MAKE IT STICK

Significant learning is often, or even usually, somewhat difficult. You will experience setbacks. These are signs of effort, not of failure. Effortful learning changes your brain, making new connections, building mental models, increasing your capability. Your intellectual abilities lie to a large degree within your own control.

Failure

A fear of failure can poison learning by creating aversion to the kinds of experimentation and risk taking that characterize striving, or by diminishing performance under pressure, as in a test setting. Difficulty is a crucial part of learning, errors are natural and to be expected, and practice helps.

The qualities of *persistence* and *resiliency*, where failure is seen as useful information, underlie successful innovation in every sphere and lie at the core of nearly all successful learning. Failure points to the need for redoubled effort, or liberates us to try different approaches. It's not the failure that's desirable—it's the dauntless effort despite the risks, the discovery of what works and what doesn't that sometimes only failure can reveal; it's trusting that trying to solve a puzzle serves us better than being spoonfed the solution, even if we fall short in our first attempts at an answer.

How Learning Works

Learning is at least a three-step process: Initial *encoding* of information is held in short-term working memory before being consolidated into a cohesive representation of knowledge in long-term memory. *Consolidation* reorganizes and stabilizes memory traces, gives them meaning, and makes connections to past experiences and to other knowledge already stored in long-term memory. *Retrieval* updates learning and enables you to apply it when you need it.

Learning always builds on a store of prior knowledge. We interpret and remember events by building connections to what we already know.

Long-term memory capacity is virtually limitless; the more you know, the more possible connections you have for adding new knowledge.

Because of the vast capacity of long-term memory, having the ability to locate and recall what you know when you need it is key; your facility for calling up what you know depends on the *repeated use* of the information (to keep retrieval routes strong) and on your establishing powerful *retrieval cues* that can reactivate the memories.

Periodic *retrieval* of learning helps strengthen connections to the memory and the cues for recalling it, while also weakening routes to competing memories. Retrieval practice that's easy does little to strengthen learning; the more difficult the practice, the greater the benefit.

When you recall learning from short-term memory, as in rapid-fire practice, little mental effort is required, and little long-term benefit accrues. But when you recall it after some time has elapsed and your grasp of it has become a little rusty, you have to make an effort to reconstruct it. This effortful *spaced* retrieval both strengthens the memory but also makes the learning pliable again, leading to its *reconsolidation.* Reconsolidation helps update your memories with new information and connect them to more recent learning.

When retrieval is *interleaved* with the practice of other material, we increase our abilities of *discrimination* and *induction.* Interleaving builds new connections, expanding and more firmly entrenching knowledge in memory and increasing the number of cues for retrieval.

Retrieval Practice

Retrieval practice means self-quizzing. Retrieving learning from memory has two profound benefits. One, it tells you what you know and don't know, and therefore where to focus further study to improve the areas where you're weak. Two, recalling what you have learned causes your brain to reconsolidate the memory, which strengthens its connections to what you already know and makes it easier for you to recall in the future. In effect, retrieval—testing—interrupts forgetting.

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 at 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?

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

What your intuition tells you to do:

Surveys of college students confirm what professors have long known: highlighting, underlining, and sustained poring over notes and texts are the most-used study strategies, by far.

Why retrieval practice is better:

Rereading has three strikes against it. It is time consuming. It doesn't result in durable memory. And it often involves a kind of unwitting self-deception, as growing familiarity with the text comes to feel like mastery of the content.

If rereading is largely ineffective, why do students favor it? Rising familiarity with a text and fluency in reading it can create an illusion of mastery. As any professor will attest, students work hard to capture the precise wording of phrases they hear in class lectures, laboring under the misapprehension that the essence of the subject lies in the syntax in which it's described. Mastering the lecture or the text is not the same as mastering the ideas behind them. However, repeated reading provides the illusion of mastery of the underlying ideas. Don't let yourself be fooled. The fact that you can repeat the phrases in a text or your lecture notes is no indication that you understand the significance of the precepts they describe, their application, or how they relate to what you already know about the subject.

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.

Effortful retrieval makes for stronger learning and retention. We're easily seduced into believing that learning is better when it's easier, but the research shows the opposite: when the mind has to work, learning sticks better.

Repeated retrieval appears to help memory consolidate into a cohesive representation in the brain and to strengthen and multiply the neural routes by which the knowledge can be later retrieved.

How it feels:

Compared to rereading, self-quizzing can feel awkward and frustrating, especially when the new learning is hard to recall. 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.

