

## 8

### Make It Stick

NO MATTER WHAT YOU MAY set your sights on doing or becoming, if you want to be a contender, it's mastering the ability to learn that will get you in the game and keep you there.

In the preceding chapters, we resisted the temptation to become overtly prescriptive, feeling that if we laid out the big ideas from the empirical research and illustrated them well through examples, you could reach your own conclusions about how best to apply them. But early readers of those chapters urged us to get specific with practical advice. So we do that here.

We start with tips for students, thinking in particular of high school, college, and graduate school students. Then we speak to lifelong learners, to teachers, and finally to trainers. While the fundamental principles are consistent across these groups, the settings, life stages, and learning materials differ.

To help you envision how to apply these tips, we tell the stories of several people who, one way or another, have already found their way to these strategies and are using them to great effect.

## Learning Tips for Students

Remember that the most successful students are those who take charge of their own learning and follow a simple but disciplined strategy. You may not have been taught how to do this, but you *can* do it, and you will likely surprise yourself with the results.

Embrace the fact that significant learning is often, or even usually, somewhat difficult. You will experience setbacks. These are signs of effort, not of failure. Setbacks come with striving, and striving builds expertise. Effortful learning changes your brain, making new connections, building mental models, increasing your capability. The implication of this is powerful: Your intellectual abilities lie to a large degree within your own control. Knowing that this is so makes the difficulties worth tackling.

Following are three keystone study strategies. Make a habit of them and structure your time so as to pursue them with regularity.

### Practice Retrieving New Learning from Memory

*What does this mean?* “Retrieval practice” means self-quizzing. Retrieving knowledge and skill from memory should become your primary study strategy in place of rereading.

*How to use retrieval practice as a study strategy:* When you read a text or study lecture notes, pause periodically to ask yourself questions like these, without looking in the text: What are the key ideas? What terms or ideas are new to me? How

would I define them? How do the ideas relate to what I already know?

Many textbooks have study questions at the ends of the chapters, and these are good fodder for self-quizzing. Generating questions for yourself and writing down the answers is also a good way to study.

Set aside a little time every week throughout the semester to quiz yourself on the material in a course, both the current week's work and material covered in prior weeks.

When you quiz yourself, check your answers to make sure that your judgments of what you know and don't know are accurate.

Use quizzing to identify areas of weak mastery, and focus your studying to make them strong.

The harder it is for you to recall new learning from memory, the greater the benefit of doing so. Making errors will not set you back, so long as you check your answers and correct your mistakes.

*What your intuition tells you to do:* Most studiers focus on underlining and highlighting text and lecture notes and slides. They dedicate their time to rereading these, becoming fluent in the text and terminology, because this feels like learning.

*Why retrieval practice is better:* After one or two reviews of a text, self-quizzing is far more potent for learning than additional rereading. Why might this be so? This is explained more fully in Chapter 2, but here are some of the high points.

The familiarity with a text that is gained from rereading creates illusions of knowing, but these are not reliable indicators of mastery of the material. Fluency with a text has two strikes against it: it is a misleading indicator of what you have learned, and it creates the false impression that you will remember the material.

By contrast, quizzing yourself on the main ideas and the meanings behind the terms helps you to focus on the central

precepts rather than on peripheral material or on a professor's turn of phrase. Quizzing provides a reliable measure of what you've learned and what you haven't yet mastered. Moreover, quizzing arrests forgetting. Forgetting is human nature, but practice at recalling new learning secures it in memory and helps you recall it in the future.

Periodically practicing new knowledge and skills through self-quizzing strengthens your learning of it and your ability to connect it to prior knowledge.

A habit of regular retrieval practice throughout the duration of a course puts an end to cramming and all-nighters. You will need little studying at exam time. Reviewing the material the night before is much easier than learning it.

*How it feels:* Compared to rereading, self-quizzing can feel awkward and frustrating, especially when the new learning is hard to recall. It does not feel as productive as rereading your class notes and highlighted passages of text feels. But what you don't sense when you're struggling to retrieve new learning is the fact that every time you work hard to recall a memory, you actually strengthen it. If you restudy something after failing to recall it, you actually learn it better than if you had not tried to recall it. The effort of retrieving knowledge or skills strengthens its staying power and your ability to recall it in the future.

### Space Out Your Retrieval Practice

*What does this mean?* Spaced practice means studying information more than once but leaving considerable time between practice sessions.

*How to use spaced practice as a study strategy:* Establish a schedule of self-quizzing that allows time to elapse between study sessions. How much time? It depends on the material. If you are learning a set of names and faces, you will need to

review them within a few minutes of your first encounter, because these associations are forgotten quickly. New material in a text may need to be revisited within a day or so of your first encounter with it. Then, perhaps not again for several days or a week. When you are feeling more sure of your mastery of certain material, quiz yourself on it once a month. Over the course of a semester, as you quiz yourself on new material, also reach back to retrieve prior material and ask yourself how that knowledge relates to what you have subsequently learned.

