
make it stick - The Science of Successful Learning

A notebook and summary

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1 Learning Is Misunderstood

- Learning is deeper and more durable when it's effortful.
- *Rereading text* and *massed practice* of a skill or new knowledge among the least productive study strategies.
- *Retrieval practice* - recalling facts or concepts or events from memory (eg testing) - is a more effective learning strategy than review by rereading. Flashcards are a simple example.
- A single, simple quiz after reading a text or hearing a lecture produces better learning and remembering than rereading the text or reviewing lecture notes.
- Periodic practice arrests forgetting, strengthens retrieval routes, and is essential for hanging onto the knowledge you want to gain.
- When you space out practice at a task and get a little rusty between sessions, or you interleave the practice of two or more subjects, retrieval is harder and feels less productive, but the effort produces longer lasting learning and enables more versatile application of it in later settings.
- Trying to solve a problem *before being taught the solution* leads to better learning, even when errors are made in the attempt.
- Learning styles, for example an auditory or visual learners, are not supported by the empirical research.
- When you're adept at extracting the underlying principles or "rules" that differentiate types of problems, you're more successful at picking the right solutions in unfamiliar situations.
 - This skill is better acquired through interleaved and varied practice than massed practice.
- In virtually all areas of learning, you build better mastery when you use testing as a tool to identify and bring up your areas of weakness.
- Elaboration is the process of giving new material meaning by expressing it in your own words and connecting it with what you already know. 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.
 - Warm air can hold more moisture than cold air; to know that this is true in your own experience, you can think of the drip of water from the back of an air conditioner
- Learning is stronger when it matters, when the abstract is made concrete and personal.
 - Pilot that trains how to react to an engine failure.
- It makes sense to reread a text once if there's been a meaningful lapse of time since the first reading, but doing multiple readings in close succession is a timeconsuming study strategy that yields negligible benefits.
- Mastering the lecture of the text is not the same as mastering the ideas behind them. However, repeated reading provides the illusion of mastery of the underlying ideas.

- Questions to ask oneself:
 - Could you look at a concept define it, and use it in a paragraph?
 - While you were reading, have you thought of converting the main points of the text into a series of questions and then later tried to answer them while you were studying?
 - Have you at least rephrased the main ideas in your own words as you read?
 - Have you tried to relate them to what you already knew?
 - Have you looked for examples outside the text?
- Most people fall victim to 2 liabilities:
 - a failure to know the areas where their learning is weak
 - a preference for study methods that create a false sense of mastery
- Mastery requires both the possession of ready knowledge (memorized facts) and the conceptual understanding of how to use it.
- One of the best habits a learner can instill in oneself is regular self-quizzing to recalibrate one's understanding of what one does and does not know.

2 To Learn, Retrieve

- Reflection can involve several cognitive activities that lead to stronger learning: retrieving knowledge and earlier training from memory, connecting these to new experiences, and visualizing and mentally rehearsing what you might do differently next time.
- Retrieval makes learning stick far better than reexposure to the original material does.
- To be most effective, retrieval must be repeated again and again, in spaced out sessions so that the recall, rather than becoming a mindless recitation, requires some cognitive effort.
- Students who take practice tests have a better grasp of their progress, spot gaps and misconceptions. Giving students corrective feedback after tests keeps them from incorrectly retaining material they have misunderstood and produces better learning of the correct answers.

3 Mix Up Your Practice

- The mixing of problem types, which boosted final test performance by a remarkable 215 percent, actually impeded performance during initial learning.
- Placing too much emphasis on variety runs the risk of underemphasizing repeated retrieval practice on the basics.
- Daily reflection, as a form of spaced retrieval practice, is probably just as critical in the real world as quizzing and testing is in school.

