, peer groups, and employers compete for our students' time and exhaust their energy—all of which make academics less of a priority. Past negative classroom experiences, especially those that have made students feel marginalized, contribute to students' lack of engagement. A teacher's actions in class also affect the students' behavior. Disparaging comments, sarcasm, a monotonous voice, confusing or inadequate instructions, and even a consistent lack of eye contact can cause students to shut down.

What does student resistance look like in the classroom?

- Arguing with the teacher
- Making snide comments
- Coaxing classmates to disrupt activities
- Refusing to participate or being minimally involved
- Being chronically late to class or absent
- Failing to turn in assignments

Many of us teachers loved school—we loved it so much, we made a career of it. For us, student resistance is particularly frustrating. If proximity (moving closer to the student), a quick, nonthreatening verbal reminder, redirection, or a teacher look doesn't nip the behavior, we suggest meeting with the student individually. (Some behaviors are never to be tolerated. In those instances, rely on your school's code of conduct and discipline policy.)

A common error is waiting until the problem has escalated to intervene. If you do have to intervene, never embarrass a student in front of her peers. Embarrassment is just the opening sortie in a battle you will never win. Some students will turn passive-aggressive, shut down, and refuse to participate or do work altogether. Other students will not only wage a more active war against you but will even recruit their friends against you.

Meeting one-on-one with students can be an effective way to get them on your side. Often when students are frustrated or angry and act out, it may have nothing to do with you. They may not have the words to describe what they are feeling, or they may feel like no one cares, so why bother? When you take time to meet with students individually, you show that you care. Letting them explain their situation allows you to empathize. But make sure students leave the conversation knowing what they did wrong and how they will remedy the situation. Creating a written plan of action with the student is advisable because it makes the expectation clear and serves as a mutual contract. It also provides documentation if there's no improvement or if matters escalate.

### Key Ideas of This Chapter

- Use direct instruction to teach procedures for everyday tasks such as entering a classroom or asking for help:
  - Show and tell students what you desire ("I do").
  - Practice with students what you desire–and provide praise as warranted ("We do").
  - Demonstrate mastery of the behavior until it becomes a habit ("You do").
- Procedures need to be taught from the first day, then reinforced and retaught as necessary. Consistency is paramount. When students learn to respond habitually, they will quickly follow the procedure without even having to think about it.
- *Unexpected* rewards squirt dopamine at synapses, which enables students to make new neural links more effectively.
- *Expected* rewards can build motivation, but students might sometimes be seeking expected rewards that are different (for example, social acceptance) from the ones you might think they want (for example, getting a good grade).
- Even when procedures are in place, there are times students will resist learning. When subtle behavior cues don't redirect the student, a one-on-one meeting provides an opportunity to build a relationship and plan ways to improve behavior.

# 8

# Linking Learners:

## The Power of Collaborative Learning

Today's the day! It's time for group[1] presentations!

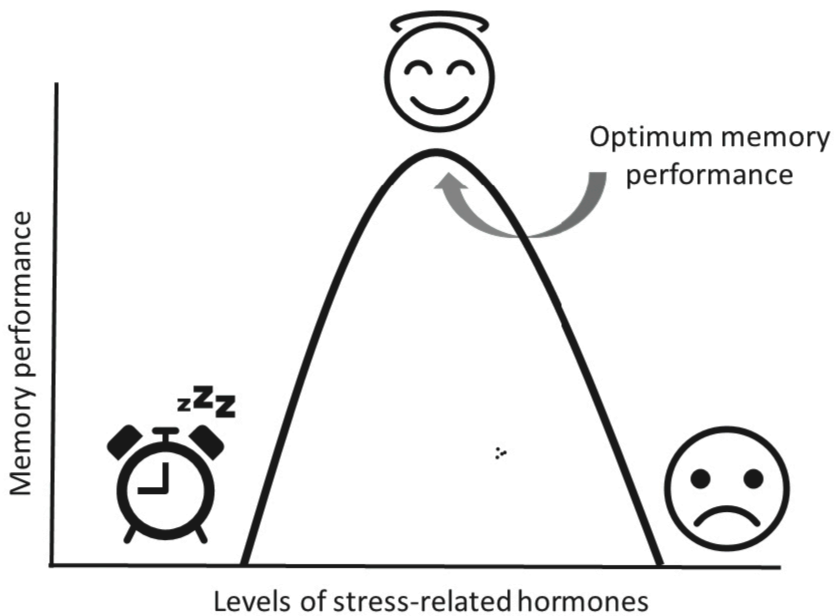
You've been teaching the intricacies of U.S. geography for several weeks now. Today is the culmination of the unit, and your excited students are finally delivering their group presentations on the U.S. state they've selected. The air in the classroom sparks with nervous tension. Shy Shauna nervously twirls her hair, while even Derek, usually the wisecracking life of the classroom, looks intimidated. You wonder whether the stress you put your students through in presenting their work to the class is worth it.

## The Role of Stress in Learning

We should dive now into one of the most important areas of teaching and life in general: stress. Stress comes in several varieties. *Chronic* stress creates *dis*tress—the kind of stress you or your students have little control over, such as a bad boss, an ill family member, or a furtive classroom bully.

This stress can have serious long-term consequences for your health, including the cardiovascular, immune, and reproductive systems.

On the other hand, *transient* stress is the kind of stress experienced when you are studying for a test, reacting rapidly as a race-car driver, or taking the challenge of a demanding hike. Transient stress, which students have some control over, isn't generally harmful to health—it is instead a *eu*stress (good stress) that can improve cognition, working memory, and physical strength. The neural chemicals released by transient stress may explain why students are more efficient and focused when studying for a nerve-racking test rather than simply lounging around "studying" at their leisure. Transient stress also explains why the information you learned for a presentation in front of the entire school can stay with you for years.




A moderate amount of transient stress can improve performance without harming the body.[2]

Transient stress releases hormones such as adrenaline and cortisol in the brain. In moderate amounts, these molecules enhance the connections between neurons—almost like greasing a pan to prevent fried potatoes from sticking to the bottom. But too much stress, even if it's just transient, changes the effects of the glucocorticoid "oil." Instead of greasing the connections, the excess stress causes neural connections to burn and stick, so nothing flows. This behavior, where working memory peaks at optimal moderate stress, is similar to the shape of a hill.[3] Boredom and sleepiness can arise with humdrum no-stress (and no stress hormones) work. But too much stress is where panic sets in and productivity plummets.

A common belief is that stress is always bad—that it leaves students paralyzed or in a frenzy. But the uncommon sense teacher knows that moderate stress can be your and your students' friend.[4] Rather than demonize all stress, use eustress to your students' advantage!

## The Vital Importance of Socioemotional Learning

We should step back now and look more broadly at how students react emotionally to stress, and more generally at how students interact with one another. Socioemotional learning is the process of developing the self-awareness, self-management, responsible decision-making, relationship skills, and social awareness that are vital for school, work, and life success.[5] Some aspects of this type of learning are biologically primary. When Mom has an "owie," for example, it's natural to try to make her feel better. But as children grow older, their need for socioemotional learning grows more sophisticated. Students often need coaching to learn to share, take turns, set boundaries, manage conflict, and be assertive when they need to be.

Students and teachers alike are used to working in groups and teams outside of school—from playing on a sports team to participating in volunteer groups. But for some students, especially those who are new, shy, or in any way different from other students, school can be a lonely, sometimes painful place. Collaborative learning[6] groups are those with a common goal, an equal distribution of workload, and close contact within the group while they work toward the goal.[7] (What was initially a group at the beginning of a term may cohere into a tight-knit team by the end.) Collaborative activities do more than provide opportunities for socioemotional learning. They can also provide students with support, feedback, a sense of belonging, and opportunities for friendship.[8] We can see how this all plays out by watching stress hormone levels.

## Using Collaborative Learning to Build Social Skills and Buffer Stress Levels

Developing habitual procedures, as we discussed in the previous chapter, is a natural way to build a positive classroom culture. But we teachers can go even deeper to encourage social skills by assigning occasional in-class assignments that simultaneously teach students effective collaborative learning strategies. Research indicates that the "social buffering" provided by *supportive* group members can reduce a student's skyrocketing stress hormone levels when they encounter new and difficult tasks. Supportive teammates, in other words, can keep stress hormones in the "happy middle" that allows for optimal learning.

We've emphasized the word *supportive* because when it comes to groups, obstructive group members can increase instead of reduce another student's stress.[*] Sometimes students can be obstructive even when they don't mean to be. The challenge is that most students don't walk into classrooms with the time management, conflict resolution, and communication skills required for high-performance group work. As thirteen-year-old Veronique Mintz explains in *The New York Times*:

> *I go to a school that puts a big emphasis on collaborative learning; approximately 80 percent of our work is done in teacher-assigned groups of three to five students. This forces students who want to complete their assignments into the position of having to discipline peers who won't behave and coax reluctant group members into contributing.*[9]

Yet well-done collaborative learning can provide opportunities to enhance students' self-control, patience, social problem-solving skills, self-esteem, and emotional intelligence. Ultimately it can improve academic engagement.[10] Many students feel less anxiety about participating in discussions with a smaller group than in front of the whole class, making collaborative learning groups an appealing instructional choice.

### The Art of Deft Interruption

Students are often taught to allow one another to speak without interrupting. This is good–up to a point. But interruptions can also sometimes be essential to prevent one person from dominating conversations. You may wish to institute a one-minute or two-minute rule. Teach students to listen carefully to what someone is saying. But if that person goes on too long, it's all right to deftly interrupt by waiting until the person is taking a breath and then diving in with a point that acknowledges and builds from the point the student was just making.

Acknowledging and bridging from the other student's point is important. It shows that the interrupter is listening and incorporating the other's points into their own.

We should note that sometimes people master the strange but real art of breathing in while speaking–meaning there are no pauses. Others might say "Just wait for me to finish!" but then go on endlessly. In these cases, firmness is in order to prevent a bullying takeover of the discussion. The reality is, firmness in keeping a conversation on track when necessary is useful for any group of any age.

In chapter 7, we suggested assigning students to groups on the first day of school. Some teachers will assign seats on the first day but wait until they get to know their students better before assigning them to groups. Either method works. In any case, groups are never meant to last the entire school year.

As a teacher works with her students over the first few weeks of school and gets to know individual students' abilities and dispositions, she'll be able to make adjustments to groups. For example, it's never a good idea to place two chatty students next to each other or place an intellectual outsider next to a known bully. Coauthor Beth made a habit of changing up groups each marking period. While making these shifts, she would think about students' strengths and personalities and try to pair them with students who would work well together. In this way, she would encourage new friendships.

And as we mentioned, a good team can provide social buffering that moderates stress levels. Coauthor Terry, for example, had been branded a troublemaker in high school for his many questions. A high school club for science aficionados saved him, giving him direction along with a way to bond with kindred spirits, and teaching him the beginnings of the leadership skills that he uses to this day.

Much of the brain contributes in some way or another to the regulation of emotion. But at its core the processes rely in part on communication between the prefrontal cortex, in particular the medial regions, and subcortical structures, which include the amygdala, the hippocampus, the hypothalamus, and the basal ganglia.

If your eyes glazed over just now, all you need to know is that socioemotional learning involves virtually every system we've discussed so far in this book—and more. It is also one of the most sophisticated areas of learning, and one of the best ways to develop it is through practice.

Collaborative learning in groups allows for that practice—making it blend nicely with the "We do" stage of direct instruction. For example, using think-pair-share provides students with a partner to practice retrieving newly learned material. It also eases students into developing social skills and taking responsibility for their own learning. After students have demonstrated proficiency with key concepts and skills, more student-directed collaborative learning tasks involving problem-solving can be effective.

But such learning shouldn't simply consist of putting students in groups, giving them an assignment, and telling them to have at it. When teachers take this approach, groups can quickly become dysfunctional, and the resulting experience can leave students dreading the thought of group assignments. There's a much better approach to collaborative learning.*

# Analyze Your Teaching:
## A Case Study in Resolving Group Dysfunction

**The Setup**
The most common challenge in group work is when group members do not pull their weight.* In this exercise, your students will read and discuss a case study: "How to Manage Yourself in a Collaborative Team." (The essay is in appendix A of this book.) This case study will allow your students to learn not only how to work productively together but also how to set expectations for the group and boundaries for themselves.

When designing any collaborative learning experience, you may wish to consider these components of cooperative learning:[11]

1. Positive interdependence. Ask yourself, does each student have a role? Are roles linked in a way that individual members rely on other members of the group? Is the workload equally distributed?
2. Individual accountability. How is each student responsible for their own learning? What artifacts will I collect from individual students to provide evidence?
3. Face-to-face interaction. Are interactions set up so that the group sometimes must meet face-to-face, as opposed to each member doing their own thing and then just stapling the products together?
4. Social skills. What social skills need to be taught or reinforced (for example, initiating conversation or conflict management)?
5. Group processing. What mechanism am I providing for group members to reflect on their own performance in the group as well as their peers'?

**Prep the Activity**
Collaborative groups work best when everyone has a role and students contribute equally. Plot the responsibilities for each role that you assign to each member of the group. There needs to be enough work so that each student can make meaningful contributions. In this way, each student will be responsible for submitting the information they collect.

Here is a typical set of roles that involve reading:*

- Previewer: Draws students' attention to the title of the article and has his group members predict what the article is about. Also responsible for recording responses and circling back at the end of the discussion to compare the group's predictions to what was found in the text.

- Clarifier: As students read the article together—either through choral reading or taking turns—the clarifier is in charge of noting the group's stumbling blocks. She stops the group after every few paragraphs and helps them restate difficult parts of the text, looks up unfamiliar words, and records the group's questions.

- Connector: Records how the group connects to the article—text to self; text to other texts, including media; and text to world. The connector also ensures that everyone has a chance to speak and no one speaks too long.
- Summarizer: Identifies the two most important concepts found in the article. She also provides two pieces of new insights or interesting details the group contributed. The summarizer shares these points with the class during the whole class debriefing.

**Define Social Skills**
On the board, present your behavioral expectations for students. Or you can use chart paper and have the skills posted in the room for a quick referral each time the groups work together. For added fun, have students role-play a few of your expectations.

***Example of Behavioral Expectations***

- Address group members by name. No put-downs. If this is their first time working together, remind students in advance what it *looks like* when you meet new group members (a smile goes a long way) and what it sounds like (you won't hear any sighs or muffled comments).

- Remain with the group. When group tasks are assigned, this is not a cue for a bathroom break.

- Take turns speaking—and don't go on too long when it is your turn to speak. That may mean assigning one student to get the conversation started and then rotating clockwise every thirty seconds to one minute through the rest of the members to make sure each person is heard if they wish to speak, and one student doesn't monopolize the conversation.

- Actively listen to one another. This encompasses eye contact, facial expressions, and body language.

- Define an appropriate noise level. Noise-level-monitoring apps and sites use the microphone on the teacher's computer to indicate when students' sound level is appropriate or too loud—for example, Zero Noise Classroom or BouncyBalls.org.

- **Disagree civilly.** Criticize ideas, not people.
- **Integrate multiple group members' ideas** into group responses.

**Standard Procedures for Collaborative Group Work**

As we've mentioned, it's a good idea for you to choose groups and seat them together from the very first day of class. Typically, smaller collaborative learning groups of three to four work better than larger groups, where students find it easier to hide. Students who sit next to one another make for easy *shoulder partners*. Shoulder partners are particularly useful for quick interactions. For more involved tasks, two sets of shoulder partners can easily make a group of four.

Forming collaborative groups in advance and using them consistently for some time (a month or a marking period, for example) cuts the time it takes to transition to collaborative work and gives the students the time it takes to begin functioning well as a team. Assigning groups, rather than allowing students to pick their own, ensures no student feels left out. It also allows you to choose students based on diverse ability levels or separate potential behavioral concerns.

1. **Assign the task** that the groups will be completing. For multi-step tasks, support students' working memory by providing a written copy of the steps to be completed. These steps can turn into a checklist for students to mark off as they complete the work. In addition to noting their findings, students can make notations of who contributed what and any stumbling blocks they encountered.
2. **Specify the amount of time you are giving** students to complete the task, and if possible, prominently place a countdown timer in students' view (there are many apps for this purpose). This keeps students from procrastinating. Champion teacher Doug Lemov recommends using specific, atypical increments of time—instead of five minutes to work, try four minutes.[12] (When you use round numbers, people tend to believe that the numbers are more like estimates than an actual limited amount of time.)
3. **Follow up with students before they get started** by asking: What are you supposed to do? How much time do you have?
4. **Keep students on the clock and monitor their progress** by circulating the room. Students stay on point when they know you are nearby, and appreciate your immediacy in being able to clarify roles and tasks. Don't feel obligated to interject unless a group is off task or has questions—your presence alone generally keeps students on task. As you circulate, notice interesting

responses and points of confusion to bring up when you debrief with the whole class.

5. Use the "three before me" approach to reduce redundant questions during group work. This simple strategy requires students to check with three different people or resources when they find themselves stuck before asking the teacher. Often their questions involve small details you have already covered that another student can quickly answer. Becoming responsible for discovering ways to answer questions other than just asking the teacher nudges students toward taking responsibility for their learning while building community. You will also find you have more time to mentor a group that may be struggling.

6. Provide a transition cue to switch back to the whole class. Giving students a thirty-second warning allows them to wrap up loose ends and to prepare for the ensuing whole class discussion.

**Process the Activity**

Be intentional about having students provide personal and group feedback regarding the behaviors and contributions that made for effective communication and task completion. Often you get the greatest honesty when students *write down* their responses and you assure them of confidentiality. The feedback doesn't have to entail filling out an elaborate questionnaire. It can be as simple as answering questions such as "What worked?" "What didn't?" and "What improvements can be made?" Use the feedback to develop mini-lessons for collaboration clinics (more on collaboration clinics ahead). Sometimes students will even offer you suggestions that define individual roles better or further improve social skills.

**Use the Power of Collaboration Clinics**

One of the best ways to tackle challenges in collaborative work as weeks pass and problems arise is to conduct periodic ten-minute *collaboration clinics*.[13] These clinics can help students resolve challenges that may be brewing in their teams. Before beginning a clinic, you may wish to mix up the groups, so there is more of an opportunity to speak candidly about any challenges. Above all else, emphasize that students should *not* use names and should instead focus on dysfunctional behaviors!

To know what problems to address in the clinic, have each student submit a written process-focused reflection on how their group is doing. Be explicit about asking them what kinds of things are bothering them, which is what you need to know to pick a topic for the clinic.

For example, some groups may be having a problem with students who are not pulling their weight or with students who are domineering. To address such behaviors, have the groups brainstorm different strategies they might try to improve the situation.

You can have a little fun with this exercise, saying that humorous solutions (within the bounds of good taste) are just fine. List on the board some of the strategies the groups provide and perhaps add a few suggestions of your own.

Collaboration clinics teach students how to handle uncomfortable social situations themselves instead of ignoring them or relying on the teacher to solve them. The emotions that can emerge during collaboration clinics from students who feel they've been treated unfairly can often teach far more than you could about the consequences of issues such as leaving work to others or dominating a group.

## Points for the Uncommon Sense Teacher to Consider

### *Criticize the Project—Not the Person*

It's best to teach students to separate criticizing the *project* from criticizing the *person*. Criticizing ideas related to the project is acceptable and helps students learn to think critically. But criticizing other students themselves is not.[14]

Even with a "project—not person" approach, be aware that group members can occasionally team up to bully a shy outsider or in-any-way-different group member. Sad as it may be for us teachers to realize, each unexpected opportunity to bully sends a dopamine rush to the bully. Such bullying will continue and even escalate if bullies experience no negative consequences that would allow them to "unlearn" their behavior. If you see such bullying, swift intervention is in order. Talk individually to the bullies and let them learn *your* boundaries, emphasizing that their behavior will not be tolerated.

### *Competition and Collaboration*

Although excessive competition is distressful for students, moderate occasional competition can be a form of eustress. Wise forms of competition, in fact, can create a healthy type of interactive collaboration that pushes students to do their best.[15] So don't throw the baby out with the bathwater and eliminate all competition in the classroom. Like a modicum of spice, a bit of competition can make things more interesting.

### *Empathy Should Be Accompanied by Wisdom*

One of the most important values teachers can impart to students is empathy. But while empathy can be invaluable in making the world a better place, it can also be a double-edged sword. On teams, for example, an overly empathic student can be easily taken advantage of by students who are happy to let someone else do all the work while they still get credit. In a related vein, codependency, where an adult puts up with deeply abusive behavior from their partner, may have its roots in excessive empathy that is encouraged and rewarded beginning from childhood.[16] By teaching students the importance of boundaries, you can help students gain strength and wisdom and avoid falling into codependent relationships as they mature.

In groups and cliques, empathy can fuel an excessive desire for acceptance, because being disliked can be painful. When students learn to set boundaries and put their foot down when it comes to problematic behavior on teams in the classroom, it can also help them learn to say no to inappropriate behavior *outside* the classroom.

**The Uncommon Sense Trade-offs of Group Work**

Teamwork is an integral part of a well-functioning society, but individual contributions can also be valuable. As Suparna Rajaram, a professor of psychology at Stony Brook University, observes:[17] "Psychologists have found that people working in larger groups tend to generate fewer ideas than when they work in smaller groups, or when working alone, and become less receptive to ideas from outside."[*]

This is why we like the idea of *brainwriting*. In this process, participants first brainstorm individually, writing down their ideas without judging them. The group then comes together, shares all their ideas, and proceeds to a second stage of conventional brainstorming to augment the combined list.

In the end, research on millions of scientific papers and patents has shown that large teams are vitally important in developing areas of science and technology that have already been conceived. But it is individuals working alone, or at most in tiny teams of two or three, who are essential in innovative, creative advances. Every person added to a team reduces the potential that the work is a genuinely creative breakthrough.[18] Good teaching develops students' abilities in both group and individual work.

## Key Ideas of This Chapter

- Chronic stress can have serious long-term consequences on health. Moderate transient stress, on the other hand, releases glucocorticoids and other chemicals that improve the ability to learn and can improve cognition, working memory, and physical strength.
- It helps to plan group work with the following characteristics in mind: positive interdependence, individual accountability, face-to-face interaction, social skills, and group processing.

- Create standard procedures for collaborative group work. Provide example behavioral expectations and describe how to avoid hitchhiking behavior.
- Remember that empathy should be accompanied by wisdom. Too much emphasis on empathy alone can allow for manipulation by group members, or even spur the underpinnings of later codependent behavior.
- Group work has trade-offs. As research shows, the larger the group, the bigger the accomplishment. In general, the smaller the group, the more creative the results.

# 9

# Online Teaching with Personality and Flair

One major university system, which we'll leave unnamed, spent $2 million to produce a series of eight online courses. The course had beautiful videography, followed all the proper pedagogical rules—and was dull as dirt. Few bothered to enroll, so the university eventually opted to shut it down.