If you use flashcards, don't stop quizzing yourself on the cards that you answer correctly a couple of times. Continue to shuffle them into the deck until they're well mastered. Only then set them aside—but in a pile that you revisit periodically, perhaps monthly. Anything you want to remember must be periodically recalled from memory.

Another way of spacing retrieval practice is to interleave the study of two or more topics, so that alternating between them requires that you continually refresh your mind on each topic as you return to it.

*What your intuition tells you to do:* Intuition persuades us to dedicate stretches of time to single-minded, repetitive practice of something we want to master, the massed “practice-practice-practice” regime we have been led to believe is essential for building mastery of a skill or learning new knowledge. These intuitions are compelling and hard to distrust for two reasons. First, as we practice a thing over and over we often see our performance improving, which serves as a powerful reinforcement of this strategy. Second, we fail to see that the gains made during single-minded repetitive practice come from short-term memory and quickly fade. Our failure to perceive how quickly the gains fade leaves us with the impression that massed practice is productive.

Moreover, most students, given their misplaced faith in massed practice, put off review until exam time nears, and then they bury themselves in the material, going over and over it, trying to burn it into memory.

*Why spaced practice is better:* It's a common but mistaken belief that you can burn something into memory through sheer repetition. Lots of practice works, but only if it's spaced.

If you use self-quizzing as your primary study strategy and space out your study sessions so that a little forgetting has happened since your last practice, you will have to work harder to reconstruct what you already studied. In effect, you're "re-loading" it from long-term memory. This effort to reconstruct the learning makes the important ideas more salient and memorable and connects them more securely to other knowledge and to more recent learning. It's a powerful learning strategy. (How and why it works are discussed more thoroughly in Chapter 4.)

*How it feels:* Massed practice feels more productive than spaced practice, but it is not. Spaced practice feels more difficult, because you have gotten a little rusty and the material is harder to recall. It feels like you're not really getting on top of it, whereas in fact, quite the opposite is happening: As you reconstruct learning from long-term memory, as awkward as it feels, you are strengthening your mastery as well as the memory.

### Interleave the Study of Different Problem Types

*What does this mean?* If you're trying to learn mathematical formulas, study more than one type at a time, so that you are alternating between different problems that call for different solutions. If you are studying biology specimens, Dutch painters, or the principles of macroeconomics, mix up the examples.

*How to use interleaved practice as a study strategy:* Many textbooks are structured in study blocks: They present the solution to a particular kind of problem, say, computing the volume of a spheroid, and supply many examples to solve before moving to another kind of problem (computing the volume of a cone). Blocked practice is not as effective as interleaved practice, so here's what to do.

When you structure your study regimen, once you reach the point where you understand a new problem type and its solution but your grasp of it is still rudimentary, scatter this problem type throughout your practice sequence so that you are alternately quizzing yourself on various problem types and retrieving the appropriate solutions for each.

If you find yourself falling into single-minded, repetitive practice of a particular topic or skill, change it up: mix in the practice of other subjects, other skills, constantly challenging your ability to recognize the problem type and select the right solution.

Harking back to an example from sports (Chapter 4), a baseball player who practices batting by swinging at fifteen fastballs, then at fifteen curveballs, and then at fifteen change-ups will perform better in practice than the player who mixes it up. But the player who asks for random pitches during practice builds his ability to decipher and respond to each pitch as it comes his way, and he becomes the better hitter.

*What your intuition tells you to do:* Most learners focus on many examples of one problem or specimen type at a time, wanting to master the type and “get it down cold” before moving on to study another type.

*Why interleaved practice is better:* Mixing up problem types and specimens improves your ability to discriminate between types, identify the unifying characteristics within a type, and improves your success in a later test or in real-world settings

where you must discern the kind of problem you're trying to solve in order to apply the correct solution. (This is explained more fully in Chapter 3.)

*How it feels:* Blocked practice—that is, mastering all of one type of problem before progressing to practice another type—feels (and looks) like you're getting better mastery as you go, whereas interrupting the study of one type to practice a different type feels disruptive and counterproductive. Even when learners achieve superior mastery from interleaved practice, they persist in feeling that blocked practice serves them better. You may also experience this feeling, but you now have the advantage of knowing that studies show that this feeling is illusory.

### Other Effective Study Strategies

ELABORATION improves your mastery of new material and multiplies the mental cues available to you for later recall and application of it (Chapter 4).

*What is it?* Elaboration is the process of finding additional layers of meaning in new material.

*For instance:* Examples include relating the material to what you already know, explaining it to somebody else in your own words, or explaining how it relates to your life outside of class.