- What happened?
 - What did I do?
 - How did it work out?
 - enhanced with elaboration (What would I do differently next time?).
- Scientists call the heightened performance during the acquisition phase of a skill “momentary strength” and distinguish it from “underlying habit strength.” The very techniques that build habit strength, like spacing, interleaving, and variation, slow visible acquisition and fail to deliver the improvement during practice that helps to motivate and reinforce our efforts.
- The simple act of spacing out study and practice in installments and allowing time to elapse between them makes both the learning and the memory stronger, in effect building habit strength.
 - The interval should be big enough so that practice doesn’t become a mindless repetition.
 - At a minimum, enough time so that a little forgetting has set in.
 - Sleep seems to play a large role in memory consolidation, so practice with at least a day in between sessions is good.
- Something as simple as a deck of flashcards can provide an example of spacing.
- The better your mastery, the less frequent the practice, but if it’s important to retain, it will never disappear completely from your practices.
 - Beware of the familiarity trap: the feeling that you know something and no longer need to practice it.
- Interleaving two or more subjects during practice also provides a form of spacing.
 - Interleaving can also help you develop your ability to discriminate later between different kinds of problems and select the right tool from your growing toolkit of solutions.
 - In interleaving, you don’t move from a complete practice set of one topic to go to another. You switch before each practice is complete.
- Something the researchers call “blocked practice” is easily mistaken for varied practice. It would be like always practicing flashcards in the same order. You need to shuffle your flashcards.

4 Embrace Difficulties

- Shortterm impediments that make for stronger learning have come to be called *desirable difficulties*.
- How readily you can recall knowledge from your internal archives is determined by context, by recent use, and by the number and vividness of cues that you have linked to the knowledge and can call on to help bring it forth.

- It is a critical point that as you learn new things, you don't lose from long-term memory most of what you have learned well in life; rather, through disuse or the reassignment of cues, you forget it in the sense that you're unable to call it up easily.
 - Context can unleash memories, as when the right key works to open an old lock.
- The easier knowledge or a skill is for you to retrieve, the less your retrieval practice will benefit your retention of it.
- In all of these examples, the change from normal presentation introduces a difficulty - disruption of fluency - that makes the learner work harder to construct an interpretation that makes sense. The added effort increases comprehension and learning.
- In testing, 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.
- “write to learn”: students reflect on a recent class topic in a brief writing assignment, where they may express the main ideas in their own words and relate them to other concepts covered in class, or perhaps outside class.
- Not all difficulties in learning are desirable ones. Anxiety while taking a test seems to represent an undesirable difficulty.
 - Intuitively it makes sense that difficulties that don't strengthen the skills you will need, or the kinds of challenges you are likely to encounter in the real-world application of your learning, are not desirable

4.1 How Learning Occurs

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.

5 Avoid Illusions of Knowing

- System 1 is automatic and deeply influential, but it is susceptible to illusion, and you depend on System 2 to help you manage yourself: by checking your impulses, planning ahead, identifying choices, thinking through their implications, and staying in charge of your actions.
- Imagination inflation refers to the tendency of people who, when asked to imagine an event vividly, will sometimes begin to believe, when asked about it later, that the event actually occurred

- Another type of memory illusion is one caused by suggestion, which may arise simply in the way a question is asked.
- Interference from other events can distort memory.
- Accounts that sound familiar can create the feeling of knowing and be mistaken for true.
 - Even a big lie told repeatedly can come to be accepted as truth.
- Confidence in a memory is not a reliable indication of its accuracy.
 - Respondents' most emotional memories of their personal details at the time they learned of the attacks are also those of which they are most confident and, paradoxically, the ones that have most changed over the years relative to other memories about 9/11.
- The better you know something, the more difficult it becomes to teach it.
 - As you get more expert in complex areas, your models in those areas grow more complex, and the component steps that compose them fade into the background of memory (the curse of knowledge).
- The failure to recognize when your solution doesn't fit the problem is another form of faulty self-observation that can lead you into trouble.
- Incompetent people lack the skills to improve because they are unable to distinguish between incompetence and competence.
- The answer to illusion and misjudgment is to replace subjective experience as the basis for decisions with a set of objective gauges outside ourselves, so that our judgment squares with the real world around us.
- Don't make the mistake of dropping material from your testing regime once you've gotten it correct a couple of times.
- Pay attention to the cues you're using to judge what you have learned.
 - Ease of retrieval after a delay, however, is a good indicator of learning.
 - How ably you can explain a text is an excellent cue for judging comprehension.
- In many fields, the practice of peer review serves as an external gauge, providing feedback on one's performance.