Spaced Practice

Spaced practice means studying information more than once but leaving considerable time between practice sessions. How big an interval, you ask? The simple answer: enough so that practice doesn't become a mindless repetition. At a minimum, enough time so that a little forgetting has set in. A little forgetting between practice sessions can be a good thing if it leads to more effort in practice, but you do not want so much forgetting that retrieval essentially involves relearning the material. The time periods between sessions of practice let memories consolidate. Sleep seems to play a large role in memory consolidation, so practice with at least a day in between sessions is good.

How to use spaced practice as a study strategy:

Establish a schedule of self-quizzing that allows time to elapse between study sessions. 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. 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.

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.

Why spaced practice is better:

It's a common but mistaken belief that you can burn something into memory through sheer repetition. *Cramming*, a form of massed practice, has been likened to binge-and-purge eating. A lot goes in, but most of it comes right back out in short order. Lots of practice works, but only if it's spaced.

Why is spaced practice more effective than massed practice? Embedding new learning in long-term memory requires a process of consolidation, in which memory traces (the brain's representations of the new learning) are strengthened, given meaning, and connected to prior knowledge—a process that unfolds over hours and may take several days. Rapid-fire practice leans on short-term memory. Durable learning, however, requires time for mental rehearsal and the other processes of consolidation. Hence, spaced practice works better. The increased effort required to retrieve the learning after a little forgetting has the effect of retriggering consolidation, further strengthening memory.

How it feels:

Spaced practice feels more difficult, because you have gotten a little rusty and the material is harder to recall; you don't get the rapid improvements and affirmations you're accustomed to seeing from massed practice. Even in studies where the participants have shown superior results from spaced learning, they don't perceive the improvement; they believe they learned better on the material where practice was massed.

Interleaved Practice

In *interleaved practice*, you don't move from a complete practice set of one topic to go to another; you switch before each practice is complete. 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 the principles of economics, mix up the examples.

How to use interleaved practice as a study strategy:

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.

What your intuition tells you to do:

Most learners focus on many examples of one problem 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 improves your ability to discriminate between types, and improves your success in a later test where you must discern the kind of problem you're trying to solve in order to apply the correct solution.

How it feels:

Blocked practice (i.e., mastering all of one type of problem before progressing to practice another type) feels 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.

Elaboration

Elaboration is the process of giving new material meaning by expressing it in your own words and connecting it with what you already know. Elaboration improves your mastery of new material and multiplies the mental cues available to you for later recall and application of it.

For instance:

All new learning requires a foundation of prior knowledge. To learn trigonometry, you need to remember your algebra and geometry.

If you're just engaging in mechanical repetition, you quickly hit the limit of what you can keep in mind. However, if you practice elaboration, there's no known limit to how much you can learn. The more you can explain about the way your new learning relates to your prior knowledge, the stronger your grasp of the new learning will be, and the more connections you create that will help you remember it later.

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.

Generation

Generation is an attempt to answer a question or solve a problem before being shown the solution. Generation has the effect of making the mind more receptive to new learning.

For instance:

The act of filling in a missing word in a text (i.e., 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. Being required to supply an answer rather than select from multiple choice options often provides stronger learning benefits. Having to write a short essay makes them stronger still. Overcoming these mild difficulties is a form of active learning where students engage in higher-order thinking tasks rather than passively receiving knowledge conferred by others.

As you cast about for a solution, retrieving related knowledge from memory, you strengthen the route to a gap in your learning even before the answer is provided to fill it and, when you do fill it, connections are made to the related material that is fresh in your mind from the effort. Unsuccessful attempts to solve a problem encourage deep processing of the answer when it is later supplied, creating fertile ground for its encoding, in a way that simply reading the answer cannot.

Reflection

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

For instance:

After a lecture or reading assignment, for example, you might ask yourself: What are the key ideas? What are some examples? How do these relate to what I already know?

Following an experience where you are practicing new knowledge or skills, you might ask: What went well? What could have gone better? What might I need to learn for better mastery, or what strategies might I use the next time to get better results?

Calibration

Everyone is subject to a host of cognitive illusions. Mistaking fluency with a text for mastery of the underlying content is just one example. *Calibration* is the act of aligning your judgments of what you know and don't know with objective feedback.

For instance:

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

Source: Brown, Peter C., Henry L. Roediger III, and Mark A. McDaniel. Make It Stick: The Science of Successful Learning. Belknap Press, 2014.