On the other hand, our massive open online course "Learning How to Learn" was made by amateurs who dodged the sounds of lawnmowers and meowing cats and constructed the course in a basement for virtually no money at all. In fact, "Learning How to Learn" has garnered millions of students and rave reviews despite (or perhaps because of) its corny, not professionally edited videos, along with well-organized quizzes, discussion forums, and course materials.

The moral of the story is that you don't need to be an experienced technology professional or have unlimited financial resources to use tools that transform your online teaching from good to great. The teaching approaches you've already become familiar with in this book also work well online: including retrieval practice, active learning, and direct instruction. No surprise here—after all, the brain is the same, whether learning online or in a conventional classroom.

But there are even more brain-related pointers that will put your online teaching on a sound pedagogical footing. You'll find that if you design your online materials in ways that align with how the brain learns, you will sometimes be able to teach online students even better than you do your face-to-face students. Online learning provides for self-paced learning, which allows you to differentiate your instruction effectively. On top of all that, online teaching can improve your face-to-face teaching—we'll show you how.

The online learning experience has been shown to be just as good as face-to-face—sometimes even better.[1] (Surprisingly often, studies "proving" that online learning isn't as good as face-to-face use laughably inadequate techniques for conveying the information online—precisely the approaches we will help you avoid.[2]) Many teachers swear that flipped classes—a combination of online and face-to-face—are the best of all worlds.[3]

In this chapter, we'll lay out the basics of the online world[4] and show you how to teach online while retaining your natural flair (or at least allowing you to fake it!).

## Right Now (Synchronous) Versus Whenever (Asynchronous) Teaching

There are two types of online teaching: *synchronous* and *asynchronous*.

*Synchronous* teaching is when you teach in real time, using a streaming platform like Zoom, Microsoft Teams, or Google Meet to broadcast your image. Through screen share, you can show a PowerPoint, Google Slides, Prezi, or other visuals. Engaging synchronous learning, as with any well-planned direct instruction, can keep students engaged with a minute-by-minute sense of accountability. It also allows you to answer questions and interact personally with students—and for students to interact with one another.

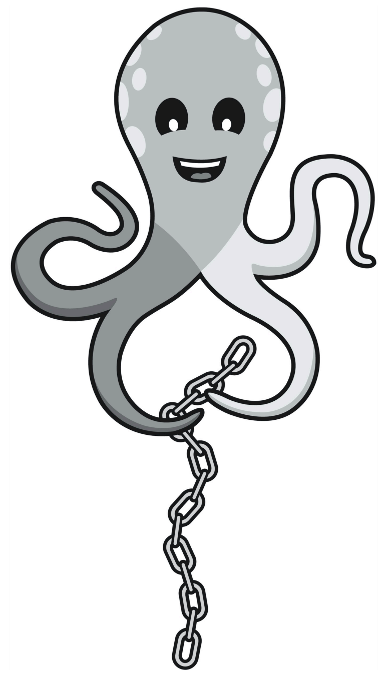
But, as we'll describe further on, the synchronous world can be more exhausting for both you and your students. And there are other drawbacks—some state agencies caution against overreliance on synchronous approaches, since coordinating meeting times of students, parents, and teachers can often make the strategy unsustainable.[5]

In contrast, *asynchronous* teaching involves creating materials and posting them on your school's learning management system (LMS) so that students can access them at their convenience. Documents, videos, quizzes, discussion forums—all can be uploaded to support learning. But how do you keep students from procrastinating? And how do you know which types of materials are most useful for learners?

Which type of online teaching should you choose, synchronous or asynchronous? In our experience, online courses for K-12 students are best when they have a mixture of both. In this chapter, we'll give you tips and help you weigh the trade-offs.

## It's Best to Both Hear and See (Multimedia Learning Theory)

Before diving into the structure of creating an excellent online experience for students, it's worthwhile to touch on something called *multimedia learning theory*. The basic idea is straightforward. A picture with an accompanying verbal explanation can help students grasp a concept much more quickly than either a picture or a verbal explanation alone. This is because working memory typically has both a hearing and a seeing component (these are the *multi* parts of multimedia theory). Simultaneously using both visual and verbal explanations allows students to make better use of their limited working memory.[6]



Working memory has both a hearing and a seeing component (symbolized here by the different shades of the arms of the "attentional octopus" you met in previous chapters). If you teach so that students simultaneously hear and see what you are explaining, it's much easier for students to engage with the ideas (sets of neural links).

Educational psychologist Richard Mayer has spent decades studying best practices for teaching in a multimedia format.[7] Many of his findings also relate to face-to-face teaching. Here's a list of what we find to be the most important insights from Mayer's work, along with some of our additions and thoughts:

- **Speak clearly and enthusiastically.** Remember that students have enough negativity and boredom in their lives, so they are looking to you for upbeat inspiration. When making a prerecorded video, try to speak relatively quickly—around 150 to 185 words per minute. (Students can always stop the video if they need to think about what you just said; if you speak too slowly, students will become bored and more easily distracted.) Synchronous sessions are prone to problematic audio, so you want to ask questions and introduce other excuses for pauses to make sure the students are staying with you.

Enunciate clearly—this is especially helpful for non-native speakers of English.

- **Introduce complex material gradually and highlight important information.** Complicated images should appear part by part, and arrows or highlights should draw students' attention to what you're explaining. Drawing arrows or circles is easy to do if you have a pen and tablet hooked into your computer.
- **Get rid of extraneous on-screen material.** Do you really need that entire graphic of the complexities of photosynthesis? Or all that verbiage in the bullet points? Or that busy bookcase in the background?[8] You can place very brief phrases on the screen to emphasize what you are saying in words. But don't put a long paragraph of text on the screen and then read it aloud. Rather than reinforcing learning, this simultaneous reading/seeing of the same information interferes with it.[9]
- **When you are in front of the camera, you need to be bold and bigger than life.** Use your hands and an expressive set of facial emotions. It can be useful to think of the camera as a device that automatically subtracts ten charisma points. So you need to be extra outgoing to compensate. Don't worry if talking to the camera seems unnatural at first; just think of the camera and its light as a supportive friend. If need be, put a stuffed animal on top of the camera. (It might help to know that if you watched Barb's first online videos, you would have thought she was looking down the barrel of a shotgun.)

## Getting Started: Organizing Yourself and Your Students

Your course should grow from your syllabus or class overview, which contains your expectations and schedule. The online layout of your course may seem simple and obvious to you, but for students, it can be bewildering —a little like being dumped blindfolded out of a car in the middle of the night and told to find their way home. Students need to form a *cognitive map* that allows them to begin navigating your course.[10] What's a cognitive map? It's a veritable zoo of neurons interconnected in a way that allows students to understand what they are supposed to do. For example, students must learn to click on the lower left corner of the web page to get to quizzes. Or the upper right for discussion forums. Once they have spent a little time navigating around your course, the newly formed cognitive map will start to become second nature.

To help students develop their new, course-related cognitive map, create a screencast (more on that soon) that walks them through the main elements of your course even as it also introduces you and your subject. In your screencast, point to the different key elements on your learning management system—the discussion forums, quizzes, and videos—and describe how students can best contact you. Students (and parents) appreciate one handy document that serves as a resource for the term or the year. Providing monthly event calendars can be an added bonus and is especially useful to parents and students in getting oriented in time as well as space.

What should you include in your class overview?

- **The logistics.** Class name, day and time it meets (if synchronously), your contact information and when you are available for individual consultation, technology requirements and where to go for tech support, as well as course texts and other required resources.
- **The content.** A descriptive overview of what students will learn, followed by specific course objectives that target what students will know and be able to do by the end of the year.
- **Your policies and the school's policies.** Do you accept late work? If yes, is there a deduction in points? Spend time thinking about your policy on late work and attendance because there will *always* be late work and missed classes. Be sure to read your school handbook for their policies as well—especially for policies on academic integrity

and acceptable use of equipment. It's wise to remind students of these policies and how you will enforce them.

- **A class calendar.** Your class calendar can cover the week, the month, the marking period, or the year. Planning for the year gets tricky when trying to stick to specific dates. Instead, list your intentions and inform your students that dates and activities are subject to change at your discretion.
- **Assignments and class grades.** Provide a brief description of the major class assignments and their point values. For recurring assignments such as lab reports or book talks, it is worthwhile to include the directions for the assignment, its rubric, and an exemplar.

### Initiating and Maintaining Contact via Email

Email is a great way to reinforce and supplement what you include in the LMS. If planning for the class has gone smoothly (sometimes the world doesn't cooperate as we might like!), you should be able to send:

- **An introductory email** one to two weeks before class begins, communicating your excitement about working together and giving some information about where to preview course materials if you make them available to students early. If you've made an introductory video about yourself, include a link to the video. Students tend to be full of nervous excitement for the new school year, and friendly outreach from you goes a long way to reassure them.
- **A course kickoff email** one or two days before the course formally begins, telling students exactly where to go and what to do to get started. Include the link to the introductory video if applicable and attach your syllabus or class overview.
- **A weekly email** once class begins that recaps the week's work and tells students what they need to do for the next week, as well as any upcoming assignments. If you make videos about common challenges students may encounter on an assignment, also include a link to the video. You may wish to add a personal side note about something

interesting you are doing, reading, or learning that week. Highlighting exceptional student work is also super motivating!

Save these emails as templates for years to come. Make it a habit to remind students (and guardians in elementary and middle grades) via email multiple times about the due date of a major assignment—emails show your presence and personality. They also cut down on procrastination.

Upbeat and sparkly messages from you will solicit the best back from your students. Using emoticons helps prevent possible negative interpretations. ☺ Not to mention that emoticons along with Bitmojis can be fun! As students adjust to the shift in classroom environment, forgive their early technology failures, which will be inevitable.

## Getting Reticent Students to Engage

For students who aren't responding or involved, it's a good idea to reach out with a call home to a guardian and to check in with the student's other teachers or their guidance counselor. You may need to do some sleuthing to find out what's going on with the elusive student. Personal presence matters. You build presence through individual emails to students, kudos for great work, or words of encouragement for those in need. You are creating an online community for your students, and this sense of community will go a long way toward helping your students be committed to success.

Starting with a low-stakes online quiz on course expectations forces students to review the essential information from your syllabus and allows them to realize their active responsibilities in the class. You might include true or false statements such as "I understand that I need to check my email each Monday to review the weekly class task sheet" and "I understand that the first draft of the major essay assignment is due on . . ." An additional goofy question or two—for example, a multiple-choice question including your name as the teacher, nestled in with names of celebrities—can assist in breaking the ice.

## Audio Quality Is Critical for Both Synchronous and Asynchronous Teaching

Video production experts like to say sound is 51 percent of the video, because without good sound, a video is worthless. Next time you are in a virtual meeting, listen to the difference—it's very discernible—between a built-in laptop mic and a more professional microphone. Not paying attention to audio is a common mistake. People focus too much on how they look and not enough on how they sound.

If you purchase a microphone, take a look at the video reviews posted by reviewers and critics on websites like Amazon to get a quick sense of how to use them. The features may seem complicated but can be simple once you see a demonstration. (Of course, that's the benefit of teaching through video!) As an alternative or supplement to their audio recordings, sometimes teachers like to download the free Audacity app to their cell phone, then set the phone nearby, pointing directly at their face but out of the shot. Audacity will record clean, clear audio that you can use to replace the poorer audio on your video recording later. It's also nice having the cell phone audio backup in case your primary audio recording didn't work. A low-budget option to produce a high-quality audio recording can be made by sitting on a bed underneath a sheet. The mattress absorbs the sound and the sheet collects the audio waves to produce optimal audio.[11]

But there is an even more important aspect of audio quality—the tone and voice of the instructor. Some people have very mellifluous voices, while other voices can be gratingly difficult to listen to at any length. The irritating quality of these voices can arise because, among other factors, they can invoke memories of the angry shouts of your parents when you were getting into mischief, or the shrill shriek of someone in danger. Imagery even shows how these shrill voices can hijack the emotional circuitry of the amygdala, just as can other unpleasant sounds.[12] Unfortunately, those with naturally higher-pitched voices can be particularly prone to screeches, since speaking nervously on camera can tighten the vocal cords still further, turning the high pitch into a grating one.

One often finds newscasters and politicians with high-pitched voices taking voice coaching. If you watch their videos over time, you can see how their pitch lowers and becomes more melodic. One good tip if you suspect you might have this problem is to start a sentence at a lower pitch than you normally would, to help keep the natural and gradual rise in your voice as you complete that sentence or paragraph from turning into a squeak.

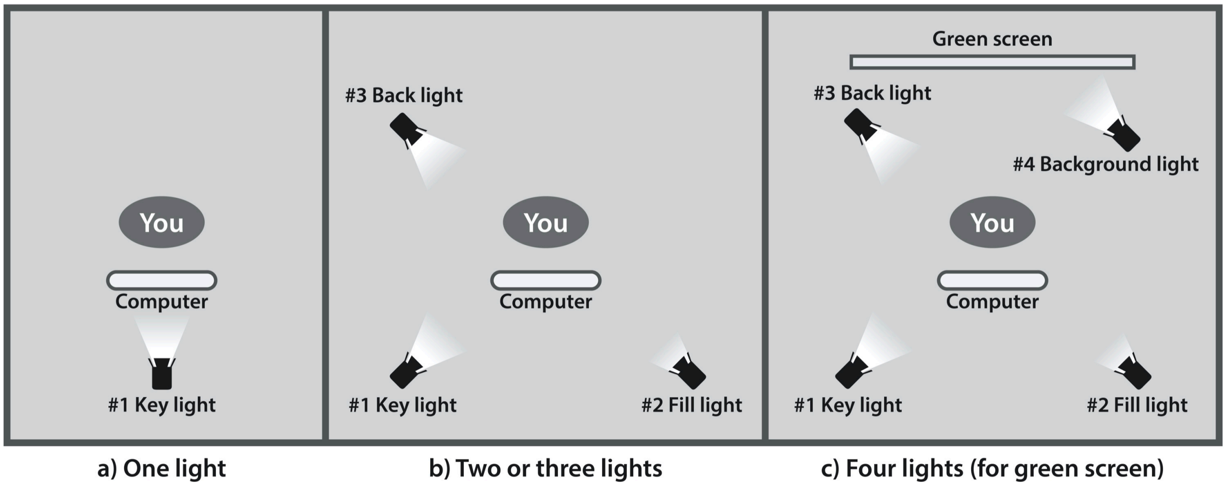
A challenge, however, is that many people who could benefit from voice coaching simply cannot believe they have a problem. This is because our voices are something we learn to use procedurally. Our own voice can seem natural and easy to listen to no matter how grating it might be to others—which means changing our voices can take concentrated effort and lots of practice, preferably with a voice coach. Your first step is to determine whether your voice is sometimes problematic.

We believe that becoming aware of your voice, and correcting potential problems with your voice, is even more important for your online teaching than your face-to-face interactions.

## Pointers for Going On-camera

Ordinarily, teachers sit in front of their computer or laptop and stream or videotape their image using their webcam. It can be helpful to follow the usual lighting rules, as shown in the following illustration. Place a stronger light, called a *key light*, in front of you, but slightly off to one side. A second lamp—the *fill light*—should be placed a bit farther away on the other side of you—or alternatively, be a bit dimmer—than the key light. This second light gets rid of shadows. If you want to make yourself pop out from the background, use a third light, called a *back light.* If all you have is the key light, place it right in front of you. Avoid having bright windows behind you; it can leave your viewers feeling as if they're looking at your silhouette in the sun. If you wear glasses, you may need to play with the light a little to find a sweet spot with low glare. Avoid ring lights, which can leave devilish-looking circular reflections if you wear glasses. Flat panel

LEDs are great. Sometimes simply raising the height of your lights can eliminate or reduce glare on glasses.

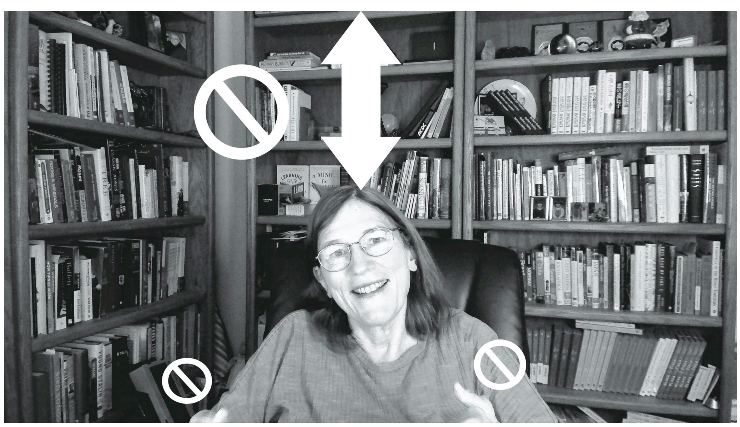



A typical home video recording setup. You can use from one light to four lights. (Four lights are preferable for green screen, which makes it easy to substitute in another background.)

Be sure to watch your positioning on the screen. What generally happens is you'll sit up tall to start with, but then as you tire, you begin to slump, so you droop down on the lower part of the screen. You think it's fine, because your head appears centered in the middle of the frame, but the problem is that your hand motions can be cut off below the camera frame. Some people set their laptops on boxes—it's easier to be energetic and to make good use of hand gestures when you're standing. Try to be conscious, at least at first, of where your hands are on screen. You want them to be visible, particularly when you are emphasizing important points. Thanks to your procedural system, with time, holding your hands in a visible yet natural position will become a habit and you won't need to think about it.


Beth's face is too close to the camera, so her hands are cut off, thus removing a valuable teaching tool. Notice the glare on her glasses, which is invisible to her but obvious to her viewers. She's also slightly underexposed—her face is a little shadowy.

Beth's virtual background is a photo of her campus. Although the photograph is cluttered, the familiar building and mascot helps her students feel at home even while they are in the virtual world.



Barb models the common mistake of slumping down in her chair while centering her face in the frame (aka the prairie dog effect). This inadvertently cuts off her hands. She's also overexposed—there is too much light hitting her face.

Here, Terry's head is perfectly positioned in the upper part of the frame (high up but without the Frankenstein effect of cutting off the top of the head). There is plenty of room in the lower part of the image frame for his hands.

Make sure any lights you use have the same type of bulb in them, so your camera doesn't get confused. All this gives your image a full, real-tone look. It's nice if your on-camera background tells a little about you. If you can, try to go beyond the usual bookcase in the background. But sometimes a bookcase is all you've got. If that's so, go with it and display some of your favorite books. If the room is filled with hard walls and floors, try to add rugs and soft surfaces like blankets or cushions to minimize echoes.

## Synchronous Teaching

Synchronous usually means that you are streaming your image along with your visuals in real time using a platform like Zoom. As you'll see, there are many similarities between a face-to-face class and a synchronous class.

The challenge is, you're not *quite* in real time. There are tiny delays and jumps in what students see on their end, not to mention a loss of sound quality. These can result in what's called Zoom fatigue—mental exhaustion from following clipped or distorted audio and catching incomplete body language (it's hard to read facial expressions in a tiny corner image).[13]

How can you keep students engaged and on task? First, look directly at the camera (not your screen!) when you are speaking to your students. This direct eye gaze is as critical online as it is when you're personally face-to-face with your students. Try to set the camera so it is at the level of your eyes. (If you're looking up or down at the camera you can inadvertently hint at weakness or snobbishness.) If you want to seem a real pro, try to look directly at the camera itself, not the light beside it—despite the fact that that pesky light can draw your gaze.

As far as conducting the class itself, it's nice to know that some of the approaches that work well in an online classroom are variants of our old friend direct instruction. Here are points to keep in mind:

**1. Set ground rules.** Do this at the very beginning of your course before you do anything else. Asking students to help create ground rules is vital. It takes more time to have a discussion and come up with a list of their suggestions, but it improves student buy-in in the long run. Store your rules in a prominent location in your LMS. Typical rules can include:

- Mute on entry.
- Sit in an upright position facing the camera.
- Do not wear your pajamas to class.
- Have enough lighting in the room so we can see you.
- Do not play with your dog or have a side conversation with someone else who physically enters your room. It's distracting even if you are on mute.
- Do not message your friends during class.

You will also want to establish procedures for students involving issues such as:

- How do they ask a question?
- What should they do if they have to leave to go to the bathroom?
- How do they participate in class discussions? Who talks? When?

Since synchronous teaching is about as close to live, face-to-face teaching as you can get, it's essential to be consistent with the times of your sessions, just as you would with a real class.

**2. The sixty-second rule.** Use the first sixty seconds or so of your lesson to engage your learners and to encourage them to be on time. You need a hook—the more startling, the better. Remember, curiosity and novelty up-regulate neural proteins related to memory, which enables the information to stick better. Occasional brief personal anecdotes enable your students to connect better with you.

**3. The five-minute rule.** Try to keep your explicit instruction to no more than five minutes—even shorter times for younger students—before you go to breakout groups or do something that elicits an active response from students. Focus on the key idea you are trying to convey, except for occasional brief humorous asides. (As we'll describe later, occasional humor plays a vital role in online learning.)

You can share your computer screen, and students can watch as you type in a Google Doc or display slides in PowerPoint. But it's better if you can also *write by hand* on the screen.[14] Writing by hand forces you to slow down and emphasize specific points—making it easier for students to grasp your key ideas.

We like to use a "pen" with a writing tablet (either a Wacom tablet or an iPad can work fine). As you demonstrate and elaborate, show your image in the corner of the video feed, along with the shared screen. Putting yourself in a corner box, called a picture-in-picture, allows you to convey both your presence and your enthusiasm to keep students engaged. (There are drawbacks, though, in that students have to process two separate images simultaneously.)

**4. The nowhere-to-hide rule.** After each brief bit of explicit instruction, it's important to engage your students.

- **Breakout groups:** Many online platforms provide a way for you to assign students to *breakout groups*. Learn to use this valuable tool—if need be, get your family or friends to participate in a preliminary practice session, so you can ensure you know how to facilitate breakouts. (Some platforms will allow you to toggle so that you can join and see the breakout room as if you were a student; otherwise consider creating a secondary account for the same purpose.) What's nice about online breakout groups is that they're so much quicker to form than face-to-face groups—a push of the button, and students can be randomly scrambled, introducing them to potential new friends.