6 Get Beyond Learning Styles

- People who as a matter of habit extract underlying principles or rules from new experiences are more successful learners than those who take their experiences at face value, failing to infer lessons that can be applied later in similar situations.
- Dynamic testing has three steps.

1. a test of some kind - perhaps an experience or a paper exam - shows me where I come up short in knowledge or a skill.
 2. I dedicate myself to becoming more competent, using reflection, practice, spacing, and the other techniques of effective learning.
 3. I test myself again, paying attention to what works better now but also, and especially, to where I still need more work.
- Knowledge is not knowhow until you understand the underlying principles at work and can fit them together into a structure larger than the sum of its parts. Knowhow is learning that enables you to go do.
 - Be the one in charge.
 - You have to suit up, get out the door, and find what you're after. Mastery, especially of complex ideas, skills, and processes, is a quest.
 - Embrace the notion of successful intelligence.
 - Tap all of your "intelligences" to master the knowledge or skill you want to possess. Describe what you want to know, do, or accomplish. Then list the competencies required, what you need to learn, and where you can find the knowledge or skill.
 - Adopt active learning strategies like retrieval practice, spacing, and interleaving.
 - Don't rely on what feels best: use quizzing, peer review, and the other tools described to make sure your judgment of what you know and can do is accurate, and that your strategies are moving you toward your goals.
 - Distill the underlying principles; build the structure.
 - If you're an example learner, study examples two at a time or more, rather than one by one, asking yourself in what ways they are alike and different.
 - Are the differences such that they require different solutions, or are the similarities such that they respond to a common solution?
 - Break your idea or desired competency down into its component parts.
 - If you think you are a low structure-builder or an example learner trying to learn new material, pause periodically and ask what the central ideas are, what the rules are.
 - Describe each idea and recall the related points.
 - Which are the big ideas, and which are supporting concepts or nuances?
 - If you were to test yourself on the main ideas, how would you describe them?
 - What kind of scaffold or framework can you imagine that holds these central ideas together?
 - By abstracting the underlying rules and piecing them into a structure, you go for more than knowledge. You go for knowhow. And that kind of mastery will put you ahead.

7 Increase Your Abilities

- We have been raised to think that the brain is hardwired and our intellectual potential is more or less set from birth. We now know otherwise
- The brain is not a muscle, so strengthening one skill does not automatically strengthen others.
- There are strategies that can serve as cognitive “multipliers” to amp up the performance of the intelligence I’ve already got. Here are three: embracing a growth mindset, practicing like an expert, and constructing memory cues.

7.1 Growth Mindset

- Your level of intellectual ability is not fixed but rests to a large degree in your own hands.
- Dweck came to see that some students aim at performance goals, while others strive toward learning goals. In the first case, you’re working to validate your ability. In the second, you’re working to acquire new knowledge or skills. People with performance goals unconsciously limit their potential. If your focus is on validating or showing off your ability, you pick challenges you are confident you can meet. You want to look smart, so you do the same stunt over and over again. But if your goal is to increase your ability, you pick ever-increasing challenges, and you interpret setbacks as useful information that helps you to sharpen your focus, get more creative, and work harder
- Emphasizing effort gives a child a rare variable they can control. But emphasizing natural intelligence takes it out of a child’s control, and it provides no good recipe for responding to a failure.