A powerful form of elaboration is to discover a metaphor or visual image for the new material. For example, to better grasp the principles of angular momentum in physics, visualize how a figure skater's rotation speeds up as her arms are drawn into her body. When you study the principles of heat transfer, you may understand conduction better if you imagine warming your hands around a hot cup of cocoa. For radiation, visualize how the sun pools in the den on a wintry



day. For convection, think of the life-saving blast of A/C as your uncle squires you slowly through his favorite back-alley haunts of Atlanta. When you learned about the structure of an atom, your physics teacher may have used the analogy of the solar system with the sun as the nucleus and electrons spinning around like planets. The more that you can elaborate on how new learning relates to what you already know, the stronger your grasp of the new learning will be, and the more connections you create to remember it later.

Later in this chapter, we tell how the biology professor Mary Pat Wenderoth encourages elaboration among her students by assigning them the task of creating large “summary sheets.” Students are asked to illustrate on a single sheet the various biological systems studied during the week and to show graphically and through key words how the systems interrelate with each other. This is a form of elaboration that adds layers of meaning and promotes the learning of concepts, structures, and interrelationships. Students who lack the good fortune to be in Wenderoth’s class could adopt such a strategy for themselves.

GENERATION has the effect of making the mind more receptive to new learning.

*What is it?* Generation is an attempt to answer a question or solve a problem before being shown the answer or the solution.

*For instance:* On a small level, the act of filling in a missing word in a text (that is, generating the word yourself rather than having it supplied by the writer) results in better learning and memory of the text than simply reading a complete text.

Many people perceive their learning is most effective when it is experiential—that is, learning by doing rather than by reading a text or hearing a lecture. Experiential learning is a

form of generation: you set out to accomplish a task, you encounter a problem, and you consult your creativity and storehouse of knowledge to try to solve it. If necessary you seek answers from experts, texts, or the Web. By wading into the unknown first and puzzling through it, you are far more likely to learn and remember the solution than if somebody first sat you down to teach it to you. Bonnie Blodgett, an award-winning gardener and writer, provides a strong example of generative learning in Chapter 4.

You can practice generation when reading new class material by trying to explain beforehand the key ideas you expect to find in the material and how you expect they will relate to your prior knowledge. Then read the material to see if you were correct. As a result of having made the initial effort, you will be more astute at gleaning the substance and relevance of the reading material, even if it differs from your expectation.

If you're in a science or math course learning different types of solutions for different types of problems, try to solve the problems before you get to class. The Physics Department at Washington University in St. Louis now requires students to work problems before class. Some students take umbrage, arguing that it's the professor's job to teach the solution, but the professors understand that when students wrestle with content beforehand, classroom learning is stronger.

REFLECTION is a combination of retrieval practice and elaboration that adds layers to learning and strengthens skills.

*What is it?* Reflection is the act of taking a few minutes to review what has been learned in a recent class or experience and asking yourself questions. What went well? What could have gone better? What other knowledge or experiences does it remind you of? What might you need to learn for better

mastery, or what strategies might you use the next time to get better results?

*For instance:* The biology professor Mary Pat Wenderoth assigns weekly low-stakes “learning paragraphs” in which students are asked to reflect on what they learned the previous week and to characterize how their class learning connects to life outside the class. This is a fine model for students to adopt for themselves and a more fruitful learning strategy than spending hours transcribing lecture slides or class notes verbatim into a notebook.

CALIBRATION is the act of aligning your judgments of what you know and don’t know with objective feedback so as to avoid being carried off by the illusions of mastery that catch many learners by surprise at test time.

*What is it?* Everyone is subject to a host of cognitive illusions, some of which are described in Chapter 5. Mistaking fluency with a text for mastery of the underlying content is just one example. Calibration is simply the act of using an objective instrument to clear away illusions and adjust your judgment to better reflect reality. The aim is to be sure that your sense of what you know and can do is accurate.

*For instance:* Airline pilots use flight instruments to know when their perceptual systems are misleading them about critical factors like whether the airplane is flying level. Students use quizzes and practice tests to see whether they know as much as they think they do. It’s worth being explicit here about the importance of answering the questions in the quizzes that you give yourself. Too often we will look at a question on a practice test and say to ourselves: Yup, I know that, and then move down the page without making the effort to write in the answer. If you don’t supply the answer, you may be giving in to the illusion of knowing, when in fact you would have difficulty rendering an accurate or complete response. Treat prac-

tice tests as tests, check your answers, and focus your studying effort on the areas where you are not up to snuff.

MNEMONIC DEVICES help you to retrieve what you have learned and to hold arbitrary information in memory (Chapter 7).

*What are they?* “Mnemonic” is from the Greek word for memory, and mnemonic devices are like mental file cabinets. They give you handy ways to store information and find it again when you need it.