- Keep in mind that, depending on the platform, **students in breakout rooms may not be able to see your presentation.** One solution is to provide students with a link to a Google Doc or a slide with explicit instructions. A smart approach suggested by Harvard's Rhonda Bondie is to have one student in each breakout group responsible for taking notes of the group's discussion on a shared document or slide.[15] You can monitor these Docs in real time—getting a feel for whether the groups are on track and assisting individual breakout groups as needed.
- **Polls** are also available with many synchronous platforms. These help you monitor students' comprehension and also allow you to break up explicit instruction. You can set up polls ahead of time using platforms like directpoll.com, www.sli.do, polleverywhere.com, or Microsoft Office 365 Forms, and then reuse the polls by putting the link in a chat room. Because it can be hard to read the body language of online students, polls provide ongoing feedback that allow teachers the opportunity to make real-time adjustments in their instruction.
- **Call on students:** Doug Lemov of *Teach Like a Champion* recommends the tried-and-true practice of cold-calling students regardless of whether they have raised their hands.[16] (If you worry that cold-calling makes your students uncomfortable, worry no more. Research shows that cold-calling actually increases students' comfort with participation and also heightens students' desires to answer voluntary questions when you do pose them.[17]) Cold-calling provides a check for understanding, creates a culture of engaged accountability, and maintains the pace of the lesson. To call on students randomly, it

can save time and ensure equity if you use an app that includes a random student generator. ClassDojo is one of our favorites.

## TEACHING TIP:

### Using the Chat Room and Getting Students to Re-engage

- When you pose a question online, several people can respond simultaneously, which repeatedly wastes time as you restore order. A better approach is to pose a question verbally and state that you will wait for five responses to be typed in the chat room.
- Advise students to ask questions in the chat room. Sometimes it can be easier to see a chat-room question than a tiny symbolic hand being raised.
- Designate another person—perhaps a paraprofessional, a student who's already on top of the material, or a volunteer parent—to monitor the flow of the chat room. Stop periodically to catch up on messages and questions.
- Students inevitably tire of staring at a screen. If you have the sense that your students are disengaging, it's time for a "brain break" like those we introduced in chapter 3. Ask your students to turn off their video feeds for a minute. Then ask students to stretch, move around, jump up and down, do a yoga pose, or just breathe in and enjoy the air around them. You'll be surprised at how refreshed students can be when they return a minute or so later.

## NOW YOU TRY!

### SIMON SAYS

Depending on the sophistication of the students, online learning can be choppy as both students and teachers learn how to navigate things like where a yes/no button versus the thumbs-up button is located, or who should be speaking first. A good idea is to play Simon Says to familiarize your students with the platform and your procedures.[18] (If your students are past the Simon Says stage, you might put in a self-deprecating "Bear with me—it'll help if we think back to our childhood for a moment and play Simon Says together, just to get used to the platform.") When you have a particular button you want students to become familiar with, say something like "Simon says 'press the yes/no button.'" Two minutes of this kind of playing around with the platform can make a class run much more smoothly.

## Asynchronous Teaching

Asynchronous teaching generally means placing materials onto an LMS that students can access at any time. What's placed online can be anything from videos to quizzes, discussion forums, and a variety of documents. Quizzes and discussion forums can be especially powerful in encouraging retrieval practice—this is one of the great strengths of asynchronous teaching.

Sometimes when you are creating asynchronous materials, the most comfortable choice is to upload documents for students to read and digest. But sadly, this approach can lose the best of what you provide as a teacher—your presence. A lack of teacherly guidance can make learning far more difficult as students struggle to navigate the material on their own. Hiker students with lesser-capacity working memory can quickly find themselves lost and overwhelmed.

Learning experts will sometimes say, "It's interacting with one another that gets students engaged in the course." Consequently, teachers work to liven up their asynchronous materials by using asynchronous supportive elements such as discussion forums, shared sticky notes, peer editing, and quizzes. These are indeed useful, and we'll discuss them in this chapter. But the reality is, *students focus on videos*.[19] And well-explained videos are one of the most powerful tools in all of teaching.[20]

You can sometimes find good explanatory videos made by other instructors. But your students have an understandable desire to hear *your* voice and see *your* face. Instructor presence, in fact, has been determined "to be one of the most important components connected to students staying engaged with and completing online courses."[21]

Even a single cheesy amateur video that *you* make can earn students' respect because you're at least trying to step into their world of engagement. And if you engage with your students, they're more likely to engage with you. If you're all about social relationships in your classes, your students will feel more connected to you when they see you in action via video.

If you're already feeling overwhelmed with your teaching duties, there's good news. Some of the approaches we suggest next should take you only a few minutes to learn. And what's even better is that creating videos can save you much-needed time because you can reuse them.

## Super Simple Video Making—Just Do It!

Before we walk you through the basics of good video making, we want to make one crucial point. The key to making a good video is to make your first video. It doesn't need to be a great video. It doesn't even need to be a good video. It just needs to *be* a video.

There are free or low-fee programs, such as Screencastify and Screencast-O-Matic, which use screen capture to create videos. Using screen capture, whatever you see on-screen, along with your accompanying voice, can be turned into a video. Along these lines, Explain Everything is an interactive whiteboard tool that works particularly well for touch screens.

Another option is to use PowerPoint's Record Slide Show feature to record your voice as you present your PowerPoint and, optionally, a picture-in-picture of you. PowerPoint then makes an audio file (and an optional picture-in-picture video) for each slide. You can move your image at different points of the presentation to fill the entire screen, appear in a corner, or not show at all, depending on what feels right to you at the time. Mix it up! Students can then go through the PowerPoint file in "slide show" mode, and both hear and see your explanation for each slide.

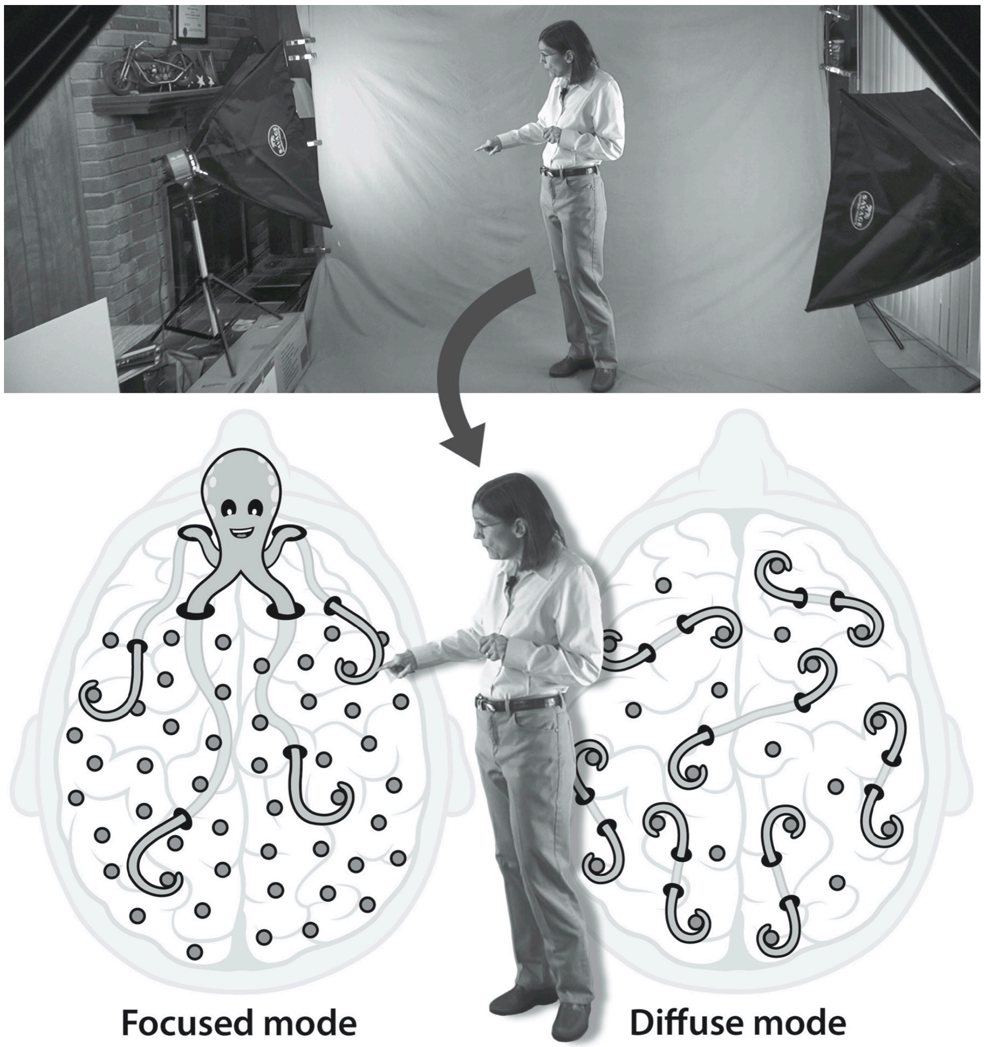
You can go further, though, and use the PowerPoint export function to turn your PowerPoint into an MP4 video. What's nice about PowerPoint is that you can also easily rerecord and change individual slides if you want to modify them later. Even a short video created from PowerPoint, with your face in the corner as you give tips on a particularly tricky homework problem, can be a real boost for students. Standard rules about creating good PowerPoint presentations apply: a five-hundred-word slide is worthless; a slide with five key bulleted phrases can be invaluable.

If you would like to use guided notes with your students, save two different versions of your PowerPoint: the full version for your personal reference and a version with strategic words or problem-solving sections removed. You'll use the partially filled version to "write in" answers as you talk, so what you are doing becomes more interactive.

## Do Students Really Need to See You?

Teachers sometimes ask us whether it is all that important to show the instructor in a video. To answer that question, let's use a thought experiment. Imagine that you had a video of your presentation (not including your image) on a screen at the front of your class. Your voice would be heard over a speaker. Here's our question: Could you keep your students engaged and interested in the materials for the long haul without showing yourself? Especially if they've never even had the opportunity to meet you face-to-face?

> The best long-term solution for online absenteeism is your consistent presence in the course. In general, the courses with the lowest student absenteeism are the courses where teachers are the most present.
>
> —Aaron Johnson, *Excellent Online Teaching*[22]




If you want to get extra fancy, you can film yourself in front of a plain background (traditionally, a green background is used–hence the name green screen) and then use editing tricks to insert yourself into your video. Modern video wizardry means that you can do this even while sitting in an ordinary background in your office. This image shows Barb filming the massive open online course "Learning How to Learn" in her basement. The advantage of this approach is that you are integrated into what you are trying to point out, which reduces the load on your students' working memory.

You may think, *Look at Sal Khan of Khan Academy—he never shows himself in his videos.* This is true—but on the other hand, students generally go to his videos *voluntarily.* They're already motivated to learn what he's teaching, even if the motivation arises just because they can't understand their teacher's explanations. But your students are *not* necessarily volunteering to take your class. Sharing your personality allows you to connect with and motivate your students—an essential first step in getting them to engage with the course materials.

As you record yourself, look out for “crutch words.” These are words you use over and over again—you’re oblivious to them, but these words can be irritating for students watching or listening to you. Common crutch words are *right, okay,* and *ummm*. These are often the same crutch words you use when teaching in front of live classes, so monitoring your recording provides a valuable opportunity to improve your teaching both online and face-to-face.

Many people struggle initially with seeing and hearing themselves on video. It’s perfectly normal to have these feelings, but be encouraged that the more videos you make, the less self-consciousness you will feel. Hour by hour your expertise doesn’t seem to change much, but over the weeks and months, you will notice dramatic changes. Just think of yourself as a pilot who needs to accumulate flying hours to gain mastery of the skies. Or as a procedural as well as a declarative learner.

## How Long Should Videos Be?

Basically, you want to break up the material into the smallest chunks possible but not so small that a student needs to watch multiple videos in a row to understand the concept. We recommend that if you’re constructing a set of online materials, whether as the mainstay or as a supplement for your class, these videos should each be about three to twelve minutes in length—that is, about the amount of time you would give an explicit piece of instruction. A shorter video “allows learners to engage with small pieces of new information and gives them control over the flow of new information.”[23] Note that this doesn’t mean taking an hour-long video and snipping it into ten six-minute videos. It means taking a bit of care with each video so it has a very short introductory hook, a good explanation, and a wrap-up that places the idea in context. It’s amazing how often cutting a minute or two of material can fix the pacing.

That said, you should also realize it's possible to turn an entire hour-long synchronous teaching session into an hour-long video just by recording your screen. This video, lengthy though it may be, can be a useful tool, at least for older K-12 students.[24] They can use it for review and clarification, or for first-time viewing in case they weren't able to attend the synchronous session.[25] Finally, research intriguingly titled "The myth of the six-minute rule" has shown that twenty- to twenty-five-minute videos are also effective, at least for college students.

A challenge with lengthy videos, however, is that they can be a little like asking students to read encyclopedias. Even if you did lots of activities during, say, a synchronous session, once you transpose the session to video, it all just turns into a lengthy lecture. And we know how problematic extended lectures are for student learning! Even inserting interactive material like quiz questions into or after a long video does little to relieve the boredom.

Good visuals are an especially important part of video creation, and getting good visuals takes time. It may seem counterintuitive, but it's worth noting that shorter videos demand extra planning and longer preparation time.

## Adding a Touch of Fun—Even if You're Not Naturally Funny

The challenge of making online materials engaging, whether in the form of documents, videos, or live synchronous sessions, brings us to an important point. If there's one big difference between the online and the brick-and-mortar world, it's that the online world loses the sense of immediacy. In the real world, you can walk right up to a student. In the online world, you might be visible only occasionally, in a tiny corner of the screen. A little time spent this way isn't too bad. Hours of it? Not so good.

Just as with face-to-face learning, humor in online teaching can be a magic wand that compensates for many, if not all, flaws. Occasional bits of positive, nonaggressive humor are associated with a more exciting and relaxed learning environment, higher instructor evaluations, greater perceived motivation to learn, easier ability to recall key information, and more enjoyment of the course. It also enables your students to bond with you.[26]


Occasional use of humor, as with memes like this one, GIFs, or snippets from movies or television shows, can help spice up your teaching. Just check the rules for your country and institution.

We don't mean that you need to become a comedian! If you find a way, for example, to add in a little something funny or unexpected every five to seven minutes, or at least once somewhere in each of your videos, students will start looking for that little unexpected dopamine boost of pleasure. This boost will allow them to power through the harder-to-grasp, sometimes boring stuff in between the bits of humor.[27] Don't worry if you don't feel you have the comedic touch. Learning to add a bit of humor is like learning to ride a bike—you don't have to be world class to get around.

A good source for laughter? Tiny snippets from movies, as well as memes and Bitmojis. The TEACH Act of 2002 allows U.S. teachers affiliated with accredited nonprofit educational institutions to incorporate video snippets of movies and videos into their teaching materials. Permissions vary around the world, so check to see what's allowed in your country for your type of institution.[28]

## NOW YOU TRY!

### WATCH TELEVISION OR VIDEOS WITH A DISCERNING EYE

**People vary** widely in their perspectives on the value of television or YouTube. After all, there's a lot of schlock out there, even while there is also brilliant storytelling and teaching. Educational YouTube videos have racked up hundreds of billions of views. Watching some of the most popular of these shows can not only help you improve your online teaching—it can also help you stay in touch with your students.

For one week, set yourself a daily goal of watching a half hour or so of a popular educational video, documentary, or television show that your students like. Make notes for yourself on how the program was edited. Did they use motion to attract attention? A hook? Unexpected materials? Humor? How can you integrate some of these ideas into your own online and classroom teaching?

Exemplary Educational YouTube Shows

- Crash Course
- Michael Stevens's Vsauce
- *Drunk History* (not that we're advocating this approach, but it's pretty funny!)

Sources for Streaming Movies (and E-books) Via Local Libraries

- Kanopy
- Hoopla
- Libby

## Top-down Versus Bottom-up Attention

We've been making a tacit assumption: that you are holding your students' attention when you teach. Master teachers keep students' attention in dozens of different ways—from eye contact to a snap of the fingers to a dramatic leap onto a desk.

But when you're online, leaping on a desk doesn't have the same impact as it does in person—and maybe that's not your style, anyway. Keeping attention online requires somewhat different tools, but anyone can master them.

First, we need to understand attentional processes. There are two ways students can turn their attention to you: by using *top-down* or *bottom-up* processes.[29]

Top-down processes involve personal free will* and arise in the prefrontal cortex, propagating back into the rest of the brain. Bottom-up processes are involuntary and arise toward the back of the brain, where environmental stimuli are first perceived, and then propagate forward.

> It is only when you have your students' attention that other neural mechanisms can start locking in the information the student is trying to understand and absorb.

Attentional processes are finicky. Once a scene stays the same for too long, a student's attention will tend to wander. Students must force their attention back using top-down processes—in other words, through willpower.

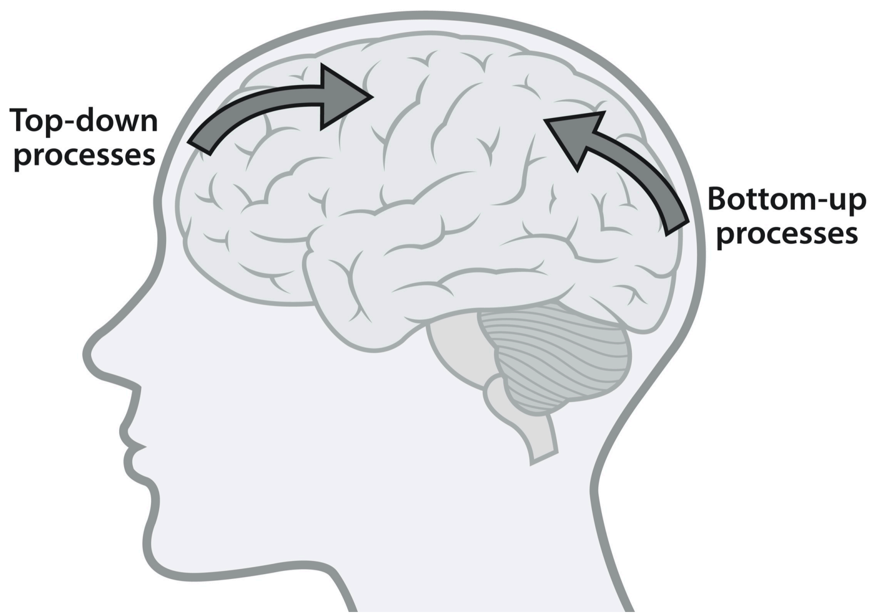
The other way to lure attention back is to use bottom-up processes, such as:

- Motion (especially motion that gives the illusion of moving swiftly closer)
- Sound (video games make clever use of sound)

- Anything unexpected (humor plays a role here)

It’s easy to respond to bottom-up stimuli—much easier than trying to force your attention back using top-down processes. If you build bottom-up attention grabbers into your videos, you can keep students’ attention without forcing them to expend their willpower.

To attract students’ attention, try sporadic small tricks. For example, use video editing to switch your body occasionally from one side of the screen to another. Transition between full body and half body. Have an arrow fly in to emphasize a point. Use a *ta-da* sound when you’ve finished a triumphant derivation.




Top-down (left arrow) versus bottom-up (right arrow) attentional processes control the direction of a student’s focus.

But note that everything *doesn’t* need to be motion, sounds, or the unexpected. Good video editing provides enough sizzle to draw students’ attention back to the screen occasionally by using bottom-up, subconscious processes but without overdoing things. These modest video tricks make it easier for students to keep their attention on your explanations because they do not have to force their attention back to you when their gaze naturally wanders. Instead, their focus is being drawn repeatedly to what you are presenting on-screen. For guidance as to when to insert an attention grabber, see when your own attention begins to wander as you watch your footage.

Keep in mind that a talking head in a box in the corner of the screen is not really motion—it's too static and predictable. This, indeed, is why well-made asynchronous videos often form the foundation of good online teaching. Asynchronous videos are much more in line with what grabs students' attention.

### A Script Isn't Always Necessary—But It Can Be Helpful

Many teachers cover so much during a day that to put together a word-by-word script for even one day's worth of teaching would cause you to shudder. You certainly wouldn't want to script every word of a synchronous session. After all, part of the magic of live sessions is their immediacy, vibrancy, and spontaneity. But when creating short videos—for example, your introductory video, or a video about a particularly tricky concept—scripts can come in handy. Some teachers use "half scripts," in which they outline, without fully scripting every word. "First, I'll do that. Then I'll explain this. Then I'll show this." This approach keeps you on topic while avoiding the artificial feeling of reading from a script.

Scripting has some advantages because it allows for more precise control over what you say, and also allows you to plan for great metaphors and visuals. Once you've written a script and are ready to film, put the script on the screen, optimally right below the camera lens. (Teleprompter apps can make this easy.) Make sure the script isn't too wide on the screen, so your eyes aren't moving back and forth as you read (it makes you look shifty-eyed). Having a script can help you create captions, which are important for accessibility by all learners, especially those with special needs and non-native speakers.[30]

It's common when creating PowerPoints to use a lot of text even though you're not supposed to, just because the text on the slide reminds you of what to say. If you use a script, you'll always know what to say, and it's much easier to keep the text on your slides to a minimum.

## Assessment and Engagement

Just as it can be all too easy to read a book passively, it can be easy to watch a video passively. How to stop the passivity and rather engage students more deeply in the material? Why, retrieval practice, of course! Collaboration, discussions, and quizzes are vital in the retrieval process. These engaging practices can reinforce the content you introduce in your videos.

### Online Collaboration

Students have become used to sharing documents online to work together. And they can, of course, talk "live" or via chat rooms. There are also a phenomenal number and variety of asynchronous engagement tools such as Padlet, Quizlet, Kahoot!, GoNoodle, PeerWise, iDoRecall, and Quizizz. These tools allow students to interact via online bulletin boards, to create flash cards and quizzes, to answer and discuss questions posed by their peers, and so forth. Introducing these tools to students can allow them to interact more easily.

### Quizzes

What we like about the online world of asynchronous quizzes is that these quizzes can be "just in time." There is plenty of evidence that multiple-choice questions can do a good job of helping students learn.[31] Many LMSs or tools like HapYak and Zaption allow you to embed quiz questions within a video, or immediately after a video. Frequent quiz questions can bring students' attention back to the material and make a significant improvement in student performance.[32] There is no hard-and-fast rule about when to add questions—some instructors tell entrancing stories in their videos, such that it doesn't make sense to stop the flow with intrusive questions until the end. There are also tools like Edpuzzle or PlayPosit that can help you build a complete lesson around your video, and even track the data to see how well students are doing on your embedded questions.

## Guiding Questions

The creation of a document with guiding questions as students watch short videos can be beneficial. One study showed that students who answered the guiding questions while watching a video scored significantly higher on a later test.[33]

## Homework

Making the information in the videos a part of a homework assignment is also useful in getting students to engage with the video content actively. One study showed that embedding videos in a homework assignment improved students' understanding of difficult concepts when compared to a similar assignment without videos.[34] Try to keep your homework doable within twenty minutes.[35]

## Discussion Forums

Discussion forums allow you to assess student knowledge of the material and give students practice retrieving the content in different contexts. Smaller discussion groups foster both familiarity and friendship. Questions that start with action verbs—like *find, explain, describe, identify,* and *compare*—make for an active and vibrant forum.[36]

Make sure your questions don't all elicit the same correct response. To ensure a variety of responses, ask students to find the three most important quotations from the assigned reading, and explain why they chose each. Then have them pair with another student to compare quotes and decide on one to share and defend with another group.

