

# make it stick

*The Science of Successful Learning*

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THE BELKNAP PRESS *of* HARVARD UNIVERSITY PRESS

*Cambridge, Massachusetts*

*London, England*

2014

## 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 students 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 “reloading” 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.