*For instance:* Here is a very simple mnemonic device that some schoolchildren are taught for remembering the US Great Lakes in geographic order, from east to west: Old Elephants Have Musty Skin. Mark Twain used mnemonics to teach his children the succession of kings and queens of England, staking the sequence and length of their reigns along the winding driveway of his estate, walking it with the children, and elaborating with images and storytelling. Psychology students at Bellerbys College in Oxford use mnemonic devices called memory palaces to organize what they have learned and must be prepared to expound upon in their A-level essay exams. Mnemonics are not tools for learning per se but for creating mental structures that make it easier to retrieve what you have learned.

Brief stories follow of two students who have used these strategies to rise to the top of their classes.

### Michael Young, Medical Student

Michael Young is a high-achieving fourth-year medical student at Georgia Regents University who pulled himself up from rock bottom by changing the way he studies.

Young entered medical school without the usual foundation of premed coursework. His classmates all had backgrounds in biochemistry, pharmacology, and the like. Medical school is plenty tough under any circumstances, but in Young's case even more so for lack of a footing.

The scope of the challenge that lay before him became abruptly evident. Despite his spending every available minute studying his coursework, he barely eked out a 65 on his first exam. "Quite honestly, I got my butt kicked," he says. "I was blown away by that. I couldn't believe how hard it was. It was nothing like any kind of schooling I had done before. I mean, you come to class, and in a typical day you get about four hundred PowerPoint slides, and this is dense information."<sup>1</sup> Since spending more time studying wasn't an option, Young had to find a way to make studying more effective.

He started reading empirical studies on learning and became deeply interested in the testing effect. That's how we first learned of him: He emailed us with questions about the application of spaced retrieval practice in a medical school setting. Looking back on that stressful period, Young says, "I didn't just want to find somebody's opinion about how to study. Everybody has an opinion. I wanted real data, real research on the issue."

You might wonder how he got himself into medical school without premed coursework. He had earned a master's degree in psychology and worked in clinical settings, eventually as a drug addiction counselor. He teamed up with a lot of doctors, and he slowly began to wonder if he would be happier in medicine. Had he missed his calling? "I didn't think of myself as being especially intelligent, but I wanted to do more with my life and the idea wouldn't leave me." One day he went to the biology department of his local university, Columbus State in Columbus, Georgia, and asked what courses he would need to become a doctor. They laughed. "They said, 'Well, nobody

from this school becomes a doctor. People at the University of Georgia and Georgia Tech go to medical school, we haven't had anybody go to medical school in a decade.'” Not to be put off, Young cobbled together some courses. For example, for the biology requirement, the only thing he could take at Columbus State was a fishing class. That was his biology course. Within a year he had gotten whatever medical background was available from the school, so he crammed for a month for the Medical College Admission Test and managed to score just well enough. He enrolled at Georgia Regents.

At which point he found himself very far indeed from being over the hump. As his first exam made all too clear, the road ahead went straight up. If he had any hope of climbing it, something about his study habits had to change. So what did change? He explains it this way:

I was big into reading, but that's all I knew how to do for studying. I would just read the material and I wouldn't know what else to do with it. So if I read it and it didn't stick in my memory, then I didn't know what to do about that. What I learned from reading the research [on learning] is that you have to do something beyond just passively taking in the information.

Of course the big thing is to figure out a way to retrieve the information from memory, because that's what you're going to be asked to do on the test. If you can't do it while you're studying, then you're not going to be able to do it on the test.

He became more mindful of that when he studied. “I would stop. ‘Okay, what did I just read? What is this about?’ I'd have to think about it. ‘Well, I believe it happens this way: The enzyme does this, and then it does that.’ And then I'd have to go back and check if I was way off base or on the right track.”

The process was not a natural fit. “It makes you uncomfortable at first. If you stop and rehearse what you're reading

and quiz yourself on it, it just takes a lot longer. If you have a test coming up in a week and so much to cover, slowing down makes you pretty nervous.” But the only way he knew of to cover more material, his established habit of dedicating long hours to rereading, wasn’t getting the results he needed. As hard as it was, he made himself stick to retrieval practice long enough at least to see if it worked. “You just have to trust the process, and that was really the biggest hurdle for me, was to get myself to trust it. And it ended up working out really well for me.”

Really well. By the time he started his second year, Young had pulled his grades up from the bottom of his class of two hundred students to join the high performers, and he has remained there ever since.

Young spoke with us about how he adapted the principles of spaced retrieval practice and elaboration to medical school, where the challenges arise both from the sheer volume of material to be memorized and from the need to learn how complex systems work and how they interrelate with other systems. His comments are illuminating.

*On deciding what’s important:* “If it’s lecture material and you have four hundred PowerPoint slides, you don’t have time to rehearse every little detail. So you have to say, ‘Well this is important, and this isn’t.’ Medical school is all about figuring out how to spend your time.”

*On making yourself answer the question:* “When you go back and review, instead of just rereading you need to see if you can recall the learning. Do I remember what this stuff was about? You always test yourself first. And if you don’t remember, then that’s when you go back and look at it and try again.”