Have students post in a discussion forum before a synchronous session so you know what their issues and thoughts are. If students are supposed to both post and respond to others' posts, make sure the due date for the initial post and the due date for the response are clearly specified and are at least one day apart. If you can interject on the discussion forums—briefly—several times a week, on average, it will allow students to feel your presence without your becoming overwhelmed. It is also useful to provide a minimum word count for posts. When students know how much of a response you expect, they can tailor the depth of their response to meet (and sometimes exceed) your expectation.

### NOW YOU TRY!

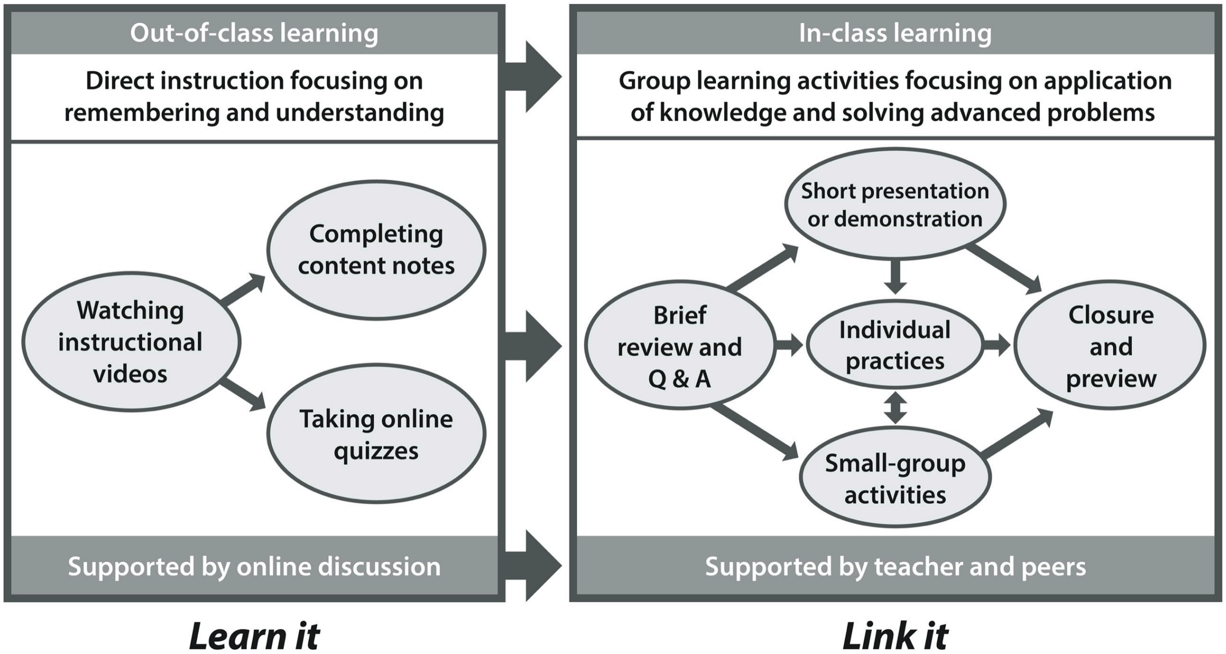
#### HAVE YOUR STUDENTS CREATE VIDEOS

**Many students** enjoy creating videos and can be much better at this than teachers. If you want students to truly grasp a topic, ask them to create a video explaining that topic.[37] There are many simple free video-editing and screen capture programs such as TechSmith Capture, Adobe Spark, and iMovie. You can give a "make a video" assignment to your students in Flipgrid or ask them to do a screen share if you teach synchronously (you can set the maximum length of the video). Save some of the best of these explanatory videos and (with appropriate permissions) reuse them to help students learn in years to come.

The only caveat to these assignments is that students can become so engrossed with the video-making process that they learn little about the topic they've been assigned to master.[38] Make sure that your assessment evaluates what you actually want students to learn, rather than just flash and sizzle.

## Mixing Synchronous (or In-person) and Asynchronous Instruction: Learn It, Link It

Depending on the age and ability level of your students (more experienced students tend to be more self-directed), the hybrid *learn it, link it* approach we first described in chapter 1 can be useful online. On Mondays, for example, make videos and text available for students online (*I do*). Provide preliminary exercises or discussions to help students engage with the material. This time is meant for students to begin to *learn it*—at least as much as possible on the first pass.




Integrating asynchronous with synchronous or face-to-face teaching–a *learn it, link it* approach.

On Wednesdays, you can provide personalized feedback on students' work and add additional content and practice through synchronous instruction (*We do*). This day helps students strengthen their neural links on the topic.

When students first learn a new concept or skill, they are creating new sets of links between neurons in long-term memory. Some students are starting from scratch and will need additional time and reinforcement from you to build strong links. Race-car students who may not need the extra support can get a jump start on Friday's student-directed activities.

On Fridays, ask students to turn in homework and perhaps take a quiz. These days are meant for students to *link it*. Have students demonstrate competency and then apply their new learning to real-world situations and make connections to other topics (*You do*). In essence, you are dividing Monday-Wednesday-Friday into *learn it, respond, link it* days. (Sometimes teachers move the Friday materials onto the weekend—it depends on your school's culture.)

# Analyze Your Teaching:
## Make a Video

What is the topic your students have the most trouble grasping in your regular face-to-face classes? This could be the topic of your first video.

1. **Get the screen-capture software of your choice and record yourself,** using whatever imagery you usually use in your class—often it's just a simple set of PowerPoint slides. We recommend filming yourself, picture-in-picture, just so you get used to seeing yourself on-screen. Picture-in-picture isn't optimal, but it's an excellent way to get started. Remember to position yourself properly so both your head and hands are showing.
2. **Post the video on your LMS,** adding a quiz question or several questions right after it.
3. **Ask students to watch the video and answer the quiz questions** or do another creative exercise to show they've captured the essential content of the video.
4. **Ask yourself what video you'd like to do next.** Can you step it up by adding a little sizzle above and beyond what you did in your first video? How about an added arrow indicating a vital topic—an arrow that appears and wiggles? Or a bit of gamified music?

Sources of Free Music

- http://www.freesound.org
- http://dig.ccmixter.org
- http://freemusicarchive.org
- http://www.freemusicpublicdomain.com

Watching and listening to yourself on-screen can give you insights that can also improve your face-to-face teaching. Once you've observed your first video, ask yourself, *Would I watch it again?* Why? Is the video insightful? Enjoyable? Personable? Can you continue to use it in the next couple of years? If you have answered no to one of those questions, then you probably need to rethink and adjust your video.

## Key Ideas of This Chapter

- The two primary forms of online teaching are synchronous ("right now") and asynchronous ("any time").
- **It's best for students to both see and hear the material they are learning** (multimedia theory).
- **Students are lost when they first start an online course.** Make a short video to help them form a cognitive map that allows them to navigate the site.
- Use email to reinforce and supplement what you include in the LMS. Reach out to disengaged students to try to bring them on board.
- **Pay attention to the quality of your audio.** A good microphone is worthwhile here. Watch the lighting and positioning of the camera, too.
- A key to making good asynchronous materials is creating videos that allow your presence as an instructor to shine.
- **The first step to making a good video is making a bad video.** Keep your videos around five minutes in length and have at least a minute or two where you are visible as you speak.
- **A little humor here and there is especially important in online classes.**
- Try to engage your online students using their bottom-up, automatic attentional processes, not their top-down processes, which demands willpower. A sprinkling of motion, sound, and use of the unexpected can help with this bottom-up process.
- Online discussion forums, quizzes, and other interactive tools provide powerful reinforcement to new learning.
- Mixing synchronous and asynchronous or in-person and asynchronous approaches can be the best of all worlds—keeping students engaged and accountable.

# 10

# Charting Your Course to the Finish Line:

## The Power of Lesson Plans

It's August and you're relaxing by the pool reading this book. School starts in just a few weeks. Your mind wanders to the passion you have for your subject matter; you think about how you'll spark a fire in your students. Your love of literature is perhaps what drove you to become an English teacher. Or maybe you're a math teacher and you remember your excitement when Mia was *finally* able to calculate the slope of a line (you have to rise before you can run). Mentoring the next generation of scientists, artists, technicians, teachers, and historians motivates you.[1] But success doesn't happen magically—it's a process. It's a journey.

Showing the world to your students in only 180 days is a lofty goal—so much territory, so little time. Time that is even further reduced when accounting for bathroom breaks, breakdowns, and unexpected detours.

We've taken a deep dive into how learning occurs. At its simplest, neurons link, are strengthened with practice, and are extended with new and diverse learning experiences. Your students—the hikers and race cars—take their mark, get set, and go! Their final destination—the neocortex—is where long-term memories are stored.

There are two paths your learners can travel—the declarative and the procedural. One path may take longer, and sometimes it's better to use both paths, but there are no definitive rules about who takes which path or how often students should switch paths. What matters is that all your students reach the finish line. It sounds simple, but teachers know it is anything but easy. The brain is complicated terrain. The instructional decisions you make are critical in helping your students to navigate that terrain. As your excitement to start this adventure builds, you organize your classroom and write lessons for the first few weeks of school.

But by the end of September, you've run out of plans. In the meantime, you've become inundated with testing, remediation, acceleration, parent emails, faculty meetings, student mental health issues, food insecurities, bullying, school violence, grading—and the list goes on. The result? Time runs out and lesson planning gets neglected. You take last year's plan and change the date.

Master teachers are among the best planners.[2] They start by plotting a map—that is, a lesson plan.[*] Lesson plans allow teachers to lay out precisely what they want their students to achieve and what success looks like. Their lesson plans may not be written in the standard format preservice teachers learn during training,[3] but master teachers routinely take the format's essential components into careful consideration when blazing new trails. Ahead, we break down those components, offer you a sample sequence to follow, and include some useful travel tips. Once you find your footing, you'll see how easy (and fun!) lesson planning can be.

## Plot the Path: Standards → Objectives → Focus Questions → Assessments

Master teachers begin with the final destination in mind. Students achieve more when they know where they are going and what it looks like when they get there.[4] Master teachers rely on the standards and eligible content for the essential vocabulary, skills, formulas, concepts, and patterns that students need to advance in the subject.

> **Forging New Pathways**
>
> **Plot the Path**
> 1. Standard
> 2. Objective
> 3. Focus Question
> 4. Assessment
>
> **Guide the Journey**
> 1. Bell Ringer
> 2. Hook
> 3. Lesson Body: Learn it → Link it
> 4. Closure
>
> **At the Finish Line**
> 1. Reflect
> 2. Celebrate

### Standards

Standards are *broadly* written "learning goals for what students should know and be able to do at each grade level."[5] In the United States, standards are broken down by subject matter. That overwhelming feeling you may get while combing through pages and pages of standards is likely the same feeling you get planning a complicated trip with several dozen people. Yikes!

Instead of taking on the entire world, narrow your itinerary—prioritize *the most essential* knowledge and skills.

Keep in mind that standards are written for teachers—after all, what is an eighth grader going to do with the following Common Core State Standard for English Language Arts?

> *CCSS: Grade 8—ELA: Cite the textual evidence that most strongly supports an analysis of what the text says explicitly as well as inferences drawn from the text.*[6]

Because standards are so broad, master teachers break them apart and decide what materials, examples, and resources work best for their students. This deconstruction of the standard builds the objective.

## Objectives: The Goal of One's Efforts and Actions

Objectives may be referred to as learning intentions, goals, competencies, outcomes, targets, and more. While each term has a different nuance, the purpose is to transition from the standard (which is broad) to the lesson (which is specific). Objectives state what students will know, understand, and be able to do.[7] They set your goal for teaching and the students' goal for learning, and establish what success looks like.

At the heart of an objective is the verb—what students do.[8] The verb indicates the mental workout the lesson entails. It is easier to *identify* and *recall* than it is to *apply* or *synthesize*.[9] The verb communicates the expected student performance, which in turn makes it easier to map out assessments used during and after instruction. Depending on the demands of the objective, a lesson plan may span several days or take less than a full class period.

That eighth-grade English language arts standard we introduced previously may morph into the following objective: Using a graphic organizer, eighth-grade ELA students will be able to locate three examples of imagery found in “The Tell-Tale Heart” and explain how each example helps to establish mood.

## Focus Questions

Master teachers see the finish line—X marks the spot—and make it visible to their travelers. Students need to know the objective to have a shot at achieving it. Otherwise they wander aimlessly and oftentimes remain lost.

Many teachers post their lesson’s objective on the board and state it at the start of class. An issue we’ve found with this approach is that students don’t respond particularly well to objectives. They see difficult-to-parse sentences and tune out. The solution? Try turning your objective into a lesson-based focus question. For example: *How does Poe use imagery to establish the mood in “The Tell-Tale Heart”?*

The objective is the top of the mountain, but there are several ways to get there: declarative or procedural; hiking or racing.

Why a question? Because questions spark curiosity. And questions can promote those spurts of dopamine that not only draw the students' attention and interest but also help the answers to stick better in long-term memory. Answering questions lies at the heart of active learning because it forces students to think and check what they have stored in long-term memory. If we keep the focus question in mind throughout the lesson, it allows students (and us teachers) to remain laser-focused on accomplishing the objective.

### Assessments

Teachers and students alike know their final destination, but what proof do they have that they've reached it? Enter formative and summative assessments. Formative assessments are markers along the path that indicate a student's progress.[10] These quick informal assessment checks happen during instruction. They allow a teacher to gauge each student's distance toward meeting the objective. When you think formative assessments, think retrieval practice. This practice offers students feedback on where they are going, the progress they have made, and where they are going next.[11] Like a GPS system, when students take wrong turns, master teachers help their students "recalculate" and get back on route.

Summative assessments, on the other hand, provide evidence that students have made it to the finish line. A summative assessment can be as simple as an exit ticket[12] at the end of the lesson or a chapter exam covering multiple lessons.[13]

## Guide the Journey: Sequencing the Lesson

You've determined your objective, communicated it with your passengers, and created your assessments. Knowing where you are going is half the fun! You're ready to plan *how* to get there—which includes the materials you'll use and the different paths you'll take. You'll double-check that you've packed enough gear and take note of those travelers who may need alternative provisions.

We recognize that you can't always control the curricula you teach, but you can choose the best strategies to use in helping students learn. Your hiker-type learners may opt for a more scenic route, while your race cars may speed ahead in the fast lane. Differences in working memory capacity, as well as prior knowledge, mean differences in learning speeds. Likewise, some travelers may prefer to go it alone for stretches of the journey, while others will travel best in pairs and small groups.

## The Bell Ringer

Start class on time. When students enter your classroom, they need to get busy. This task is often referred to as the bell ringer, or as Doug Lemov terms it, “Do Now.”[14] Although the task varies, the bell ringer should be posted in the same location every day so that students know instantly what they need to do. The bell ringer then becomes habit and gets students on “your time.” If you allow students to catch up with their friends or go to the bathroom during the first few minutes of class, they are on “their time” and it wastes *all* students’ instructional time as you work to get everyone on task.

Use the bell ringer to review or preview. Some teachers have students get their homework out from the night before to compare two or three specific responses with their partner. Other teachers may have students write a gist response to the day’s focus question. Whether you are reviewing or previewing, students should be able to work on the bell ringer independently, while in their seats. As your students work, use these few minutes to greet other arriving students at the door, visually take attendance, and adjust your materials—all of which takes place during the transition time between classes and no more than three to five minutes into the start of class.

### **TEACHING TIP:** PROCEDURES

Teaching procedures during the first week of school saves instructional time and establishes effective classroom management throughout the year. Many of these procedures involve the creation of habits–that is, actions or reactions cued into the procedural learning system. This means students do what they need to do automatically, without thinking about it.

Consider teaching procedures for:

- Entering class and completing the bell ringer
- Distributing or collecting materials
- Going to the bathroom or getting a drink
- Listening to and responding to questions

- Forming groups
- Submitting work

## The Hook

Not every student will be excited to learn what you are teaching. You need to capture their interest and make the lesson relevant. Just as with a good framing question for the lesson plan, a good hook can spur those spurts of dopamine and make what you are teaching stick. Good hooks provide anticipation of an *unexpected* surprise payoff—which means your hooks should vary. (This isn't easy, but who said teaching's easy!) The good thing is that you can reuse your hooks from class to class or year to year, fine-tuning and improving them. You can also mine the gold you see in other teachers' classrooms. If a colleague has a great hook, why not put it into action in your own classroom?

Effective hooks tap into what students already know and connect to the critical content you are about to teach. To hook our students into a math-based physics lesson, connect it to space travel focused on time, distance, and the task of getting astronauts to Mars. When you present a challenging real-life problem to solve, the students will be more enthusiastic (especially those students who dream of becoming astronauts!).

You can also think of hooks as trailers designed to get us to watch the movie. To hook our students into our lesson on how Poe uses imagery to create mood, for example, we may actually show the trailer of a current scary movie and ask students what images and effects make the trailer so terrifying. It helps if you model becoming excited when *you* watch the clip, even if you've seen that clip a dozen times before. Brief, one- to two-minute multimedia clips are particularly effective with our twenty-first-century learners. Be sure to establish the purpose for viewing the clip before hitting the play button. Follow up with a clear connection to the upcoming lesson.

Everyone should participate in the hook; don't just ask a thought-provoking question and call on one or two students. You might have everyone jot their answer before soliciting verbal responses through a whip-around. Or have students post their written response to an online collaborative whiteboard, like Jamboard, for all students to see.

Once you've baited the hook, so to speak, now's the time to reel in your learners and prepare them for what's to come. Transition to the focus question and agenda, a projected to-do list that relieves the heavy demands on working memory for both you and your students as you navigate the lesson. It is also helpful if the agenda includes the materials the students need to have out on their desks.

### **TEACHING TIP:** EXAMPLE HOOK FRAMEWORKS

The devil is in the details when it comes to creating a good hook. These example frameworks may spark ideas.

- Present an intriguing real-world problem or case study.
- Provide students with a provocative or even funny quotation related to your lesson and have them share their thoughts.
- Conduct a quick experiment and leave them hanging.
- Poll your students to put the lesson into a real-life context and make it personal.
- Solicit student volunteers to act out a role-play.
- Provide examples and non-examples of the concept you're about to teach and have students notice the similarities and differences.

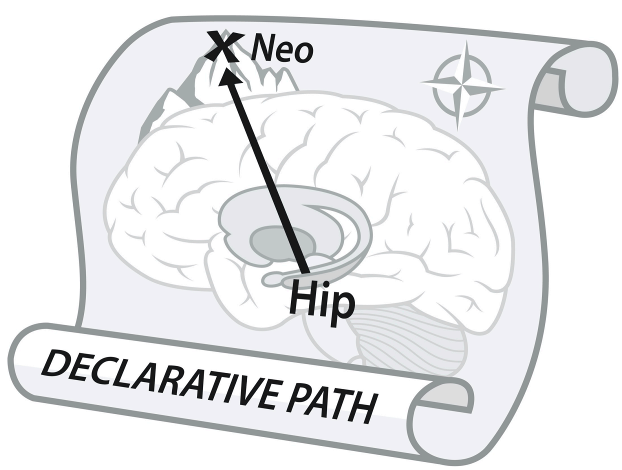
## The Lesson Body: Learn It, Link It

We suggest you start out in the driver's seat to support your students as they first *learn it*. Once students have shown they understand the terrain and can navigate themselves, let them take over the wheel and *link* to new paths. Of course, they're never completely on their own—in student-directed learning, you become the backseat driver.

Students generally learn unfamiliar *hard stuff* best through the declarative pathway. In the declarative path, working memory delivers new information to the neocortex with the help of the hippocampus.

When we explain to our students what they are learning and demonstrate step by step what to do, we target the declarative pathway. Students *learn it* during the initial phase of direct instruction: “I do, we do.” They are conscious of the new learning and are primed to begin the process of making connections between neurons.

As you transition into the body of the lesson, ease your students into the new material. Start by tapping into and building upon your students’ prior knowledge. Students may have a schema already in place for the concept you are about to teach. New information can be assimilated and stored rapidly when it is tied together with preexisting knowledge and experiences. If prior knowledge is nonexistent, now is the time for you to create it. Students need this transition time to acclimate because they can quickly become overwhelmed. It’s like diving right into the deep end of an ice-cold pool. Most people find it less jarring to wade in gradually. Ahead are several strategies and tips to consider as you lead your students into learning.




The declarative path climbs to the top of the mountain (long-term memory in the neocortex) via the hippocampus.

**Think-aloud.** As you present new material, make your thinking visible to your students. Verbalizing your thought processes helps your students understand how to approach a similar complex task.[15] Anticipate stumbling blocks your students may have and model how you tackle tricky problems. Students generally know that error is part of learning. What they *don't* know is how you will react to their error. Will you embarrass them? Once they see they're in safe hands even if they err, they'll be more willing to take risks and see the value in their own mistakes.

**Beware of excessive teacher talk.** It seems like common sense that the more content teachers cover, the more students learn. But as an uncommon sense teacher, you know this isn't necessarily true. Some teachers take a deep breath, start talking, and keep talking and talking until the bell rings.[16] While there is no definitive time limit on teacher talk, a good rule of thumb for elementary students is to teach for five minutes and pause for one minute of retrieval practice. For upper middle and high school students, teach ten minutes and spend two minutes retrieving the information. These pauses in your instruction are essential for speeding up the consolidation of neural links in the neocortex.

**Plan your questions.** Teachers ask hundreds of questions each day, the majority of which are low-level recall questions. We ask these quick questions to make sure our students are paying attention and to maintain the pace of our lesson. Don't be fooled into thinking these quick recall questions woven throughout our instruction replace deeper, more thoughtful retrieval practice. Both types of questioning are essential to learning. When students are new to a concept—during the early stages of direct instruction—comprehension questions are important to ensure that students have a literal understanding of the material. "Low-level" recall thinking, after all, is a prerequisite to higher-level thinking.

But questions need to advance with layers of complexity. With some advanced planning, you can frame questions that open dialogue among students that go beyond surface level knowledge.[17] Try talking less and listening more by purposely planning open-ended questions that build conceptual understanding. For example, instead of (or after) asking, “How many centimeters are in a meter?” ask “What are two lengths of centimeters that together equal the length of one meter?”

**Show-and-tell.** Pair your explanations with multimedia instruction.[18] A one-minute video clip of the human respiratory system in action can be far more effective than a wordy description. Multimedia works because it allows working memory to hold both verbal and pictorial information—which means it’s less likely to be overloaded.