7.2 Deliberate Practice

- Doing something repeatedly might be considered practice, deliberate practice is a different animal: it’s goal directed, often solitary, and consists of repeated striving to reach beyond your current level of performance
- Deliberate practice usually isn’t enjoyable, and for most learners it requires a coach or trainer who can help identify areas of performance that need to be improved, help focus attention on specific aspects, and provide feedback to keep perception and judgment accurate.
- Ten thousand hours or ten years of practice was the average time the people Ericsson studied had invested to become expert in their fields, and the best among them had spent the larger percentage of those hours in solitary, deliberate practice.

7.3 Memory Cues

- Mnemonic devices, are mental tools to help hold material in memory, cued for ready recall.

- A memory palace is a more complex type of mnemonic device that is useful for organizing and holding larger volumes of material in memory. It's based on the method of loci, which involves associating mental images with a series of physical locations to help cue memories. For example, you imagine yourself within a space that is very familiar to you, like your home, and then you associate prominent features of the space, like your easy chair, with a visual image of something you want to remember. (When you think of your easy chair you may picture a limber yogi sitting there, to remind you to renew your yoga lessons.)
- Images cure memories.
- Rhyme schemes can also serve as mnemonic tools. The peg method is a rhyme scheme for remembering lists. Each number from 1 to 20 is paired with a rhyming, concrete image: 1 is bun, 2 is shoe, 3 is tree, 4 is store, 5 is hive, 6 is tricks, 7 is heaven, 8 is gate, 9 is twine, 10 is pen. After 10 you add penny- one and start over with three- syllable cue words: 11 is penny- one, setting sun; 12 is penny- two, airplane glue;
- A song that you know well can provide a mnemonic structure, linking the lyrics in each musical phrase to an image that will cue retrieval of the desired memory.
- The versatility of mnemonic devices is almost endless. What they hold in common is a structure of some kind - number scheme, travel route, floor plan, song, poem, aphorism, acronym - that is deeply familiar and whose elements can be easily linked to the target information to be remembered.
- She tackles the dieting essay first. Pret-a-Manger is Marlys's memory palace for the safekeeping of what she has learned about the success and failure of dieting. Through a prior visit there, she has become thoroughly familiar with its spaces and furnishings and populated them with characters that are very familiar and vivid in her imagination. The names and actions of the characters now serve as cues to the dozen key points of her essay. She enters the shop in her mind. La Fern (the man-eating plant in "Little Shop of Horrors," one of her favorite movies) is holding Marlys's friend Herman captive, her vines wrapped tightly around him, restraining him from a large dish of mac and cheese that sits just beyond his reach. Marlys opens her exam book and begins to write. "Herman and Mack's restraint theory suggests that attempting not to overeat may actually increase the probability of overeating. That is, in restrained eaters, it is the disinhibition (loss of control) that is the cause of overeating..."
- The value of mnemonics to raise intellectual abilities comes after mastery of new material, as handy mental pockets for filing what they've learned, and linking the main ideas in each pocket to vivid memory cues so that they can readily bring them to mind.

8 Make It Stick

8.1 Practice Retrieving New Learning from Memory

- “Retrieval practice” means self-quizzing. Retrieving knowledge and skill from memory should become your primary study strategy in place of rereading.
- 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?
- 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.
- After one or two reviews of a text, self-quizzing is far more potent for learning than additional rereading.
- 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.

8.2 Space Out Your Retrieval Practice

- Spaced practice means studying information more than once but leaving considerable time between practice sessions.
- 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
- 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.

8.3 Interleave the Study of Different Problem Types

- 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.
- 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.
- 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.

8.4 Other Effective Study Strategies

8.4.1 ELABORATION

- Elaboration improves your mastery of new material and multiplies the mental cues available to you for later recall and application of it.
- Elaboration is the process of finding additional layers of meaning in new material.
- 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.
- 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.

8.4.2 GENERATION

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

8.4.3 REFLECTION

- Reflection is a combination of retrieval practice and elaboration that adds layers to learning and strengthens skills.
- 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?
 - What strategies might you use the next time to get better results?

8.4.4 Mnemonic Devices

see Memory Cues.