*On finding the right spacing:* “I was aware of the spacing effect, and I knew that the longer you wait to practice retrieval the better it is for memory, but there’s also a trade-off with how successful you are when you try to recall it. When you have these long enzyme names, for example, and this step-by-step process of what the enzyme is doing, maybe if you learn ten steps of what the enzyme is doing, you need to stop and think, can I remember what those ten steps are? Once I found a good strategy for how much to space practice and I started seeing consistent results, it was easy to follow from there because then I could just trust the process and be confident that it was going to work.”

*On slowing down to find the meaning:* Young has also slowed down the speed at which he reads material, thinking about meaning and using elaboration to better understand it and lodge it in memory. “When I read that dopamine is released from the ventral tegmental area, it didn’t mean a lot to me.” The idea is not to let words just “slide through your brain.” To get meaning from the dopamine statement, he dug deeper, identified the structure within the brain and examined images of it, capturing the idea in his mind’s eye. “Just having that kind of visualization of what it looks like and where it is [in the anatomy] really helps me to remember it.” He says there’s not enough time to learn everything about everything, but pausing to make it meaningful helps it stick.

Young’s impressive performance has not been lost on his professors or his peers. He has been invited to tutor struggling students, an honor few are given. He has been teaching them these techniques, and they are pulling up their grades.

“What gets me is how interested people are in this. Like, in medical school, I’ve talked to all of my friends about it, and now they’re really into it. People want to know how to learn.”



### Timothy Fellows, Intro Psych Student

Stephen Madigan, a professor at the University of Southern California, was astonished by the performance of a student in his Psych 100 course. “It’s a tough course,” Madigan says. “I use the most difficult, advanced textbook, and there’s just a nonstop barrage of material. Three-quarters of the way through the class, I noticed this student named Timothy Fellows was getting 90 to 95 percent of the points on all the class activities—exams, papers, short-answer questions, multiple-choice questions. Those were just extraordinary grades. Students this good—well he’s definitely an outlier. And so I just took him aside one day and said, ‘Could you tell me about your study habits?’”<sup>2</sup>

The year was 2005. Madigan did not know Fellows outside class but saw him around campus and at football games enough to observe that he had a life beyond his academics. “Psychology wasn’t his major, but it was a subject he cared about, and he just brought all his skills to bear.” Madigan still has the list of study habit Fellows outlined, and he shares it with incoming students to this day.

Among the highlights were these:

- Always does the reading prior to a lecture
- Anticipates test questions and their answers as he reads
- Answers rhetorical questions in his head during lectures to test his retention of the reading
- Reviews study guides, finds terms he can’t recall or doesn’t know, and relearns those terms
- Copies bolded terms and their definitions into a reading notebook, making sure that he understands them
- Takes the practice test that is provided online by his professor; from this he discovers which concepts he doesn’t know and makes a point to learn them

- Reorganizes the course information into a study guide of his design
- Writes out concepts that are detailed or important, posts them above his bed, and tests himself on them from time to time
- Spaces out his review and practice over the duration of the course

Fellows's study habits are a good example of doing what works and keeping at it, so that practice is spaced and the learning is solidly embedded come exam time.

### Tips for Lifelong Learners

The learning strategies we have just outlined for students are effective for anyone at any age. But they are centered around classroom instruction. Lifelong learners are using the same principles in a variety of less-structured settings.

In a sense, of course, we're all lifelong learners. From the moment we're born we start learning about the world around us through experimentation, trial and error, and random encounters with challenges that require us to recall what we did the last time we found ourselves in a similar circumstance. In other words, the techniques of generation, spaced practice and the like that we present in this book are organic (even if counterintuitive), and it's not surprising that many people have already discovered their power in the pursuit of interests and careers that require continuous learning.

### Retrieval Practice

Nathaniel Fuller is a professional actor with the Guthrie Theater in Minneapolis. We took an interest in him after a dinner party where the Guthrie's renowned artistic director, Joe Dowling, on hearing of our work, immediately suggested

we interview Fuller. It seems that Fuller has the capacity to so fully learn the lines and movements of a role for which he is understudy that he can go onstage at the last moment with great success, despite not having had the benefit of learning and rehearsing it in the normal way.

Fuller is a consummate professional of the stage, having refined his techniques for learning roles over many years. He is often cast in a leading role; at other times, he may play several lesser characters in a play while also understudying the lead. How does he do it?

When he starts with a new script, Fuller puts it into a binder, goes through it, and highlights all of his lines. “I figure out how much I’ve got to learn. I try to estimate how much I can learn in a day, and then I try to start early enough to get that learned.”<sup>3</sup> Highlighting his lines also makes them easy to find and gives him a sense of the construction, so this use of highlighting is rather different from what students do in class when they highlight merely for purposes of rereading. “You get the shape of the line, and how the back-and-forth works.”