When it comes to incorporating multimedia into your lessons, Mayer offers a few tips:[19]

- Before viewing, pretrain students on what is ahead—including vocabulary, diagrams, events, and other essential information.
- During viewing, provide students with a way to organize new information. Supply students with guiding questions to help them retain more information.
- Break the multimedia into manageable segments.[20] Stop the presentation to give students a moment to consolidate one segment before moving on to the next.

**Note it.** Note-taking, once students know how to do it, improves learning.[21] It doesn’t matter if students are listening to you, participating in a discussion, watching a video clip, or reading an article—all of these require some form of note-taking. Provide students with note-taking cues along the way—for example, “We are going to talk about the similarities and differences between the organization of the federal and state government. Please draw a T-chart[*] with similarities on one side and differences on the other.” Or “We are going to describe three characteristics of honeybees. Please create a numbered list in your notebook.”

For more experienced note takers, your cues may be enough. Less experienced students benefit from guided notes to increase listening skills and improve their note-taking accuracy and organization—all of which improve student recall.[22] Your support in note-taking may take the form of a skeleton outline for students to complete as your lesson unfolds.

**Chunk it.** Most students can hold a maximum of four pieces of information in working memory at a time. When working memory can't keep up, students shut down and tune out. Instead, break your content and skills into bite-size, digestible chunks.

Below are a few suggestions for making information easier to process and remember during instruction. Have students:

- Identify similarities and differences.
- Convert a long list of information into subcategories.
- Create a graphic organizer—for example, a flow chart, a table, a timeline, steps in a process, or a Venn diagram.

**Put the brakes on your race cars.** When soliciting feedback, avoid being fooled by the race cars, who get (or at least think they get) the material swiftly. It is hard to resist their waving hands, but they are not representative of all your students. You want to make sure *everyone* understands—which means reaching beyond eager volunteers. Having all students write briefly—perhaps by completing a well-constructed sentence stem—can be an excellent way of assessing *every* student's level of comprehension.

**Get moving.** We have said that you can't teach from your seat. It is also ill advised to keep predictably fixed at the front of the room. Instead, move among your students. Use a remote clicker to advance your slides or allow students to write key points on the board for you. When you're mobile in the classroom, you will more easily notice off-task behaviors and can use your proximity to derail misbehavior. Traveling around the classroom also makes it more likely that you will notice where sticking points are for your students because you can more easily look down at their notes and are close enough to pick up on their nonverbal cues. In addition, circulating energizes you—it helps with blood flow through the brain, which improves cognition. And getting moving is a good way to get ideas!

**Retrieve it.** We frustrate our students when we expect them to demonstrate independent mastery, but we haven't provided enough teacher guidance and corrective feedback for them to launch independently. Frustrated students tune out or act out. Instead, encourage ample retrieval practice under your watchful eye. When students remember the steps of a procedure or practice a new skill, they are strengthening their neural links.

Through the preceding chapters, we have shared a variety of active learning techniques (*think-pair-share, whip-around, recall,* and *muddiest points*) that give students retrieval practice. But we know that students—and teachers, too—crave novelty. As you teach each chunk of content, try these formative assessments to add variety to your repertoire of retrieval techniques:

- **Have students create a foldable to capture key points as you teach the lesson.** Foldables are 3-D student-made graphic organizers that they can later use to quiz themselves.
- **Provide students with three to four key words you have used thus far in the lesson.** Have them use the words to create a one-sentence summary with a partner. Then have one person from each pair share their sentence with the class whip-around style. A whip-around allows students to hear the information repeated in different ways.
- **Have students provide a list of three concepts or terms that a fellow student might misunderstand.**
- Use individual whiteboards or a laminated piece of white paper with dry-erase markers for students to **complete multi-step problems or answer higher-level questions.**
- **Have students draw** what they understand instead of, or along with, writing it.
- **Play a brief tune and have students dance or march around the room** (depending on the age of your students, of course). When the

song stops, each student sits at a different desk to check each other's notes and provide feedback.

- **Have students participate in a "snowball" fight.** Students work on one problem on a worksheet with five to ten problems on it. They crumple the paper into a ball and throw it like a snowball. Give the students ten seconds to grab a snowball and return to their seat to check each other's work and complete the next problem. Repeat the exercise until the worksheet is complete. After you've reviewed all the problems together, hold up a recycling bin so they can throw in the crumpled papers.
- **Create a word diagram to organize key content area vocabulary.** Set the diagram up like a table with terms listed down the first column. The top row includes your choice of the following headers: *What It Means, What It Looks Like, Key Attributes, Example(s),* and *Non-example(s).*
- **Tech-savvy teachers and students use apps and websites** like Kahoot!, Quizzlet, and Nearpod to quiz students. Once routines are established with students for using these tech tools, they can smoothly incorporate retrieval practice.

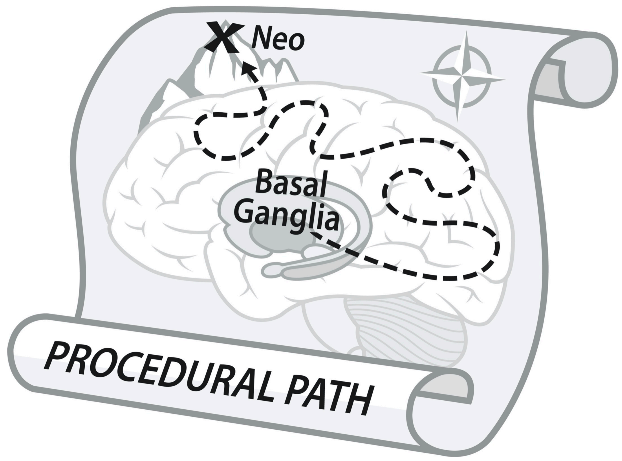
**Thumbs-down on thumbs-up.** After some teachers present a chunk of information, they may ask the class to give them a thumbs-up for understanding before proceeding with the lesson. Be wary of using such hand signals. Novice students who have a track record of success can be overconfident in their abilities and prematurely give you a thumbs-up. Uncertain students will not want to look dumb in front of their peers. If and when you feel you must use hand signals, try having students close their eyes or put their heads down so they can't see one another's signal.

**Prevent it.** Preventing problems before they happen can go a long way to creating a safe and productive classroom environment. If you know Joy and Colleen are best friends, do not seat them next to each other. Think of yourself when you attend professional development workshops and sit next to your favorite colleagues. You can't help but talk to one another, which distracts others and prevents them (and you) from learning.

The learning cycle repeats itself until students have become proficient with the foundational content and skills. Ideally this would occur at the same time for everyone—but that rarely ever happens. We know our hiker-type students will need extra practice and different levels of coaching or support, while our race-car-type students will be ready to move on to more independent student-directed learning activities. As students reach proficiency, they become ready to *link it*—where they work to reinforce and extend their neural links.

Oftentimes, students need to switch neural paths to *link it*. To make learning stick, the information that students have learned through their declarative pathway needs to be reinforced with the backup information in the procedural system. Information comes in through the senses to the basal ganglia and heads straight to the neocortex. Sounds quick and easy, right? Not so fast. We have learned that taking the procedural route often requires steady, repeated practice, and can take time.

**Mix it.** Although taking the procedural pathway requires plenty of practice, it's not just any practice. Regurgitating the same information in the same context doesn't make our students independent or resilient thinkers. Instead, practice needs to be interleaved within topics. Interleaving requires students to constantly retrieve information, tease out general rules, and use those rules in a variety of situations. If we return to our lesson on Poe's use of imagery to convey mood, we can mix it up by having our students search for examples of imagery used to establish mood from other short stories that they've read. Or, keeping within "The Tell-Tale Heart," we can ask our students to locate and explain the effects of other literary devices they've studied previously.




The procedural pathway climbs to the top of the mountain (long-term memory in the neocortex) through the basal ganglia.

**Space it.** Lessons are not one and done. Learning requires carry-over. Remember, lesson plans don't have to be written to fit a forty-five-minute block of time. The type of retrieval practice needed for long-term retention needs to infiltrate into other lessons. It's sort of like returning to your favorite lookout before you venture farther on your journey. You keep moving forward, but you revisit key stops mentally to hold on to the memory longer.

Warning: Interleaving and spacing—the types of practice students need to *link it*—create desirable difficulties that students may resist. Students resist this type of practice because it is frustrating. It often leads to more errors during the learning process. Making sure students have a firm foundation during the *learn it* stage of the lesson is key to reducing their anxiety when they *link it*.

**Extend it.** The goal of learning is for students to be able to extend their new knowledge and skills to new situations. When students' neural links are strong, they are ready to move on to more independent approaches to learning. Student-directed learning needs minimal guidance from the teacher. In essence, students take the wheel and drive their own learning. But the teacher isn't left behind; instead, she is more like the backseat driver, interjecting when the driver runs off course.

Sample student-directed extension activities:

- ☐ **Contribute to a class Padlet.** (What is Padlet? Think of it as an online corkboard for the class.) For example, after studying a unit on poetry, students can locate photos to represent symbols used in each of the poems in the unit and explain their significance.
- ☐ **Create a brief video using Screencastify** (or a similar screen capture program) to recap what was just learned and how it can be used in a different way. Screen capture programs allow students to record themselves presenting along with any applications on their desktop. Having students explain new uses of material promotes the transfer of knowledge to novel situations. As a follow-up, other students can offer informed critiques on the accuracy of information and their peers' innovative application of the material.
- ☐ **Develop higher-order test questions on what was learned.** Have students test their questions with other students and revise as necessary. Then have students upload their questions to Quizizz to share with the rest of the class. Quizizz allows students to anonymously see how their responses compare to the rest of the class.
- ☐ **Prepare for a debate by researching the opposing sides** of a controversy surrounding the topic being studied.
- ☐ **Complete a WebQuest that extends the content and skills** learned in the lesson.[23] First, the teacher presents an open-ended problem for students to solve. Students arrive at their own solution by using preselected websites that allow them to navigate the material.
- ☐ **Solve a real-world problem.** For example, after studying waterborne diseases and illnesses, have students take on the role of a budding epidemiologist investigating a disease outbreak.
- ☐ **Write a different ending to the story** they have just read or embed themselves as an additional character.
- ☐ **Take a virtual field trip.** After studying animals and their habitats, have students observe the animals in their natural environment via

a webcam. Students act like a scientist as they record their observations, develop questions, notice similarities and differences, and draw conclusions.

- ☐ **Evaluate a controversial aspect of the topic** being studied across multiple sources. Students create a graphic organizer to showcase the similarities and differences among sources, paying particular attention to word choice and missing information.

**A word of caution.** Planning *effective* student-directed learning activities isn't for the faint of heart. Such instruction requires significant prep work. Be careful not to be seduced by "Pinterest planning"—that is, using arts and crafts as an extension activity. All too often, dioramas, booklets, posters, and PowerPoint slide shows look pretty but haven't extended students' neural pathways. One surefire way to check the merit of your self-directed activity is to circle back to the *standards*. Double-check the verbs in the standards against what you're actually having your students do. *Recalling* the sequence of events in a story is much different from *analyzing* different characters' reactions to a shared experience presented in the story. If an activity isn't aligned to the standard, it may need to be eliminated.

## Closure—The Most Neglected Part of the Plan

Too often we teachers get so engrossed with the lesson that we lose track of time, and before we know it, mere seconds of class time remain. Students hear the bell, quickly pack up, and shuffle off to their next class. In chapter 3, we explored how important consolidation is to the learning process—brain breaks are vital. This means that just before class ends, you and your students need a moment to take a figurative breath while you wind down, recap what has been done, and preview what is to come.

**Review it.** Instead of telling your students what they have learned (after all, you already know this), have *them* tell *you*. Call on multiple students throughout the room. When they use new vocabulary, ask another student to tell you what it means and provide examples. When they tell you what they did, ask follow-up questions: What did you learn? How does it build upon your previous knowledge? How will you use this knowledge or skill? Have another student and then another add to each response to build comprehensive answers.

**Prove it.** The exit ticket is a simple summative assessment for the day's lesson. It lets you know if each student made it to the final destination. The simplest exit ticket is to have students answer the focus question you asked at the start of class and reinforced throughout the lesson. When creating exit tickets, keep in mind that writing cohesive thoughts in a brief period of time is really difficult, especially for students with lesser-capacity working memories. Asking students studying the Civil War to write down everything they've learned over the last two days about slavery is overwhelming and unlikely to be productive.[24] Even a more specific question like "How did the Confederates challenge the Union Army?" can be a struggle for students to tackle. For these students consider using sentence stems that require students to recall and analyze important information that has been taught—for example, "The Confederate cannons were less powerful than the Union's cannons, but the Confederates were _________________."

For the teacher who teaches over a hundred students daily, saving tickets until the end of the day and reading them at night can be overwhelming. Instead, check tickets before your students head out the door. Circulate through the rows at first and then move toward the door to catch the stragglers before they run out. Checking exit tickets before students leave class ensures that students don't leave with misinformation.

To continue to stoke the fire of excitement for learning (even in the waning minutes of class), try using colorful Post-it Notes where students jot down their responses and stick them to the window or wall.[25] It's a quick way to assess multiple students at once, and you can easily pluck wrong answers from the batch and meet with select students to provide clarification. You can also use different colors for different classes, or different groups within the same class.

If you want to avoid using all those paper sticky notes, try a tech alternative that is easy on the environment. Switch to an electronic format

—have students Tweet their exit ticket to you and project it on the board for the class to review.[26] Tweets are short messages of up to 280 characters—so students will have to be succinct with their responses. Twitter isn't your only tech option—for example, Google Forms has an Exit Ticket template you can use to create your own exit tickets that students complete and submit electronically.

## At the Finish Line

Finally! You have reached your destination. But don't break out the confetti and champagne just yet. There is work to be done once you arrive. Now is the time for you *and* your students to reflect on where you have been—including the breakthroughs and detours along the journey.

**Self-assess before shifting gears.** At the end of a unit or project, look back and consider the learning *process*. One quick method to have students examine their path and performance is to have them complete a *glows* and *grows* T-chart. Glows and grows offers a balanced approach to feedback, where one side of the T-chart is labeled *Glows* and the other side is labeled *Grows*. Glows provide students with an opportunity to comment on areas where they shined. They concentrate on the strides they've made in their learning, especially in skills they were previously lacking. On the other side of the T, students write about the bumps and roadblocks they encountered along their path and what they did to move forward. Growth requires development in learning—but sometimes there is still a discrepancy between the progress the student made and the distance yet to travel to master the objective. Using what they have written in the growth column, students can create new goals for themselves.

It's particularly helpful to provide sentence starters or questions to get students going. For example, *If I could give myself a score between 1 and 5, I would rate myself . . . because . . .*

Glows

- Before this lesson, I never knew . . .

- Three new discoveries I made . . .
- I used to incorrectly think . . . but now I know . . .

Grows

- I had a difficult time . . .
- One strategy that helped me learn better . . .
- If I could do one thing differently . . .

Goals

- One skill I will practice . . .
- Learning about . . . makes me want to investigate . . .

**Reflect and revise your lesson plans.** It is easy to skip this step. With all the daily demands on your time, you may put off reflecting on and revising a lesson that you may not see again until *next* year. But even just a few minutes and a pack of Post-it Notes can have dramatic effects on your teaching and professional growth. The bullets below will get you started.

- Pinpoint where race cars sped too fast and perhaps even sped off track versus what allowed the hikers to move more swiftly ahead. What scaffolds or enrichment can you add? It can be helpful (and energizing) to brainstorm and generate ideas with a motivated colleague.
- Add to your explanations. We teachers often come up with examples on the fly that work really well. Jot them down so you remember.
- Revise test questions and rubrics. Once we grade a few exams, essays, or projects, we begin to see sticking points for students. Go back and add clarity to your assessments. It can be useful to have a blank copy of the test or rubric with you as you grade so that you can make edits in real time.

Remember, teaching is as much about the journey as it is about the destination. If you're feeling overwhelmed with your list of revisions, don't panic. You don't have to tackle everything at once. Start with one or two changes and make a list that you can return to when you have a minute to catch your breath—say, winter or summer break.

**Celebrate.** Now you are ready to bask in the sunshine of success. Take a minute to celebrate your students' achievements—they are yours, too! It can be as simple as a high five for a job well done, a personal kudo on a Post-it, or a positive email home. You can have the best intentions to remember, but time will slip away from you, so you need to do it while it's fresh. Apps like Bloomz and ClassDojo allow you to share pictures and praise with parents efficiently.

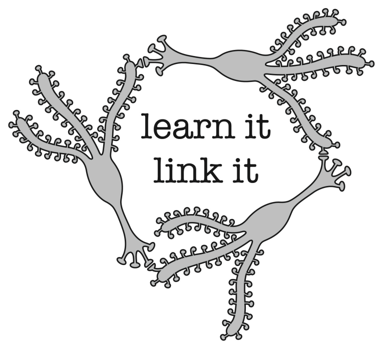
## A Big Thank-You to You—Our Uncommon Sense Teacher!

Take a moment to pause now and to celebrate your own achievements in finishing this book! We mentioned that *Uncommon Sense Teaching* may sound like a presumptuous title. But as you've come to understand how the brain learns, you've seen how teaching isn't a commonsense job that just anyone can do. Effective teaching requires counterintuitive insights and an understanding of some of the fantastic complexities of the human brain.

Leonardo da Vinci invested significant time in the sciences to create his artistic masterpieces. He studied anatomy to understand musculature, physics to understand how light reflects off subjects, and chemistry to create the perfect paints. Behind the scenes, Leonardo filled thousands of notebook pages with sketches and explanations. Teaching is an *art*—and science has led you to a richer understanding of how to express *your* art. You fill your notebook pages with lessons and strategies. You are not unlike Leonardo—using science to perfect your craft.

Like the conductor (but with better memory!), you interpret the score, set the tempo, listen critically, and adjust the beat to shape the performance of your ensemble—that is, your students. You orchestrate information, supplies, and strategies to lead students into better ways of mastering content and skills. Working memory versus long-term memory, procedural versus declarative pathways, student-directed versus teacher-directed, online versus face-to-face—your understanding of the broad spectrum of how people learn comes at the culmination of decades of exploration from research giants. And your own extraordinary work at the front lines of learning is helping form a brighter future for us all.

# Farewell and Hello!




We like to think of our *learn it, link it* approach as much more than the science of neurons linking together to master new skills and uncover deeper understandings. We've come to appreciate the community aspect of *link it*. Link it means strengthening connections among supportive educators who encourage one another to extend their skills. Want to experiment with a new instructional strategy? Link with another teacher and compare results. Need ideas to hook your learners into a lesson? Link with a colleague to brainstorm ideas. Struggling to differentiate your material? Link with a special educator. Challenged by student resistance? Link with the student, the guidance counselor, and the parents. Trying to keep up with the ever-changing demands of the profession? Link with professional development opportunities, administrators, and online communities.

Much like neurons, Barb, Beth, and Terry have linked together from vastly different backgrounds to provide you with the most helpful broad-ranging perspectives. Now it's your turn to *link it,* too! The more you link, the more you learn. You're not just a teacher now—you're a teacher with uncommon sense.

This book has been a labor of love for all three of us coauthors. We are grateful that you've joined us in understanding the revolution that is happening in the art and science of learning. May you and your students link together to be *active*, joyous learners, always!

# Appendix A: How to Manage Yourself in a Collaborative Team[1]

You will usually find your teammates as interested in learning as you are. Occasionally, however, you may encounter a person who creates difficulties. This handout is meant to give you practical advice for this type of situation.

To begin with, let's imagine you have been assigned to a group this marking period with three others: Mary, Henrietta, and Jack. Mary is okay. She struggles with some of the more difficult material, but she tries hard, and she willingly does things like getting extra help from the teacher. Henrietta is irritating. She's nice, but she just doesn't put in the effort to do a good job. She'll sheepishly hand over partially worked homework problems and confess to spending the weekend watching TV. Jack, however, has been nothing but trouble. Here are a few of the things he has done:

- Jack infrequently turns in his part of an assignment. When he does, it's almost always wrong. He obviously spent just enough time to scribble something down that looks like what it's supposed to be.
- He is off task or flees whenever the group works together, either in person or virtually. He always seems to be out of his seat for some reason—needing to go to the bathroom, getting a drink, covertly distracting other students in the class.

- When the group communicates outside of class, he ghosts them and later claims he never received any messages. If the group decides to meet before or after school, he has a litany of excuses as to why he can't meet.
- Jack's writing skills are okay, but he loses the drafts and doesn't reread his work. You've stopped assigning him work because you don't want to miss your teacher's strict deadlines.
- He speaks loudly and confidently when you try to discuss his behavior. He is convinced the problems are everyone else's fault. He is so self-assured that you sometimes find yourself thinking he's right.
- Worse yet, whenever the group has to present to the class, Jack jumps at the chance to take the lead. He is a smooth talker and presents the group's ideas and work as his own.

Your group finally was so upset they went to discuss the situation with Mr. Meanswell, your teacher. He in turn talked to Jack, who sincerely and convincingly said he hadn't understood what everyone wanted him to do. Mr. Meanswell said the problem must be that the group was not communicating effectively. He noticed you, Mary, and Henrietta looked angry and agitated, while Jack simply looked bewildered, a little hurt, and not at all guilty. It was easy for Mr. Meanswell to conclude this was a dysfunctional group, and everyone was at fault—probably Jack least of all.

The bottom line: You and your teammates are left holding the bag. Jack is getting the same good grades as everyone else without doing any work. . . . and he has managed to make you all look bad while he was at it.

## What This Group Did Wrong: Absorbing

This was an "absorber" group. From the very beginning, they absorbed the problem when Jack did something wrong and took pride in getting the job done whatever the cost. However, the nicer you and your teammates are (or the nicer you think you are being), the more you are allowing Jack to take advantage of the group. By absorbing Jack's problems, you are inadvertently training him to become the kind of person who thinks it is all right to avoid his share of the work and take credit for the work of others.

## What This Group Should Have Done: Mirroring

It's important to reflect dysfunctional team behavior, so the ones causing the problems pay the price, not their teammates. Criticism can help you grow as a person, but there will also be a few people who will unfairly accuse, blame, or criticize you—even saying things so untrue that you can't believe what you're hearing. (This is called *gaslighting* after the 1944 film *Gaslight*, in which a sinister character tries to make the heroine doubt her perception and lose her sanity by denying he could see what she saw.) You must maintain your own sense of reality despite what you may be accused of. Show you have limits to the behavior you will accept. Communicate these limits and act consistently on them. For example, here is what the group could have done:

- When Jack didn't respond to the group's messages or couldn't find time to meet in his busy schedule, even when alternatives were suggested, someone needed to talk to the teacher. The group shouldn't have wasted their time continuing to try to get him to meet.
- If Jack turns nothing in, his name does not go on the finished work. (Note: If you know your teammate is generally a contributor, it is appropriate to be supportive if something unexpected arises.) Many teachers allow a team to "fire" a student, so the student has to work alone the rest of the marking period. Discuss this option with your teacher if the student has not contributed over the course of an assignment or two, or as part of the project.
- If Jack turns in poorly prepared homework or projects, you must tell him he has not contributed meaningfully, so his name will not go on the submitted work. *No matter what Jack says, stick to what you say!* If Jack gets abusive, show the teacher his work. Do this the *second*

*time* the junk is submitted, before Jack has taken much advantage—not after a month, when you are really getting frustrated.