Fuller uses retrieval practice in various forms. First, he takes a blank sheet of paper and covers a page of the script. He draws it down, silently rendering the lines of the characters he’s playing opposite, because those lines cue his own, and the emotion in them is reflected one way or another by his own character. He keeps his own line covered and attempts to speak it aloud from memory. He checks his accuracy. If he gets the line wrong, he covers it up and speaks it again. When he has spoken it correctly, he reveals the next passage and goes on.

“Half of knowing your part is not just what to say, but knowing when to say it. I don’t have an exceptional brain for memorizing, but one of the keys I’ve found is, I need to try my

best to say the line without looking at it. I need to have that struggle in order to make myself remember it.

“I’ll work like crazy. When I get to where it feels like diminishing returns, I’ll quit. Then I’ll come back the next day, and I won’t remember it. That’s where a lot of my friends will panic. I just have faith now that it’s in there, it’s going to come back a little bit better the next time. Then I’ll work on a new chunk, until I get to the end of the play.”

As he progresses through the script, he’s constantly moving from familiar pages and scenes into newer material, the play taking shape like threads added to a growing tapestry, each scene given meaning by those that came before and extending the story in turn. When he reaches the end, he practices in reverse order, moving from the less familiar last scene to practice the more familiar one that precedes it and then continuing on through the last scene again. Then he goes to the part preceding both of those scenes and practices through to the end. His practice continues reaching back in this way until he has come to the beginning of the play. This working backward and forward helps him stitch less familiar material to more familiar, deepening his mastery of the role as a whole.

Learning lines is visual (just as they are laid out in the script), but, he says, it’s also “an act of the body, an act of the muscles, so I’m trying to say the lines in character, get how it *feels*.” Fuller examines the language of the script, the textures of the words, and the figures of speech for how they reveal meaning. He works to discover the way the character carries himself, the way he moves across the stage, his facial expressions—all facets that reveal the underlying emotions that drive each scene. These forms of elaboration help him develop an emotional approach to the role and a deeper connection to the character.

He also notches up his retrieval practice. In place of the written script, he now speaks every line of the *other* actors in the play into a palm-sized digital recorder, voiced “in character” as best he can discern it. He tucks the recorder in his hand. His thumb knows where to find the controls. The thumb presses “play,” and Fuller hears the characters’ lines, then his cue; the thumb hits “pause,” and he speaks his line from memory. If in doubt about his accuracy, he checks the script, re-plays the passage if need be, speaks his lines, and then goes on with the scene.

When he’s understudying a role, before the director and cast have worked out the blocking (how the players move in relation to one another and the set), Fuller practices at home, imagining his living room as the stage and the way the blocking might be laid out. There, as he goes through scenes with his recorder, hearing others’ lines and speaking his own, he is moving through the imagined scene, adding physicality to the part, reacting to imaginary props. When the actor he’s understudying is in rehearsal, Fuller observes from behind the theater seats at the back of the hall, walking through the blocking himself as the actors rehearse on stage. He continues to practice later at home, adapting the imaginary stage within his living room to the now-established blocking.

Fuller’s learning process is a seamless blend of desirable difficulties: retrieval practice, spacing, interleaving, generation (of his character’s soul, carriage, motivations, and idiosyncrasies), and elaboration. Through these techniques, he learns the role and the many levels of meaning that make a performance come alive to himself and to his audience.

### Generation

In 2013, John McPhee published a piece in the *New Yorker* about writer’s block. Age eighty-two at the time, McPhee of-

ferred his remarks from the vantage of a high perch, atop an illustrious career that has earned him many awards and acknowledgment as a pioneer of the craft of creative nonfiction. Writer's block is the seemingly insurmountable barrier one must somehow clamber over if he is to have any hope of engaging his subject. Writing, like any art form, is an iterative process of creation and discovery. Many would-be writers fail to find their voices for the simple fact that, until they are clear about what they want to say, they cannot bring themselves to dive in. McPhee's solution to this problem? He writes a letter to his mother. He tells her how miserable he feels, what hopes he'd had for the subject about which he wants to write (a bear), but that he has no idea how to go about it and, really, it seems that he's not cut out to be a writer after all. He would like to put across the sheer size of the bear, and how utterly lazy it is, preferring to sleep fifteen hours a day, and so on. "And then you go back and delete the 'Dear Mother' and all the whimpering and whining, and just keep the bear."

McPhee's first draft is an "awful blurting." "Then you put the thing aside. You get in the car and drive home. On the way, your mind is still knitting at the words. You think of a better way to say something, a good phrase to correct a certain problem. Without the drafted version—if it did not exist—you obviously would not be thinking of ways to improve it. In short, you may actually be writing only two or three hours a day, but your mind, in one way or another, is working on it twenty-four hours a day—yes, while you sleep—but only if some sort of draft or earlier version exists. Until it exists, writing has not really begun."<sup>4</sup>

This is the crux: Learning works the same way as McPhee's "awful blurting." Your grasp of unfamiliar material often starts out feeling clumsy and approximate. But once you engage the mind in trying to make sense of something new, the mind begins to "knit" at the problem on its own. You don't engage the

mind by reading a text over and over again or by passively watching PowerPoint slides. You engage it by making the effort to explain the material yourself, in your own words—connecting the facts, making it vivid, relating it to what you already know. Learning, like writing, is an act of engagement. Struggling with the puzzle stirs your creative juices, sets the mind to looking for parallels and metaphors from elsewhere in your experience, knowledge that can be transferred and applied here. It makes you hungry for the solution. And the solution, when you arrive at it, becomes more deeply embedded with your prior knowledge and abilities than anything pasted onto the surface of your brain by PowerPoint.

So take a page from McPhee: when you want to master something new, delete the whimpering and go wrestle the bear.

### Reflection

In Chapter 2 we tell how the Mayo Clinic neurosurgeon Mike Ebersold uses the habit of reflection to improve his skills in the operating room. Reflection involves retrieval (What did I do? How did it work?) and generation (How could I do it better next time?), invoking imagery and mental rehearsal as well (What if I take a smaller bite with the needle?). It was this habit of reflection that brought him to devise a surgical solution for the repair of a delicate sinus structure in the back of the skull that cannot be tied off because the structure is somewhat flat and tears when you snug the suture.

Vince Dooley, Georgia Bulldogs football coach (Chapter 3), helped his players use reflection and mental rehearsal to learn their playbooks and their adjustments for next Saturday's game. The Minneapolis cop David Garman (Chapter 5) uses reflection to improve his undercover strategies. The power of reflection as a learning technique is apparent throughout the

personal memoir *Highest Duty*, by Captain Chesley Sullenberger. “Sully” is the pilot who successfully and miraculously ditched US Airways Flight 1549 on the Hudson River in 2009. Time and again, in reading his autobiography, we see how he refined his understanding of flight and the control of his aircraft through training, personal experience, and the close observation of others. The process started from his earliest days at the stick of a single-engine crop duster, continued to his jet fighter days, his time investigating commercial airline disasters, and his granular analysis of the few available examples of the ditching of commercial aircraft, where he paid particular attention to the lessons for pitch, speed, and level wings. The evolution of Captain Sullenberger shows us that the habit of reflection is more than simply taking stock of a personal experience or the observed experiences of others. At its most powerful this habit involves engagement of the mind through generation, visualization, and mental rehearsal.

### Elaboration

When we met the pianist Thelma Hunter, she was learning four new works for an upcoming concert performance: pieces by Mozart, Faure, Rachmaninoff, and William Bolcom. Hunter, who is eighty-eight, won her first prize as a pianist at age five in New York and has been performing ever since. She is not a prodigy, she insists, nor even particularly renowned, but she is accomplished. In addition to a busy life raising six kids with her husband, Sam, a heart surgeon, Hunter has enjoyed a long life of learning, teaching, and performing at the piano, and she is still in the game, sought after and bent to her life’s pleasure at the keyboard.

Giving new learning multiple layers of meaning has been central to Hunter’s methods and illustrates the way elaboration



strengthens learning and memory. When she studies a new score, she learns it physically in the fingering, aurally in the sound, visually in the notes on the score, and intellectually in the way she coaches herself through transitions.

Hunter has made some concessions to age. She never used to warm up before playing, but now she does. “My stamina is not as great as it used to be. My reach is not as big. Now, if I memorize something, I have to *think* about it. I never used to have to do that, I just worked through all the aspects of it and the memorizing came.”<sup>5</sup> She visualizes the score and makes mental marginalia. “When I’m practicing, sometimes I say it out loud, ‘Up an octave, at this point,’ but in my mind’s eye I visualize the place on the sheet music, as well.” In comments that resonate with John McPhee’s observations about writing, Hunter says that at the point where a piece is almost memorized, “I’ll be driving, and I can think about the whole piece, which I do. The shape of it, as though I were a conductor, thinking, ‘Oh, that passage makes more sense if I speed it up. I have to practice that to get it faster.’ Those are the large things that I can think about away from the piano.”

Hunter’s practice regimen is daily, working through new pieces, slowing down to parse the difficult passages, and then, because she now often performs with a cellist and violinist, the ensemble works through the pieces together to synchronize their individual interpretations.

In Chapter 7 we describe Anders Ericsson’s research into how experts, through thousands of hours of solo, deliberate practice, build libraries of mental models that they can deploy to address a wide universe of situations they encounter in their area of expertise. Hunter describes experiences that would seem to manifest Ericsson’s theory. At times she must sit at the keyboard and devise a fingering plan for playing a difficult passage. Oddly, she says, after having been away from the piece

for a week, she will sit down and play it through, using a fingering pattern that she had not planned but feels entirely natural to her and familiar. It's a paradox, though perhaps not entirely surprising. She credits her subconscious, drawing from her long years of playing, with finding a more fluent solution than what she has devised by puzzling it out at the keyboard. But perhaps it has been the effort at the keys, like McPhee wrestling his bear, that has set her mind to sorting through the closets of her memory for something a little more elegant and natural to fit the occasion.