- Set your standards early and high, because people like Jack have an uncanny ability to detect just how much they can get away with.
- The only one who can handle Jack's problems is Jack. You can't change him—you can only change your own attitude so he no longer takes advantage of you. Jack will have no incentive to change if you do all his work for him.

People like Jack can be skilled manipulators. By the time you find out his problems are never-ending and he himself is the cause, the marking period has ended, and he is off to repeat his manipulations on a new unsuspecting group. Stop allowing these dysfunctional patterns early in the game—before Jack takes advantage of you and the rest of your group!

## Henrietta–Taking Things Easy

Although Henrietta stood up with the rest of the group to try to battle against Jack's irrational behavior, she also hasn't been pulling her weight.

The best way to deal with someone like Henrietta is the way you deal with someone like Jack: set firm, explicit expectations. Although students like Henrietta are not as manipulative as students like Jack, they will definitely test your limits. If your limits are weak, you then share the blame for having Henrietta's work to do as well as your own.

## But I've Never Liked Telling People What to Do!

If you are a nice person who has always avoided confrontation, working with people like Jack or Henrietta can assist you in growing as a person and learning the important character trait of firmness. Just be patient with yourself as you learn. The first few times you try to be firm, you may find yourself thinking, *But now they won't like me—it's not worth the pain!* Many people just like you have had precisely the same troubled reaction the first times they were firm. Just keep trying, and *stick to your expectations!* Someday it will seem more natural, and you won’t feel so guilty about having reasonable expectations of others. In the meantime, you will find you have more time to spend hanging out with your friends or participating in after-school activities because you aren’t doing someone else’s work along with your own.

## Common Characteristics That Allow Others to Take Advantage

- You like to make others happy, even at your own expense.
- You are willing to repeatedly make personal sacrifices so as not to abandon a teammate—without realizing you are devaluing yourself in this process.
- You can cooperate but not delegate.
- You interpret the slightest improved contribution as “progress.”
- You are not willing to allow someone else to fail and subsequently learn from their own mistakes.
- You are devoted to the idea of “the good of the team”—without the commonsense realization that this attitude can allow others to take advantage of you.

## A Related Circumstance: You’re Doing All the Work

As soon as you become aware that everyone is leaving the work to you or producing such shoddy work that you are left doing it all, you need to take action. First issue a formal verbal warning to your teammates, and if that doesn’t work, go to the teacher and request to be moved to another group. (You cannot move to another group on your own.) Your teacher will probably ask some questions before taking the appropriate action.

## Later—Out on the Job and in Your Personal Life

You will meet people like Jack and Henrietta throughout your life. People like Henrietta are relatively benign and can even become your friends. However, people like Jack can work their way into your confidence and then destroy it through gossip and gaslighting. If you encounter that situation, it will help if you keep in mind the techniques we've suggested.

# Appendix B:
# Master Teacher Checklist

It's not uncommon to create a checklist filled with to-dos and reminders as you pack for a trip. As your teaching tour guide, we've created a master teacher checklist to help you remember the key ideas behind creating a great lesson. This checklist will allow you to sequence the journey and assist you in making instructional decisions along the way.

**1. Bell Ringer**

- ☐ Found in the same location every day
- ☐ Reviews or previews key information, vocabulary, or skills
- ☐ Completed independently upon entry
- ☐ Lasts no more than three to five minutes

**2. The Hook**

- ☐ Captures students' attention
- ☐ Includes active participation by *all* students
- ☐ Asks and unpacks the focus question—which mirrors the expectations of the objective
- ☐ Provides a projected to-do list for the lesson
- ☐ Transitions to the body of the lesson

**3. Learn It**

- ☐ Connects prior knowledge with new information
- ☐ Incorporates teacher modeling and a variety of examples to support explanations
- ☐ Verbalizes thought processes when tackling complex tasks
- ☐ Chunks content into manageable segments so as not to overwhelm students' working memory
- ☐ Provides note-taking cues or structure to help students organize important information
- ☐ Includes embedded retrieval practice and formative assessment checks for each chunk of content
- ☐ Asks deeper-level open-ended questions to build conceptual knowledge
- ☐ Integrates multimedia—previewing with students first, providing guiding questions, and stopping intermittently for questions and clarifications

**4. Link It**

- ☐ Interleaves or mixes practice between topics and contexts
- ☐ Embeds retrieval practice of previous learning into new learning to reinforce learning over time
- ☐ Extends students' knowledge and skills to novel problems and tasks through student-directed learning opportunities

**5. Close It**

- ☐ Reviews lesson by having *students* highlight key learning, provide examples, and explain how new knowledge builds upon previous knowledge and skills
- ☐ Holds students *individually* accountable for meeting the objective

**6. Reflect on It (completed by the student with guidance from the teacher as needed)**

- ☐ Self-assesses the learning process through reflection on strengths and progress made on developing skills
- ☐ Sets goals to address skill discrepancies

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# Notes

## A NOTE TO OUR TEACHER-READERS

1. People often use unhelpful ways of teaching and learning: Pan and Bjork, in press, also note "A variety of research findings suggests . . . that human beings are prone to carrying around a mental model of learning and memory processes that is inaccurate and/or incomplete in some fundamental ways."
2. Claims of growth mindset outweigh the evidence: Bahnik et al., 2017; Burgoyne et al., 2020; Gandhi et al., 2020; Sisk et al., 2018.
3. Learning styles-based instruction does not equate to improved achievement: Rogowsky et al., 2015; Rogowsky et al., 2020.
4. More direct insight: Thomas et al., 2019.

## CHAPTER 1. BUILDING MEMORY

1. Research reaffirms that girls and boys have similar math capabilities. But lower-achieving girls can become more anxious than lower-achieving boys about test-taking when it comes to math. This can turn into generalized math anxiety and poor attitudes toward mathematics among the girls whom teachers are trying hardest to assist. Geary et al., 2019b; Gonzalez et al., 2019.
2. The modern version of the Hebb synapse is *spike-timing dependent plasticity*. This fancy term simply means that the type of signal going across the synapse can strengthen or weaken that synapse, depending on the amplitude of the signal at the time it arrives at the synapse (among other factors). (Sejnowski, 1999.)
3. For a more complete history of Hebbian learning, see Sejnowski, 1999.
4. Although not a rigorous source, an overview of the most recent findings related to how dendrites emerge and meet axons can be found here: https://en.wikipedia.org/wiki/Dendritic_filopodia.
5. Recent overview of memory and consolidation processes: Runyan et al., 2019.
6. What we call *sets of links* is in general the same as the concept of the *engram* in neuroscience. In reality, a single memory—say, for how a face looks—can have links in different locations in the brain, even including the amygdala, which links the engram to affective (emotional) associations (Josselyn and Tonegawa, 2020). We want to avoid getting too involved here, so we show the sets of links as contiguously located in the neocortex. Also, every time you revisit a set of links in long-term memory (that is, you remember something), it seems you are tweaking the connections —part of the process of reconsolidation. That's why the story you might have told about Uncle Fred's pratfall when you were ten years old can morph to a very different story when you retell it yet again in your thirties. For our purposes, we will consider the tweaks that might happen

through reconsolidation to be minor. For an overview of reconsolidation processes, see Elsey et al., 2018.

7. The variability effect: Likourezos et al., 2019.

8. Overviews of current conceptions of working memory: Cowan, 2017.

9. Illusions of competence in learning: Koriat and Bjork, 2005.

10. Retrieval practice is important for learning: Karpicke, 2012; Smith et al., 2016.

11. Students need to be taught the importance of retrieval practice: Bjork, 2018; Karpicke and Grimaldi, 2012.

12. The importance of working sample problems: Chen et al., 2015.

13. Faster isn't necessarily better when it comes to learning: Hough, 2019.

14. Active retrieval promotes meaningful learning: Karpicke, 2012.

15. The idea that mental images, along with verbal information, can help with learning—"dual coding theory"—was first posited by Allan Paivio of the University of Western Ontario in 1971. Richard Mayer's multimedia theory expands greatly on work in this area: Mayer, 2014a.

16. *Powerful Teaching:* Agarwal and Bain, 2020.

17. Retrieval practice produces more learning than elaborative studying with concept mapping: Karpicke and Blunt, 2011. On a side note, one recent study incorporated retrieval practice *with* concept mapping: O'Day and Karpicke, 2020. Surprisingly, it didn't help.

## CHAPTER 2. TEACHING INCLUSIVELY

1. Two types of mind: Hayek, 1978.

2. Cajal told the story of his life in Ramón y Cajal, 1989.

3. Cajal's reflections on his success: Ramón y Cajal, 1989, p. 309.

4. Review of neurocognitive architecture of working memory: Eriksson et al., 2015. There are dozens of different definitions of working memory. See Baddeley, 2003; Cowan, 2017; Turi et al., 2018.

5. Or, more technically, "interareal phase synchrony in the α-, β-, and γ-frequency bands among frontoparietal and visual regions could be a systems level mechanism for coordinating and regulating the maintenance of neuronal object representations in [visual working memory]." Palva et al., 2010. Ericsson and Kintsch, 1995. Also see Cowan, 2019; Ericsson and Kintsch, 1995.

6. Figure after Gathercole and Alloway, 2007, p. 7, by kind permission of Professor Susan Gathercole, Department of Psychiatry, University of Cambridge.

7. Quote: Gathercole and Alloway, 2007.

8. Example from Gathercole et al., 2006.

9. School psychologists often start with a standard battery cognitive test like the Woodcock Johnson IV. If the student shows deficits, additional tests specific to working memory, like the Wide Range Assessment of Memory and Learning (WRAML2), are given to rule out other issues, such as attention deficits.

10. Some ideas here courtesy Laura Wilde citing McGill, 2018.

11. Alloway and Alloway, 2010, explains that working memory is a relatively pure measure of a child's learning potential and indicates a child's capacity to learn, while academic achievement and IQ tests measure knowledge that the child has already learned. Shipstead et al., 2016, observes: "The strong correlation between working memory capacity and fluid intelligence is due not to one ability having a causal influence on the other but to separate attention-demanding

mental functions that can be contrary to one another but are organized around top-down processing goals." By *fluid intelligence,* Shipstead means the ability to reason through and solve novel problems, as opposed to *crystallized intelligence,* which refers to the ability to put learned knowledge to use (the classic example of this is vocabulary).

12. The creation and strengthening of neural links in long-term memory can extend their working memory on that topic: Cowan, 2019; Ericsson et al., 2018. (What Ericsson terms *neural representations* are largely synonymous with our terminology of *sets of neural links*.)
13. Email correspondence with Barbara Oakley and John Sweller, May 18, 2019.
14. Something that looks like the increase of working memory seems to occur within specific areas of practice: Baddeley et al., 2015. As Baddeley notes: "This is an area that is certainly worth further investigation, but I would not buy shares in it just yet!" p. 92.
15. With practice, a person with lesser-capacity working memory can outshine a person with larger-capacity working memory: Agarwal et al., 2017; Ericsson et al., 2018. Nobel Prize winner Santiago Ramón y Cajal, the father of modern neuroscience, is a sterling example.
16. Expertise reversal effect: Chen et al., 2017; Kalyuga and Renkl, 2010.
17. Jansen et al., 2017, gives a sense of the relationship between note-taking ability and working memory.
18. Restriction of working memory capacity during worry: Hayes et al., 2008.
19. The Individuals with Disabilities Education Act (IDEA) is a U.S. law that makes available a free and appropriate public education for all eligible children with disabilities and ensures special education and related services to those children. There are thirteen recognized disability categories within IDEA. They include (1) Specific Learning Disability (SLD; e.g., dyslexia, dysgraphia, auditory processing disorder, and nonverbal learning disability); (2) other health impairment covers conditions limiting the student's strength, energy, or alertness (e.g., ADHD, which impacts attention and executive function); (3) autism spectrum disorder; (4) emotional disturbance; (5) speech or language impairments (e.g., stuttering); (6) visual impairment including blindness; (7) deafness; (8) hearing impairment; (9) deaf-blindness; (10) orthopedic impairment (e.g., cerebral palsy); (11) intellectual disability (e.g., Down syndrome); (12) traumatic brain injury; and (13) multiple disabilities. U.S. Congress, 2004.
20. A summary of inclusion and co-teaching models: Solis et al., 2012. While specific adaptations and modifications are required by law for some students as mandated by their Individualized Educational Program (IEP) or 504 plan, all students can benefit from some level of support as they learn new and difficult information and skills: Szumski et al., 2017.
21. Multiple models of co-teaching explained: Beninghof, 2020.
22. For an extensive guide to incorporating differentiation into your classroom, see Heacox, 2017.
23. For an in-depth explanation on what differentiation is and isn't as well as the role of the teacher and strategies for managing a differentiated classroom, see Tomlinson, 2017, quote on p. 7.
24. Email correspondence between Beth Rogowsky and Carol Ann Tomlinson, October 6, 2020.
25. Email correspondence between Beth Rogowsky and Carol Ann Tomlinson, October 6, 2020.
26. For more information on the "teaching up" approach: Tomlinson, 2017.
27. Working memory and creativity: DeCaro et al., 2015; Takeuchi et al., 2011.
28. Being tired, which lessens working memory capacity, can increase creativity and insight: DeCaro, 2018; Wieth and Zacks, 2011.

29. Individual differences in working memory predict the effect of music on student performance: Christopher and Shelton, 2017.
30. Neural overlap between math and music: Cranmore and Tunks, 2015. Those with ADHD may benefit from white noise: Soderlund et al., 2007.
31. Cognitive effort during note-taking: Piolat et al., 2005.
32. Note-taking functions and techniques: Kiewra et al., 1991. Review of the cognitive costs and benefits of note-taking: Jansen et al., 2017. Notes should be reviewed the same day: Liles et al., 2018.
33. Impact of instructor-provided notes on learning and exam performance: Gharravi, 2018. For instructions on how to use “handouts with gaps,” another note-taking strategy where students complete omitted sections of instructor provided notes, see Felder and Brent, 2016, pp. 81–84.
34. It’s common for students with lesser-capacity working memory to struggle with math: Clark et al., 2010; Raghubar et al., 2010.
35. For a broad overview, see Dehn, 2008, p. 303, who cites three meta-analyses to conclude: “Direct instruction is considered one of the most effective instructional methodologies for students with working memory deficiencies.” More recently, see Morgan et al., 2015—this massive study involved 3,635 teachers and 13,883 first-grade students attending 3,635 classrooms in 1,338 schools. For a more general discussion of direct instruction versus discovery learning and the impact of these approaches on students, see Klahr and Nigam, 2004.

    As noted in Geary et al., 2019a, “meta-analyses conducted by Geary et al., 2008—and consistent with the results from Project Follow Through (Stebbins et al., 1977)—indicated that students with difficulties in mathematics benefit from teacher-directed instruction (Gersten et al., 2008) that may help compensate for domain-general deficits.” See also Fuchs et al., 2013, and Gersten et al., 2009. There is also a large body of literature involving the benefit for novices of the “worked example effect,” whereby initial guidance using worked problems helps novices (which encompasses those with lesser-capacity working memory) more than providing no guidance. See, for example, Chen et al., 2015; Ramón y Cajal, 1989; Stockard et al., 2018.
36. Practice preferentially helps students with lesser-capacity working memory: Agarwal et al., 2017. Reform mathematics educators observe that student-centered approaches are effective in part because they offer more representations in memory. The challenge is, if those multiple representations are not well embedded in long-term memory, they simply become more confusing for students with lesser-capacity working memory. It’s important to note that there can be effective or ineffective teaching using either student-centered or teacher-directed approaches.
37. Reading comprehension is directly related to working memory capacity: Carretti et al., 2009.
38. The relation between the type and amount of instruction and growth in children’s reading competencies: Sonnenschein et al., 2010; Xue and Meisels, 2004.
39. Active exercises are valuable: Freeman et al., 2014.
40. Reviews of the consolidation process: Runyan et al., 2019; Tonegawa et al., 2018.
41. The worked example effect, the generation effect, and element interactivity: Chen et al., 2015.
42. Finding and fixing erroneous examples improve middle school math students’ understanding of decimals: McLaren et al., 2015.

## CHAPTER 3. ACTIVE LEARNING

1. Study revealing a simple, scientifically validated way to increase test grades and retention rates—active learning: Freeman et al., 2014.
2. “Grecian urn” projects: Gonzalez, 2016.
3. Quote: Freeman et al., 2014.
4. The hippocampus and concept formation: Mack et al., 2018.
5. Quote: Wexler, 2019, p. 31.
6. Example from Wexler, 2019.
7. Learning involves retrieval practice: Karpicke and Grimaldi, 2012.
8. Learning involves two fundamental learning systems: McClelland et al., 1995. (This is a classic paper in the field.)
9. Indexing theory was originally proposed in McClelland et al., 1995. The index code idea was elaborated to explain how a small number of neurons in the hippocampus supports reinstatement of recent memories in the neocortex. Recent confirmatory research in Mao et al., 2018, found that “Indexing theory proposes that, each time an animal has a unique experience, the hippocampus creates a unique pattern of neural activity that it sends to the rest of the cortex. That unique pattern acts like a context code and is stored in different regions of the cortex, along with the raw data the regions are responsible for encoding, such as shapes, sounds and motion. If the hippocampus re-creates that index, it will simultaneously appear in all the cortical regions involved at the time, thereby retrieving the individual parts of the experience to create an integrated memory.” (University of Lethbridge press release, 2018.)

   As you go up the hierarchy of cortical areas in the neocortex to get from the sensory periphery to the hippocampus at the top, the representation is transformed in each layer and becomes more and more abstract. What the hippocampus gets is just a shadow of what is in the neocortex, which has all the details in all of the layers. If the feedback from a very small number of neurons in the hippocampus can activate many billions of cells in the neocortex, that is exactly like an index.
10. The brain places similar categories of information it has learned close together in the neocortex, near the places where that information is ordinarily sensed. So information with a robust sound component is stored in the superior temporal regions (near the primary auditory cortex). Information with a strong visual component is located downstream from the visual cortex. The more abstract, “higher level” the concept, the more it tends to be located toward the front of the neocortex. For a recent, somewhat speculative review of how the brain maps what it’s learning, see Hebscher et al., 2019.
11. The two “learners” are the two complementary learning systems, the hippocampus and the neocortex, described in McClelland et al., 1995.
12. Although not a rigorous source, an up-to-date, fairly readable description of memory consolidation processes can be found at https://en.wikipedia.org/wiki/Memory_consolidation.
13. Hippocampus turns to repeat new learning to the neocortex: Runyan et al., 2019; Wamsley, 2019.
14. Fifteen-minute period of eyes-closed rest following learning enhanced the memory: Wamsley, 2019. See also Craig et al., 2018.
15. Rest during wakefulness may be critical: Wamsley, 2019. (Reference within quote omitted.)
16. Sleep helps fix memories: Antony and Paller, 2017; Dudai et al., 2015; Himmer et al., 2019.
17. New synapses are formed during sleep: Yang et al., 2014. There is also evidence for decreases in synapse strengths during sleep: De Vivo et al., 2017. Some synapses are also pruned during

sleep: Li et al., 2017.

18. Retrieval as a fast route to memory consolidation: Antony et al., 2017.

19. Learning often involves pulling information out of the brain: Agarwal and Bain, 2019, p. 28.

20. Email correspondence between Natalie Wexler and Barbara Oakley, October 11, 2020.

21. BDNF and exercise: Szuhany et al., 2015; Chang et al., 2012.

22. A major review of neurogenesis: Snyder and Drew, 2020.

23. Physical exercise buffers the negative effects of stress on cognition: Erickson et al., 2019; Wunsch et al., 2019.

24. Image loosely after Lu et al., 2013.

25. Freeman et al., 2014. The authors weren't able to tell what percentage of active learning is optimal. As they noted, the time devoted to active learning was highly variable in the studies analyzed, ranging on the one hand from just 10 to 15 percent of class time being devoted to clicker questions, to lecture-free "studio" environments on the other hand.

26. The history of think-pair-share: Kaddoura, 2013.

27. Creating a culture of errors: Lemov, 2015, p. 64.

## CHAPTER 4 . REMEDIES FOR PROCRASTINATION

1. Steel's estimates of procrastination: Steel, 2007. References omitted in the quote.

2. Pain arises in the brain when thinking about the disliked topic—in research by Lyons and Beilock, 2012, the disliked topic was math. Although a part of the insular cortex processes pain signals, the insula has many parts with much broader functions. It is responsible for the overall regulation of homeostatic functions related to basic survival, such as taste, visceral sensation, autonomic control, and the immune system. The anterior insular cortex is involved in social emotions such as empathy and compassion, as well as disgust. This is a fascinating part of the cortex!

3. Sleep and the growth (and pruning) of synaptic connections: Himmer et al., 2019; Niethard and Born, 2019.

4. Owens et al., 2014, found that students with a good working memory did better the more stress they felt. But people with a bad working memory did worse with more stress. The study hypothesized that more stress acted as an additional load on working memory, which didn't bother those with large-capacity working memory because they had enough capacity—but affected the performance of those with lesser-capacity working memory. The authors concluded that work needed to be done to reduce the stress of those with lesser-capacity working memory.

   But it's perhaps likely that those with lesser-capacity working memory didn't prepare properly, and so of course they were more stressed. If this latter supposition is true, then stress-reduction techniques would just make students with lesser-capacity working memory feel better but wouldn't do anything to help their test scores.

5. Why students shouldn't reach immediately for their cell phones or social media: Kang and Kurtzberg, 2019; Martini et al., 2020. This also relates to a concept called *attention residue.*

6. In general, focusing intently, with minimal distraction, is one of the best approaches to learning for students. The challenge is that there are exceptions to the rule. For example, a tiny 2.5 percent of the general population are "supertaskers," those who can efficiently switch their attention between different complex activities. But most people (97.5 percent) are not supertaskers—even while they fool themselves into thinking they are (Medeiros-Ward et al., 2015).

And multitasking, task-switching, and occasional distractions aren't all bad. For example, trying to do two things at once (multitasking) reduces a student's effectiveness on both tasks while those tasks are being worked on—but can increase *subsequent* creativity, as the activated sets of links have more time to mix and meld (Kapadia and Melwani, 2020). Switching between tasks, such as taking a peek at a cell phone while working on a complex problem, can enhance creativity because temporarily setting a task aside reduces cognitive fixation (Lu et al., 2017). And occasional *slight* distracters, such as the background clink of cups in a coffee shop, can assist with learning in part because they can cause the diffuse mode (chapter 4) to pop up temporarily (O'Connor, 2013). The result, again, is a fresh perspective.

7. What we call the diffuse mode is actually a large set of neural resting states, the most well-known of which is the default mode network, which plays an important role in creativity. Kühn et al., 2014.
8. Rubric guidelines that get results: Brookhart, 2018.
9. Rubrics can provide a false sense of security: Wheadon et al., 2020a; Wheadon et al., 2020b.
10. Survey finds less than half of students understand what is required from reading rubrics alone: Colvin et al., 2016.
11. Pairing rubrics with exemplars more effective than rubrics alone: Bacchus et al., 2019.

## CHAPTER 5. HOW HUMAN BRAINS EVOLVED

1. Fast mapping and early language acquisition: Borgstrom et al., 2015.
2. The theory of biologically primary and secondary material was originally conceived by cognitive developmental and evolutionary psychologist David Geary, whose 1995 paper "Reflections of Evolution and Culture in Children's Cognition" first kicked off work in this area (Geary, 1995). See also Geary and Berch, 2016a.
3. Neuronal recycling hypothesis: Dehaene, 2005; Dehaene and Cohen, 2007.
4. The tougher the material, the more a direct instruction approach is needed: See Geary and Berch, 2016b, p. 240, where the authors note: "*We have suggested that structured, explicit, teacher-directed instruction should be most effective when acquiring secondary skills that are remote from supporting primary systems and that take place in a species atypical, classroom context where the goal is oriented toward acquiring knowledge for its own sake* [italics in original]."

   Interestingly, 2012 PISA achievement versus teaching style reveals a pattern supportive of Geary and Berch's supposition. The better the PISA scores, the more likely the country is to use direct instruction. Mourshed et al., 2017.
5. Good references for direct instruction: Boxer, 2019; Engelmann and Carnine, 1982; Estes and Mintz, 2015.
6. The variability effect: Likourezos et al., 2019.
7. Quote from email between David Geary and Barbara Oakley, June 23, 2020.
8. Lesser-capacity working memory benefits from direct instruction: Stockard et al., 2018.
9. 17 Principles of Effective Instruction: Rosenshine, 2010.
10. Students who write answers to guided questions retain more: Lawson et al., 2007.
11. Taking a deeper look at student-centered instruction: Krahenbuhl, 2016.
12. See Geary, 2007, for an attempt to understand academic learning from an evolutionary perspective.
13. Desirable difficulties: Bjork, 2018.

14. Deliberate practice: Ericsson et al., 2018.
15. How and why formal education originated in the emergence of civilization: Eskelson, 2020.
16. With too many options, it's easy to get lost (cognitive load theory): Mayer, 2004; Sweller, 2016.
17. See footnote 4, this chapter.
18. Making learning visible to students: Hattie, 2012.
19. Secondary knowledge can take centuries to generate: Geary, 2007.
20. Quote from email correspondence between Barb Oakley and Roman Hardgrave, August 4, 2020.
21. The curse of expertise: Hinds, 1999.
22. Extra effort strengthens the learning and interrupts forgetting: Cepeda et al., 2006. (This is the seminal meta-analysis that showed the effectiveness of distributed practice.)

## CHAPTER 6. ACTIVE LEARNING: THE PROCEDURAL PATHWAY

1. The hippocampus mediates rapid associative learning with and without consciousness: Henke, 2010.
2. As far as the associated structures go, Ullman and Lovelett, 2016, note: "The basal ganglia play a critical role in the learning and consolidation of new skills, whereas frontal (pre-) motor regions may be more important for processing skills after they have been automatized." In this book, we are also using the neuroscientific definition of the term *procedural learning* as meaning "acquired through the pathways associated with the basal ganglia." As Evans and Ullman observe: "the term 'procedural' is generally used differently in the math literature, where 'procedure' is often used interchangeably with 'strategy'" (Evans and Ullman, 2016). Strategies, of course, are usually explicit and are taught through the declarative system.

   Fascinating new approaches are being used to teach Alzheimer's patients how to learn and continue to process information by using their procedural systems, which are not damaged by the disease in the same way as declarative systems (Zola and Golden, 2019).

   The cerebellum also plays a role in procedural learning. And it seems that the default mode network—the diffuse mode that you learned about in chapter 4—helps when transitioning between clearly procedural and clearly declarative tasks (Turner et al., 2017). There is some overlap between the declarative and procedural systems (Xie et al., 2019).
3. Out-of-fashion habitual system coming back into fashion for analysis: Wood, 2019, pp. 37–38.
4. As Ullman and Lovelett observe, "Note that it is not the case that knowledge is in any sense 'transformed' from declarative to procedural memory. Rather the two systems seem to acquire knowledge essentially independently." Incidentally, the hippocampus is more oriented toward linking that involves *spatial* relationships, which can include more abstract ideas. A single neuron in a rodent's hippocampus, called a place cell, is active only in a small spatial location, called a place field. As the rodent navigates through space, hippocampal neurons become active in a temporal sequence. Interestingly, these same sequences are replayed to the cortex during sleep, as a chunk, to consolidate a memory of the exploration. (Yes, that's the chunk of declarative sets of links we mentioned in chapter 2.) When the rodent wakes up, it can remember how to get back to where it found food. This is similar to what takes place in humans.

   In a related way, the basal ganglia in humans puts together sequences of muscle contractions, notes, words, and thoughts so that they become one automatic sequence. Working memory works on these timing-related "chunky" sequences the same way it works on chunks involving space and more abstract concepts (Martiros et al., 2018). The act of retrieval is declarative, but that process is being monitored by the procedural system, so with practice, it becomes automatic. The automaticity arises, at least in part, because procedural sets of links are being created in the process of monitoring.

Is learning how to serve in tennis declarative or procedural? You jump-start with declarative knowledge that you can articulate (keep your eye on the ball), but after a lot of practice it become completely automatic—it has become a procedure. A pro tennis player or musician is no longer consciously aware of the mechanical details, only large-scale features like "hit the line" or "add some vibrato." Another way of saying this is that you want the declarative system to be aware of the sequential chunks created by the procedural system but not to micromanage them. The basal ganglia is often called the habit system. By the time you are an adult most of what you do is unconscious. But the declarative system can step in if something unusual happens.

See also the sidebar "Learning More About the Procedural System" on this page. Basically, the declarative and procedural systems are partners despite the fact that the declarative system can only see the outcome of the procedural system's learning efforts.

5. Dyslexia as a disorder related to the procedural system: Ullman et al., 2020.
6. Higher declarative processes: Evans and Ullman, 2016; Takács et al., 2018; Ullman et al., 2020.
7. Humans have enhanced transitions from declarative to procedural performance: Schreiweis et al., 2014. See especially figure S7 in the supplemental section.
8. Learning through one system can inhibit learning in the other: Freedberg et al., 2020; Ullman et al., 2020.
9. But also note there are nonconscious aspects of working memory, and this is a developing area of research: Nakano and Ishihara, 2020; Shevlin, 2020.
10. "The development of II automaticity is associated with a gradual transfer of control from the striatum to cortical-cortical projections from the relevant sensory areas directly to the premotor areas that initiate the behavior." Ashby and Valentin, 2017. The declarative/procedural learning systems are an example of what are call *layered architectures,* with multiple control loops working on different time scales. Coauthor Terry has a project to understand how the brain manages mountain bike trail riding. As this project shows, most humans can safely stay on the trail without crashing because of *diversity-enabled sweet spots* (DESSs) in the brain. Basically, a variety of axon diameters help provide feedback at different layers and levels of the interwoven network of neurons in the brain, helping to create control that is both fast and accurate despite being built from components that are individually slow or inaccurate. Nakahira et al., 2019.
11. "[W]ith extended training . . . rats 'switch' from a predominant use of place learning to a predominant use of response learning . . .": Packard and Goodman, 2013.
12. The declarative and procedural learning systems and their location and information flow in the brain: Ashby and Valentin, 2017.
13. Two different places in the neocortex: Ullman, 2020.
14. Learning a second language can be better through immersion-type programs: Ullman, 2020.
15. Much of the information in this table is derived from Ullman, 2020, with a few other references as noted within the table.
16. Changes in the procedural system as children mature: Zwart et al., 2019.
17. Mindfulness training enhances declarative and inhibits procedural learning: Stillman et al., 2014.
18. Mindfulness may inhibit procedural learning: Stillman et al., 2014.

19. How rapidly the shift from learning a concept declaratively to learning that concept procedurally proceeds seems to depend on FOXP2. The declarative system appears to be affected by many genes, for example, by BDNF or APOE. Ullman, 2020. Dopamine-related genes appear to affect procedural learning. Wong et al., 2012.
20. Declarative learning and developmental disabilities: Evans and Ullman, 2016; Ullman et al., 2020.
21. Indications of improved procedural learning in autism spectrum disorders and Tourette's: Takács et al., 2018; Virag et al., 2017.
22. Overlapping parts of the brain that do procedural processing and that do arithmetic: Evans and Ullman, 2016.
23. Proceduralization of math: Evans and Ullman, 2016.
24. Concept attainment: Estes and Mintz, 2015, Chapter 4: The concept attainment model: Defining concepts inductively, pp. 59–77; Gonzalez, 2016; Joyce et al., 2015, Chapter 6: Concept attainment: The explicit teaching of important concepts, pp. 125–48.
25. Incidentally, the importance of interleaving was first discovered with relation to procedural learning. See Pan and Bjork, in press, for a review.
26. Benefits of interleaving on Spanish-language verb conjugations: Pan et al., 2019.
27. Interleaving area, volume, and perimeter calculations: Carvalho and Goldstone, 2019.
28. Interleaving helps learners retain information better than blocking: Soderstrom and Bjork, 2015.
29. Interleaving benefits learning to write letters: Ste-Marie et al., 2004.
30. The value of interleaving somewhat similar materials: Brunmair and Richter, 2019.
31. Desirable difficulties, it should be noted, relate to both procedural and declarative learning: Soderstrom and Bjork, 2015.
32. Gestures help with foreign language vocabulary learning: Macedonia et al., 2019; Straube et al., 2009. For the more general role of gesture, see Kita et al., 2017.
33. For a good relatively recent introduction to the concept of desirable difficulties by the foundational researchers in the area, see Bjork and Bjork, 2019a; Bjork and Kroll, 2015. Desirable difficulties, it should be noted, relate to both procedural and declarative learning: Soderstrom and Bjork, 2015.
34. Students can dislike learning in ways that make the learning more difficult, even if they learn better using these methods: Bjork and Bjork, 2019b.
35. "Curse of specificity": Eichenbaum et al., 2019.
36. Repetitive training on large sample sets helps create better strategies: Fulvio et al., 2014
37. The difficulties of achieving transfer: De Bruyckere et al., 2020.
38. Future studies should examine interleaving subjects for different lengths of time; potential challenges with condensed coursework: Yan and Sana, 2020.
39. Quote: Anderer, 2020. Research supporting the value of cursive writing: Ose Askvik et al., 2020.
40. Email correspondence between Daisy Christodoulou and Barbara Oakley, September 14, 2020.
41. Up-regulation to help with memory: Wang and Morris, 2010. (This paper is foundational in the study of schemas and the general translation of neuropsychological ideas about the psychological and anatomical organization of memory into the neurobiological domain.)
42. Neurobiology of schemas: Gilboa and Marlatte, 2017.
43. The neocortex can learn more rapidly when it's got a schema to hook into: Tse et al., 2007.
44. The difficulty of far transfer: De Bruyckere et al. 2020.

45. This all goes back, once again, to variability effect: Likourezos et al., 2019.
46. Retrieval practice helps with transfer: Butler, 2010.
47. Bloom's taxonomy: Krathwohl, 2002. Depth of knowledge: Hess, 2013.
48. Toward a brain-based componential semantic representation: Binder et al., 2016. See also the intriguing figure and discussion in Zull, 2002, p. 18.
49. The value of graphic organizers in helping students mentally reorganize materials: Ponce et al., 2019; Wang et al., 2020.
50. Using graphic organizers to generate deep learning: Fisher and Frey, 2018.
51. The idea that procedural and declarative sets of links may connect if they relate to the same concept is related to a theory called *semantic processing*: Xie et al., 2019.
52. Sleep and mind-wandering help during spaced repetition: van Kesteren and Meeter, 2020.
53. The effect is nonlinear—this is just a quick rule of thumb. See Cepeda et al., 2008.
54. Recommendations from "APL Instructional Skills Level 1 Training," delivered by Jean Anastasio, David Perry, and John Zalonis, August 6–10, 2018, APL Associates.
55. Homework is beneficial especially for (seemingly) disadvantaged children: Bempechat, 2019.
56. "'Deep' conceptual understanding and explicit statements of concepts are not the same thing": Geary, 2007, p. 69. Dunbar et al., 2007.

## CHAPTER 7. BUILDING COMMUNITY THROUGH HABITS

1. "Stress may lead to stronger memories for negative events happening in the classroom, such as failed exams, embarrassing experiences or interpersonal conflicts (e.g., bullying) and these strong negative memories may induce long-lasting frustration and a negative attitude towards school and the individual's abilities. . . . Stress may hinder the integration of new information into existing knowledge structures, which may prevent the updating of new facts or a deep multidisciplinary understanding of concepts which is often required in education." Vogel and Schwabe, 2016.
2. Stress can be bad or beneficial for students: Rudland et al., 2020.
3. Our checklist is based on that of Wong and Wong, 2018, with our own added descriptions and applications.
4. Neural response to social exclusion is present by preadolescence and is most predominant during adolescence. EEG data finds greater frontal medial theta power to rejection strongest among adolescents (400–600 ms) but near 0 in children and adults. Tang et al., 2019.
5. Email correspondence between Beth Rogowsky and Tim Knoster, executive director of the McDowell Institute at Bloomsburg University of PA, October 14, 2020.
6. For extensive examples of classroom procedures and how to teach them, see Wong et al., 2014.
7. Landmark study finding that what one teacher expects of their students can serve as a self-fulfilling prophecy. Rosenthal and Jacobson, 1968. Fifty-year review of research on teacher expectancy effects: Weinstein, 2018.
8. Quote: Lemov, 2015, p. 383.
9. Definition of a reward: Schultz et al., 1997.
10. Influence of dopamine on learning and motivation: Berke, 2018; Miendlarzewska et al., 2016.
11. Dopamine allows the declarative and procedural systems to work together: Freedberg et al., 2020.
12. Loss of dopamine neurons in an area toward the center of the brain called the *ventral tegmental area* leads to both Parkinson's disease and anhedonia. Anhedonia is defined by a lowered ability

to experience pleasure. It is recognized to be a core symptom of major depression, and approximately 30 to 40 percent of subjects with Parkinson's disease have significant depression. Locked-in syndrome, the loss of all movement and response to outside events, is an end point after most of the dopamine neurons are gone.

The dopamine reward system regulates interest, curiosity, and drive. In the 1990s, Terry's lab was involved in developing a reinforcement learning model for the neural cells that produce dopamine, called temporal difference learning. This was based on classical conditioning, which gave rise to many brain imaging studies and was the basis for the new field of neuroeconomics (Montague et al., 1996). The dopamine reward system is found in all species, including insects (Montague et al., 1995). Temporal difference learning powers many artificial intelligence systems, such as AlphaGo, which learn complex strategies in uncertain environments. This story is told in chapter 10 of Terry's book *The Deep Learning Revolution* (Sejnowski, 2018).

13. Dopamine makes dramatic improvements in working memory: Schultz et al., 1997.
14. Negative experiences signal neurons to disconnect rather than connect: Ergo et al., 2020.
15. The background level of dopamine released in the presence of expected rewards (researchers call this *tonic* dopamine release) appears to differ from that released in response to unexpected rewards (*phasic* dopamine release). First, the level of tonic dopamine controls the level of motivation and vigor of responses. Excessively high dopamine occurs in obsessive-compulsive disorder (OCD) and in Tourette's syndrome, where patients make uncontrollable ballistic movements. Second, the tonic level of dopamine release is also thought to reflect the background rate of an expected reward (in other words, things like whether the reward is getting closer in time or space). Finally, tonic dopamine hangs around quite a while—on the order of minutes—but phasic dopamine squirts out only briefly (although its effects may last for a while). Phasic dopamine release can also be increased by stress and the engagement of the working memory.
16. Motivation and schemas: Wang and Morris, 2010.
17. The role of expected versus unexpected rewards in motivation. Cromwell et al., 2020; Mohebi et al., 2019.
18. Temporal discounting in adolescents: Hamilton et al., 2020.
19. The commonality of the impostor syndrome: Felder, 1988.
20. On being ignorant of one's own ignorance: Dunning, 2011. Narcissism largely, but not entirely, overlaps with high self-esteem. Hyatt et al., 2018
21. For an explanation of student resistance, see Chapter 1, Tolman et al., 2016. While the focus of this research is toward post-secondary education, the findings are applicable to K-12. Most causes of student resistance happen in passive classrooms.

## CHAPTER 8. LINKING LEARNERS

1. As noted in the paper "Turning student groups into effective teams," (Oakley et al., 2004), "A group of students coming together to work on an assignment is not the same thing as a well-functioning team. The students in any given group may sometimes work together, but they may also be inclined to work independently, simply pooling their work with no discussion, and they may spend a great deal of time in conflict over work-related or personal issues. In contrast, members of an effective team always work together—sometimes physically together and sometimes apart, but constantly aware of who is doing what. They take different roles and responsibilities, help one another to the greatest possible extent, resolve disagreements amicably,

and keep personal issues (which may occur when any collection of people work together) from interfering with the team functioning. With a group, the whole is often equal to or less than the sum of its parts; with a team, the whole is always greater. In survey after survey of employers, teamwork skills (along with communication skills) are at the top of the list of attributes they would like to see more of in their new hires."

In this chapter, we will primarily refer to *groups,* reserving the word *teams* for situations where students have the opportunity to work together for some time under their teacher's watchful eye so that an appropriate team relationship has time to develop.

2. Image very loosely after figure 8.1, Saksvik, 2017, and figures 3 and 4, Lupien et al., 2007.

3. For good versus bad stress, see the seminal review paper: Lupien et al., 2007. Also, there is an entire field of study, called *hormesis,* about how mildly harmful influences can be health-inducing.

4. Stress can be beneficial for students: Rudland et al., 2020; Saksvik, 2017.

5. For a review of classroom-based socioemotional programs, see CASEL, 2013; for a review of school-wide socioemotional programs, see Dusenbury and Weissberg, 2017.

6. As noted in Scager et al., 2016, "Collaborative, cooperative, and team-based learning are usually considered to represent the same concept, although they are sometimes defined differently . . . ; we consider these concepts comparable and use the term 'collaboration.'" In *Uncommon Sense Teaching,* we will follow Scager et al.'s approach to the terminology and use the terms largely interchangeably. It's worth noting, however, that cooperative learning is usually more structurally defined than collaborative learning. So cooperative learning could involve assigning roles such as clarifier and summarizer, which would be used for closed-ended problems that have specific answers—as with a group that works together to do homework. Collaborative learning would be used for higher-level content where small groups are empowered to resolve more complex, open-ended tasks. Rockwood III, 1995a; Rockwood III, 1995b.

7. See chapter 10: Cooperative learning models: Improving student learning using small, collaborative groups, in Estes and Mintz, 2015.

8. A study of 365 fifth graders finds peer acceptance and friendship tightly linked with academic achievement. Kingery et al., 2011.

9. Quote: Mintz, 2020.

10. Teaching social skills: Sorrenti et al., 2020.

11. Seminal article defining cooperative learning: Johnson and Johnson, 1999.

12. Atypical time increments: Lemov, 2015, p. 221.

13. Based on the section involving crisis clinics: Oakley et al., 2004.

14. Both participant safety and task conflict must exist in tandem to spur team creativity: Fairchild and Hunter, 2014.

15. Modern science is often an extremely competitive environment: Cowan et al., 2020, describes how several groups of research scientists have put their adversarial relationship to good use.

16. Codependency may have its roots in excessive empathy: McGrath and Oakley, 2012. See also Oakley, 2013, for a more comprehensive treatment of the advantages and challenges of empathy.

17. Quote: Carey, 2019.

18. Every person added to a team reduces the probability that that team produces a creative breakthrough: Wu et al., 2019.

## CHAPTER 9. ONLINE TEACHING WITH PERSONALITY AND FLAIR

1. Online learning can be as good as, or better than, face-to-face: Chirikov et al., 2020; Colvin et al., 2014; McKenzie, 2018.
2. Poor online pedagogy used to "prove" that online learning isn't as good as face-to-face: See, for example, Arias et al., 2018.
3. The value of flipped classes: Bergmann and Sams, 2012.
4. Perhaps the best-known of online course design resources, in case you would like to dig deeper, can begin with course design rubrics and checklists from the following organizations: Quality Matters: https://www.qualitymatters.org/qa-resources/rubric-standards; OLC OSCQR Course Design Review Scorecard: https://onlinelearningconsortium.org/consult/oscqr-course-design-review/; the University of Central Florida (a leader in this space) Center for Distributed Learning: https://cdl.ucf.edu/files/2013/09/IDL6543_CourseRubric.pdf.
5. Guidance to avoid synchronous approaches: Reich et al., 2020.
6. But see recent research revealing that the visual and aural components may not be so separate and mutually supportive of each other within working memory as might be supposed: Uittenhove et al., 2019.
7. Multimedia teaching: Mayer, 2014a; Mayer et al., 2020.
8. Get rid of extraneous materials: Ibrahim et al., 2012. See also Richard Mayer's work.
9. Don't read long pieces of text that show on the screen: Hooijdonk and de Koning, 2016.
10. Cognitive map: Behrens et al., 2018.
11. Strategy from R. Lynn Hummel, associate professor of instructional technology at Bloomsburg University.
12. "The science behind hating someone for their voice": Wong, J. 2017.
13. Zoom fatigue: Jiang, 2020, and see references within.
14. Write by hand: Mayer et al., 2020.
15. Have one student responsible for taking notes: Bondie, 2020.
16. Purposes, keys, and variations of cold-calling: Lemov, 2015, pp. 249–62.
17. Impact of cold-calling: Dallimore et al., 2012.
18. Strategy from Mary Nicholson, professor of instructional technology at Bloomsburg University.
19. Students tend to focus on videos: See references cited in Oakley and Sejnowski, 2019. And as de Koning et al. note in their overview, "Instructional video is currently considered one of the most popular ways of delivering instruction." de Koning et al., 2018.
20. The effect size of short "micro-teaching" videos: Hattie, 2009, pp. 112–13. The general power of video for instruction: Expósito et al., 2020; Stockwell et al., 2015.
21. The value of instructor presence in a class: Flaherty, 2020.
22. *Excellent Online Teaching*: Johnson, 2013.
23. Allowing learners to engage with small pieces of information ("segmenting"): Brame, 2016.
24. The myth of the six-minute rule: Lagerstrom et al., 2015.
25. There are so many variables that it's difficult to come up with concrete guidelines on video length by age. There is evidence for older (college-age) students that although six-minute video lengths are good, longer videos in the twelve- to twenty-minute range also work just fine (Lagerstrom et al., 2015). Our discussions with producers of popular YouTube videos indicate that YouTube seeks videos in the range of twenty to twenty-five minutes because their users seem to enjoy them.