### Tips for Teachers

Here again we are leery of being too prescriptive. Every teacher must find what's right in his or her classroom. Yet specifics can be helpful. So here are some basic strategies that in our judgment will go a long way toward helping students become stronger learners in the classroom. Brief descriptions follow of what some teachers are already doing along these lines. Between the recommendations and the examples, we hope you will find practical ideas you can adapt and put to work.

#### Explain to Students How Learning Works

Students labor under many myths and illusions about learning that cause them to make some unfortunate choices about intellectual risk taking and about when and how to study. It's the proper role of the teacher to explain what empirical studies have discovered about how people learn, so the student can better manage his or her own education.

In particular, students must be helped to understand such fundamental ideas as these:

- Some kinds of difficulties during learning help to make the learning stronger and better remembered.

- When learning is easy, it is often superficial and soon forgotten.
- Not all of our intellectual abilities are hardwired. In fact, when learning is effortful, it changes the brain, making new connections and increasing intellectual ability.
- You learn better when you wrestle with new problems before being shown the solution, rather than the other way around.
- To achieve excellence in any sphere, you must strive to surpass your current level of ability.
- Striving, by its nature, often results in setbacks, and setbacks are often what provide the essential information needed to adjust strategies to achieve mastery.

These topics, woven throughout the book, are discussed in depth in Chapters 4 and 7.

### Teach Students How to Study

Students generally are not taught how to study, and when they are, they often get the wrong advice. As a result, they gravitate to activities that are far from optimal, like rereading, massed practice, and cramming.

At the beginning of this chapter we present effective study strategies. Students will benefit from teachers who help them understand these strategies and stick with them long enough to experience their benefits, which may initially appear doubtful.

### Create Desirable Difficulties in the Classroom

Where practical, use *frequent quizzing* to help students consolidate learning and interrupt the process of forgetting. Make

the ground rules acceptable to your students and yourself. Students find quizzing more acceptable when it is predictable and the stakes for any individual quiz are low. Teachers find quizzing more acceptable when it is simple, quick, and does not lead to negotiating makeup quizzes. (For one example, consider the way Kathleen McDermott, whose work we describe below, uses daily quizzing in her university class on human learning and memory.)

Create study tools that incorporate *retrieval practice*, *generation*, and *elaboration*. These might be exercises that require students to wrestle with trying to solve a new kind of problem before coming to the class where the solution is taught; practice tests that students can download and use to review material and to calibrate their judgments of what they know and don't know; writing exercises that require students to reflect on past lesson material and relate it to other knowledge or other aspects of their lives; exercises that require students to generate short statements that summarize the key ideas of recent material covered in a text or lecture.

Make quizzing and practice exercises count toward the course grade, even if for very low stakes. Students in classes where practice exercises carry consequences for the course grade learn better than those in classes where the exercises are the same but carry no consequences.

Design quizzing and exercises to *reach back to concepts and learning covered earlier* in the term, so that retrieval practice continues and the learning is cumulative, helping students to construct more complex mental models, strengthen conceptual learning, and develop deeper understanding of the relationships between ideas or systems. (For an example, read in Chapter 2 how Andy Sobel uses cumulative low-stakes quizzing in his university-level course in political economics.)

*Space, interleave, and vary* topics and problems covered in class so that students are frequently shifting gears as they have to “reload” what they already know about each topic in order to figure out how the new material relates or differs.

### Be Transparent

Help your students understand the ways you have incorporated desirable difficulties into your lessons, and why. Be up front about some of the frustrations and difficulties this kind of learning entails and explain why it’s worth persisting. Consider having them read the profile earlier in this chapter of the medical student Michael Young, who vividly describes the difficulties and ultimate benefits of using these strategies.

Mary Pat Wenderoth, Biology Professor,  
University of Washington

Mary Pat Wenderoth introduces desirable difficulties in her classes to help students master their coursework. She also works at helping students learn how to be effective at managing their own learning—to be the capable student within the professional that they envision becoming. Along that path she tackles yet another challenge, helping students learn to judge where their grasp of course material stands on Bloom’s taxonomy of learning, and how to rise to the levels of synthesis and evaluation.

Bloom’s taxonomy classifies cognitive learning on six levels. It was developed in 1956 by a committee of educators chaired by psychologist Benjamin Bloom. The six levels range from gaining *knowledge* (the most fundamental level) to developing *comprehension* of the underlying facts and ideas, being able to *apply* learning to solve problems, being able to *analyze* ideas and relationships so as to make inferences, be-