26. The value of humor: Nienaber et al., 2019.
27. Humor boosts dopamine: Mobbs et al., 2003.
28. A good discussion of copyrights relevant to teaching: 2016. An overview of what is permissible under the U.S. TEACH Act: Copyright Clearance Center, 2011.
29. Bottom-up and top-down attentional processes: Thiele and Bellgrove, 2018.
30. The value of captions for a broad variety of learners: Sauld, 2020; Teng, 2019.
31. For a good review of the research literature on multiple-choice testing, see Xu et al., 2016. For a readable guide on creating good multiple-choice tests, see Weimer, 2018.
32. The value of quiz questions with relation to videos: Szpunar et al., 2013; Vural, 2013.
33. Helpful nature of guiding questions: Lawson et al., 2006.
34. Videos embedded within homework related in: Brame, 2016.
35. Keep homework restricted to twenty minutes: Lo and Hew, 2017.
36. Action verbs and other insights about discussion forums: Gernsbacher, 2016.
37. Summarizing did not lead to better test performance than restudy; teaching on video did: Hoogerheide et al., 2019.
38. Beware the danger of too much attention to video making: Christodoulou, 2020, p. 102.

## CHAPTER 10. CHARTING YOUR COURSE TO THE FINISH LINE

1. Meta-analysis finds altruistic (being of service to others, making a difference, and contributing to society) and intrinsic (a passion about teaching and about the subject matter) motivators as the key influences in becoming a teacher: Fray and Gore, 2018.
2. For an in-depth analysis of effective teaching practices for each part of the lesson plan—preparing, starting, the flow, feedback, and the end of the lesson—see *Part 2: The Lessons*: Hattie, 2012, pp. 41–155.
3. Lesson plan template: Curran, 2016, pp. 101–2.
4. Targeted learning includes (1) being clear about what is to be learned in the lesson and (2) having a method for knowing that the desired level of success has been achieved: Hattie, 2012, p. 52.
5. Definition of *standards* from the U.S. Common Core State Standards: National Governors Association Center for Best Practices, 2010b.
6. Reading Standards for Literature 6-12: National Governors Association Center for Best Practices, 2010a, p. 36.
7. For a detailed explanation of the KUD format for instructional objectives see chapter 2, *Objectives, Assessment and Instruction*: Estes and Mintz, 2015.
8. For a guide to verbs aligned with Webb's Depth of Knowledge and Bloom's revived taxonomy: Hess, 2013.
9. Although taxonomies of learning are often categorized as having lower and higher levels, only the first level (knowledge in Bloom's taxonomy and recall and reproduction in Webb's Depth of Knowledge) is considered to be lower; all others are considered higher: McMillan, 2018, p. 52.
10. Meta-analysis finds formative assessment significantly improves student learning. Study adds caution on the effectiveness due to the wide variation of formative assessments used and the form of feedback provided: Kingston and Nash, 2011.
11. For a model of effective feedback: Hattie and Timperley, 2007.
12. An exit ticket is assigned at the end of class and submitted before leaving class to assess if students caught what was taught. Exit tickets measure each student's progress toward meeting

the objective or understanding a particular concept.

13. There can be blurred lines between formative and summative assessments; the primary difference between the two is the use of the assessment results. A mini-summative assessment, like an exit ticket or a daily quiz, can be used in a formative manner if it informs subsequent instruction. Summative assessments have been traditionally used to calculate a marking period grade. Large-scale summative assessments include benchmark assessments and state standardized tests (McMillan, 2018, and Dixson and Worrell, 2016).
14. Criteria for an effective Do Now: Lemov, 2015, pp. 161–62.
15. Cognitive apprenticeship: Cardullo, 2020.
16. Teacher talk dominates instruction. 835 students in grades six, eight, ten, and twelve wore wristwatches that signaled to them multiple times a day. At each signal they recorded the activity they were engaged in and their thoughts. While students may appear attentive in class, "Many are actually thinking about themselves, other school activities, and external issues." Yair, 2000, p. 262.
17. For a review of the research on questions and teacher talk: Hattie, 2012, pp. 83–84.
18. Multimedia instruction can be generalized to any lesson containing both words and pictures, where the words can be in spoken form or printed form and the pictures can be in static form (such as illustrations, charts, graphs, or photos) or dynamic form (such as animation or video): Mayer, 2019.
19. Strategies to reduce cognitive load when viewing multimedia: Mayer, 2014b.
20. Segmenting multimedia instruction aids retention and transfer performance, as well as reduces overall cognitive load and increases learning time: Rey et al., 2019.
21. Teaching elementary students note-taking strategies significantly improved comprehension: Chang and Ku, 2015. For results on specific types of note-taking (skeletal, illustrative diagram, or no notes) and the effects of note-taking on high- and low-ability students, see Dung and McDaniel, 2015. Titsworth and Kiewra, 2004, found that note-taking resulted in 13 percent higher test achievement than not taking notes.
22. A review of thirteen studies finds guided notes to be effective for all learners and especially for students with disabilities. Results included improved test scores, note-taking accuracy, organization, and increased student responses during class. Haydon et al., 2011.
23. Study finds WebQuests effective in teaching proportion to sixth-grade mathematics students: Yang, 2014.
24. Example from Wexler, 2020, p. 228.
25. Strategy courtesy Joy Carey, middle school English teacher for Arlington Public Schools, email correspondence with Beth Rogowsky, July 10, 2020.
26. Action research effectively demonstrates conducting exit tickets via Twitter: Amaro-Jiménez et al., 2016.

### APPENDIX A. HOW TO MANAGE YOURSELF ON A COLLABORATIVE TEAM

1. This essay is a brief adapted version from Oakley, 2002.

# Index

The page numbers in this index refer to the printed version of this book. The link provided will take you to the beginning of that print page. You may need to scroll forward from that location to find the corresponding reference on your e-reader.

Page numbers in **bold** indicate charts or tables; those in *italics* indicate figures; those followed by "n" indicates notes.

# About the Authors

Barbara Oakley, PhD, is the bestselling author of *A Mind for Numbers* and a professor of engineering at Oakland University in Rochester, Michigan. Her research involves bioengineering with an emphasis on neuroscience and cognitive psychology. Dr. Oakley is an internationally recognized expert on learning and on creating high-quality online materials for massive open online courses (MOOCs). With Terrence Sejnowski, she teaches one of the world's most popular MOOCs, "Learning How to Learn."

Beth Rogowsky, EdD, is a professor of education at Bloomsburg University of Pennsylvania. She had fourteen years of experience teaching English language arts to middle schoolers in rural and urban public schools before completing her EdD in educational leadership and subsequent postdoctoral studies in cognitive neuroscience. Her research is broadly focused on translational neuroeducation with an emphasis in language, literacy, and debunking neuromyths such as learning styles.

Terrence Sejnowski, PhD, is the Francis Crick Professor at the Salk Institute for Biological Studies, where he directs the Computational Neurobiology Laboratory. He is among only twelve living scientists who have been elected to the National Academy of Medicine, the National Academy of Sciences, and the National Academy of Engineering.

* So the question then becomes "How long before, during, and after the unexpected reward?" The answer, of course, is "it depends." Some studies indicate that novelty, and presumably its accompanying dopamine squirts, along with squirts of another molecule, noradrenaline, can enhance subsequently learned material up to thirty minutes later (van Kesteren and Meeter, 2020; Dayan and Yu, 2006).

* Unexpected rewards produce transient increases in dopamine that control synaptic plasticity, which makes it easier to get future rewards. In other words, dopamine, the chemical squirted out due to unexpected rewards, helps the neurons involved in learning to link together more easily. For example, that dopamine hit of pleasure you feel after your first time successfully shooting a basket in basketball, solving a math problem, or acing a vocabulary quiz helps your brain to more easily rewire itself to accomplish these types of activities a bit more easily the next time you try them.

* Knowing when and how much praise to give is part of the art of teaching. If there's too much praise in a class, the rewards could move out of the unexpected category, and at some point *not* being praised could become a negative.

* Coauthor Barb, for example, was convinced in high school that not only did she not have the knack for learning in math and science but that math and science were useless anyway. A stint in the army as a Signal Corps officer handling technical communications convinced her that she was wrong. After Barb finished her army commitments at age twenty-six, she decided to try to rewire her brain to learn math and science. If Mr. Clark, her junior high school algebra teacher, had ever been told Barb would end up a professor of engineering, he would never have believed it.

* Which isn’t to say that animals aren’t capable of some pretty remarkable feats, including parrots that can sing like Beyoncé and chimpanzees, elephants, dolphins, and even insects that use tools.

* Even so, there has been a revolution in how stroke patients are managed. In the past, patients were told to stay in bed until they recovered, but best practice today is to start physical therapy as soon as possible, which leads to faster recovery and better outcomes. Therapy requires massive amounts of practice. It’s not fun at all, but it *is* effective. It works because damaged neurons can be rescued if they are activated as soon as possible. For a riveting book on how recovery from various types of brain damage can take place—and how we may be able to go beyond recovery to gain new senses—see David Eagleman’s *Livewired* (Pantheon, 2020).

* We should clarify here that there is a difference between Direct Instruction and direct instruction. Capitalized *Direct Instruction* is a term used to signify the original approach developed by American educationalist Siegfried Engelmann in the 1960s. It is a carefully sequenced and scripted model of instruction requiring that the curriculum be organized through concepts, that it use explicit and carefully selected examples to illustrate those concepts, and that the methods used to teach the examples follow Engelmann's guidance for how those examples are taught. Thus, capitalized *Direct Instruction* refers to a commercially available curriculum of scripted lessons—for example, Reading Mastery and DISTAR. Lowercase *direct instruction* refers to instruction developed by the classroom teacher more loosely based on the approaches of Direct Instruction.

* You may wonder precisely how long “lengthy” is. This can vary tremendously in the K-12 span of grade levels. Master teachers usually develop a feel for “too long” by watching their students from the side or back of the classroom—excessive fidgeting or falling asleep are sure indicators. Again, it can be helpful to keep in mind that attention spans are roughly the students’ age in years, plus one.

* Some approaches to inquiry and problem-based learning are more nuanced and include aspects of teacher-directed approaches.

* In a WebQuest, students are given a framework of websites and key words to use as they search the internet for specific information and solutions to real-world problems.

* There are, of course, many different models of instruction: direct instruction, inquiry, concept attainment, Socratic seminar, vocabulary acquisition, inductive model, flipped classroom, integrative model . . . and so forth. We cover direct instruction in depth because the evidence for its effectiveness is so profound. But no matter the instructional model, it is just good teaching to start with an introduction that grabs students' attention, taps into their prior knowledge, is relevant to the new learning, and asks the focus question.

* Preassessments include those methods teachers use prior to instruction to gather information about students' knowledge, attitudes, and interests. The results are often used as a starting point for designing instruction—allowing teachers to identify strengths and weaknesses, avoid redundancy, and make instruction relevant. They are also used to establish a baseline and determine growth.

* Recall (retrieval practice) is better than the alternative approaches (Karpicke and Blunt, 2011).

* You might wonder why it's called *working memory* instead of *short-term memory.* Short-term memory basically includes only what you are temporarily holding in mind—as when you look at a short sentence and can see it in your mind's eye or hear it in your "mind's ear." Working memory includes short-term memory as well as your ability to hold and manipulate the information in. So, for example, if you were to say the sentence backward, you'd keep holding it in short-term memory as you were manipulating it in working memory to say it backward.

* From a neuroscientific research perspective, the term *unconscious* either refers to someone who is below the level of consciousness (in a coma or a vegetative state, for example) or to information that we are not conscious of but still process (e.g., briefly flashed word among masking items). *Nonconscious*, on the other hand, is less clearly defined. It generally refers to something of which we are not conscious. Some European researchers prefer to use *nonconscious* to steer clear of Freud's concept of the unconscious.

* We’re saying “mostly” to make matters easier to discuss here. In reality, researchers don’t know for sure that declarative memory mostly underlies explicit knowledge. It could also be a partly implicit system—a system where we perform a process without knowing that we are doing so.

* Note that in this book, we are following the neuroscientific tradition in thinking of the declarative and procedural pathways as being associated with certain physical brain systems, not as being associated with explicit or implicit thinking.

* Technically, it’s the entire cortex. But, as usual, Neo plays the biggest role!

* We can’t help but think that when it comes to figuring out how to use a new device, people seem to like to either read the instructions or just mess around until they figure it out. It’s eerily reminiscent of declarative and procedural learning.

* Complicating matters is that when students first learn a concept or technique through one system, that system can become predominant for that concept or idea, slowing the transition to shared reliance with the other system. For example, if you learn the grammar of a new language declaratively with explanations of verb tenses and sentence structure, it can make it harder to learn the language procedurally. (You will know language has shifted to the procedural pathway when well-formed sentences are spoken effortlessly.) However, it's much slower to acquire grammar through the procedural pathway, so it is often thought to be worth it to begin learning the new language declaratively.

* There are different interpretations of constructivism. But central to constructivist approaches is that knowledge is actively constructed by learners themselves. According to this approach, teachers are not expected to dispense knowledge but rather to provide students with opportunities and incentives to build their knowledge (Fosnot, 2013).

* To solve an equation following the Order of Operations, students are often taught the order Parentheses, Exponents, Multiplication and Division, Addition and Subtraction. This is sometimes abbreviated to PEMDAS, which is in turn memorably encoded as “Please Excuse My Dear Aunt Sally.”

* This can have the odd effect that a person with a lesion in their basal ganglia can lose their grammatical fluency in their native language (which they learned through their early procedural dominance) but can still be able to speak a language they later acquired as an adult (which they learned more declaratively) (Ullman, 2020).

* This is a literal translation of the term *pierna de palo,* which is used by soccer-crazed Chilean Spanish speakers like Barb’s son-in-law.

* The table describing the key characteristics of declarative and procedural learning pathways that begins on this page, for example, was Barb's way of creating a graphic organizer to understand the similarities and differences between the two pathways. The neural sets of links related to art styles illustrated on this page were Terry's way of thinking about schemas. Beth uses her wide-ranging perspective as a teacher to see that both Barb's and Terry's perspectives make solid use of graphic organizers. (And Beth adds the iceberg touch to help us all better understand that what people seem to understand is just the tip of the iceberg of the underlying neural complexity.)

* Even some of the best editors didn't pick up their editing talents through careful endless study of grammar and punctuation. Rather, they pick up the bulk of their editing skills through lots of reading. As we authors can vouch for here, sometimes good editors can make dramatic improvements in the writing without necessarily being consciously aware of *why* the changes are better (Dreyer, 2019).

* Mapping an entire year-long curriculum is beyond the scope of this book. With this chapter, we provide a framework to help you implement strategies supported by neuroscience on a daily basis.

* A T-chart is a two-column graphic organizer where a concept is compared by noting contrasting characteristics in the left and right columns. For example, on this page, we contrasted what nice sounds like and looks like using a T-chart with eyes in one column and ears in the other.

* You might think that Farid would have had top grades overall in his engineering studies, but he didn’t—he was basically a B to B+ student in most of his engineering classes. Getting top grades just wasn’t that big a deal to him.

* Specifically, the *intraparietal sulcus*. But if you happen to be reading this as a textbook for class and a teacher ever tests you on this phrase, they are missing the forest for the trees!

* If you’re hungry for more neural geography lessons, research reveals that the hearing network (i.e., the *phonological loop*) centers on the left temporoparietal region, while the seeing network (the *visuospatial sketchpad*) is cradled in the right temporoparietal region. The *central executive* is toward the front of the brain; it works in tandem with the *focus of attention* that helps direct thinking.

* Students on the autism spectrum may feel uncomfortable or unable to do this, so don’t make looking at you a hard-and-fast rule (Hadjikhani et al., 2017).

* You may wonder what the size of the balls of information (chunks) could be, and what the range is between minimum and maximum—a word, a sentence, a concept, or more? These are issues that researchers are currently grappling with. For now, it's best to just think of the ball as a generic chunk of information that could get bigger—sometimes much bigger—with practice.

* Although it does seem there is a single factor that may generally increase learning memory capacity: simply becoming literate as opposed to remaining illiterate (Kosmidis, 2016).

* Colloquially, general education teachers in the U.S. often call themselves “regular” teachers. But this usage can imply that special education instructors are somehow irregular. So the term *general education teacher* is preferred.

* To gauge where supports are needed most, consider pre-assessing your students' knowledge and skill level of the material, possibly through an informal electronic app like Quizlet.

* Texts designed for students at a specific grade or reading level are typically written differently from "authentic" texts designed for the general public. Take, for instance, a textbook that starts with an overview, has review questions at the end of sections, and highlights new vocabulary in bold. That isn't how students would find authentic, real-world texts, such as newspaper articles, excerpts from a book, journal articles, blog posts, or speeches. Even podcasts, videos, and pictures that can be interpreted are often considered authentic texts.

* Paragraph frames look like a skeleton of a paragraph. Here’s an example:
(Title of short story) is about ______________________. The main characters in the story are_________________, _________________, and _________________. One word to describe (name of character) is ______________. ______________ is a great word to describe this character because (cite evidence from the text) . . .

* It seems that when it comes to learning, there's an exception for nearly every rule. Brilliant mathematician John von Neumann, for example, played marching music so loudly while doing his work at Princeton that he annoyed his neighbor down the hall—Albert Einstein (Macrae, 1992, p. 48).

* And maybe, as we'll see in the next chapter, into the index-links of the hippocampus and faintly into the neocortex.

* Okay, kibitzers, we know what you’re thinking. But let’s not get into the philosophy of free will . . .

* Some partners can definitely increase stress, at least in tree shrews and rats and, presumably, their mammalian human counterparts (Hennessy et al., 2009).

* One fascinating but neglected way to help improve collaboration at schools, institutions, and more generally in life, is to encourage choral singing. Singing together can allow for surprisingly beneficial alignment of neural rhythms that can also improve people's moods. (For an extensive discussion, see the opening chapters of Vanderbilt, T., 2021.)

* This has led to the snarky internet meme “When I die, I want my group project members to lower me into my grave so they can let me down one last time.”

* In STEM topics, the roles can be quite different. For example, to work together in completing a set of problems, you might want to make assignments as follows:

- **Coordinator:** Keeps everyone on task and makes sure everyone is involved.
- **Recorder:** Prepares the final solution to be submitted.
- **Monitor:** Confirms that everyone understands both the solution and the strategy used to get it.
- **Checker:** Double-checks work before it is handed in. Ensures agreement is reached on the next meeting time and roles are assigned for next assignment. For teams of three, the same person should cover the monitor and checker roles.

* Proponents of group work can be taken aback by this statement. But see, for example, the copious citations in Paulus et al., 2013, which notes: “Although it is generally presumed that brainstorming with others will enhance the number and quality of the ideas generated, controlled studies that compare interactive brainstorming with nominal groups have shown that verbal brainstorming in groups actually hinders the number of ideas generated.”

In essence, if you take everybody’s ideas generated *individually* and then pull together the results, the number of ideas generated for the group are far greater and richer than initially brainstorming *together*. The *Nature* study of millions of research papers and patents bears out the idea that the bigger the group, the less creative it is (Wu et al., 2019).

* To keep things simpler, we will use the term *neocortex,* meaning that thin layer on the outer edges of the cortex. But sometimes information is stored a little more broadly, in the *cortex,* which includes both the neocortex, which has six layers of neurons, and the allocortex, a much smaller portion of the cortex that can have three to five layers of neurons.

* See our caveats about “mostly conscious” in chapter 6.

* The information passes through long axons (neural “arms”) that are like telegraph lines linking working memory, the hippocampus, and the neocortex. We’re throwing enough complexities at you as it is. But just in case you’re interested, axons have a fatty wrapping around them called *myelin.* Myelin helps serve as a sort of insulator that helps signals travel more quickly and easily along the axon. Remember those days when you polished playground slides with waxed paper so you could slip down the slide more quickly? Metaphorically speaking, myelin is like that wax residue: it makes the axons super slippery and speedy. When students practice what they learn, they are not only creating and strengthening links between the synapses but also building the thickness of the myelin sheets, which helps the axons conduct signals better.

Neuroscientists sometimes speak of the white matter as opposed to the gray matter of the brain. White matter areas have many axons covered with their fatty myelin sheaths, which is why the areas look white. Bundles of axons with their myelin sheaths help distant parts of the brain link together for complex skills such as reading or doing math.

* Sleep is when your brain goes offline for repair, renovation, and large-scale reorganization. Constructing new synapses and enlarging others requires proteins and other building materials to be synthesized. This involves biochemical reactions that build the cytoskeleton scaffolding and enormous macromolecular complexes at synapses. When you are renovating your house, would you rather move out or try to live in it while all the construction is going on around you?

* As we mentioned, the hippocampus has the job of strengthening some long-term memory links in the neocortex and weakening others—consolidating the memory. (This relates to the *spike-time dependent plasticity* we mentioned in endnote 2 of chapter 1, on this page.) The sine waves within the dots of this consolidation illustration, with its vertical lines, give a sense of how the hippocampus talks to the neocortex. The phase of the arriving spike (the position in time of where the vertical line pops up) determines whether the connection is strengthened or weakened. A lot of this takes place during sleep, when wave after wave of 10 to 14 Hz sleep spindles rotate around the brain, sloshing in just such a way as to strengthen some links and weaken others (Muller et al., 2016).

* Active retrieval of the key ideas from memory also helps to differentiate those memories from other, related memories. It's *active retrieval,* not merely restudying the material, that helps firm up those long-term memory links. As Antony et al., 2017, notes: "Because restudy triggers less coactivation of related memories it does not adaptively shape the hippocampal–neocortical memory landscape in the same way as active retrieval."

* Ignoring cosmic dust and meteorites, of course.

* A common variant of *think-pair-share* in language instruction is *think-pair-square-share.* This can help in the event that a student may find herself with a partner who doesn’t have a lot to say. The larger group of four (which completes a “square) can open up the types, varieties, and amount of language use.