**Make It Stick**

**Preface:**

* The most effective learning strategies are not intuitive.
* If learners spread out their study of different topics, they learn each better than if they had studied them one at a time in sequence.

1. **Learning is misunderstood**

* The authors started with a story on a pilot (Matt Brown) who was flying a twin engine in Texas, when he noticed a drop in oil pressure in his right engine. Alone, he was flying at 11,000 feet at night. He reduced altitude and kept an eye on the oil gauge, hoping to fly as far as planned to Louisiana. He ran a mental check list figuring his options. If he let the oil pressure get too low he risked the engine’s seizing up. How much further can he travel before shutting it down? What would happen when he did? He’d lose lift on the right side, but could he stay aloft? He reviewed the tolerances he’d memorized for the plane. Loaded, the best you could do on one engine is slow your descent. But he had a light load, and he would burned through most of his fuel. So he shut down the ailing right engine, feathered the prop to reduce drag, increase power on the left, flew with opposite rudder, and limped another ten miles toward his intended stop. There, he made his approach in a wide left hand turn, for the simple but the critical reason that without the power in his right side it was only from a left hand turn that he still had the lift needed to level out for a touchdown.
* **Learning**: is acquiring knowledge and skills and having them readily available from memory so you can make sense of future problems and opportunities.
* Learning should be useful. It requires memory.
* We need to keep learning and remembering all our lives.
* Learning is an acquired skill. The most effective strategies are often counterintuitive.
* Learning that’s easy is like writing in sand, here today and gone tomorrow. It should be effortful.
* We are poor judges when we are learning well and when we are not.
* Rereading text and massed practice of a skill or new knowledge are by far the preferred study strategies of learners of all stripes, but they are also among the least productive.
* **Retrieval practice**- recalling facts from memory- is a more effective learning strategy than review by rereading. “flash cards, flight simulator”
* **Periodic Practice**- arrest forgetting, strengthen retrieval routes and it is essential for hanging into the knowledge you want to learn. (in my view it is similar to RRMS curve).
* Trying to solve the problem before being taught the solution leads to better learning, even when errors are made in the attempt. (similar to our EBM lectures- questions prior to lecture).
* People have multiple forms of intelligence to bring to bear on learning. You learn better when you go wide.
* We are all susceptible to illusions that can hijack our judgment of what we know and can do. Testing can help clarify that.
* All new learning requires a foundation of prior knowledge.
* Every time you learn something new, you change your brain. “high education profile is protective against dementia, similar to learning a new instrument, or a new language”
* Brain can’t be full. Use **Elaboration**- the process is giving a new material meaning by expressing it in your own words and connecting it with what you already know.
* Making mistakes and correcting them builds the bridges to advanced learning.
* Problems and opportunities come to us unpredictably, out of sequence.
* Gaines achieved during massed practice are transitory and melt away quickly.
* Rereading has three strikes against it- Time consuming, doesn’t result in a durable memory, and produces “unwitting self-deception” familiarity with the text comes to feel like mastery of the content.
* Matt Brown went into rigorous and extensive training for 18 days, 10 hours per day with 10 days in a class room “power point” presentation. IT WAS BORING! On day 5 the teacher asked “has anybody here had the fuel filter bypass light go in flight?” The pilot across the room raises his hand, and the instructor asked tell us what happened? “And suddenly you are thinking what if that was me?”. *Learning is stronger when it matters, when the abstract is made concrete and personal.*
* The repetition tactic when looking for a phone number but not for durable learning. Mere repetition doesn’t enhance learning.
* 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 time consuming study and it is not effective.
* Repetition is an illusion of mastery. Secretary of State Donald Rumsfeld in 2002 press briefing about US intelligence: “there are known knowns; there are things we know that we know. There are known unknowns; that is to say, there are things that we know we don’t know. But there are also unknown unknowns- There are things we do not know we don’t know”.
* It is important to know the areas the learning is weak.
* You don’t want to see your neurosurgeon or pilot with a shirt saying “creativity is more important than knowledge” –Albert Einstein. We need to learn and teach how to do both.
* Testing is not a dipstick to measure learning. It is a tool for learning. Practicing retrieval! It is another method of learning.

Chapter 2:

To Learn, Retrieve

* Repeated retrieval solidifies memory
* “Forgetting curves” show that you lose approximate 70% of what you just heard or read
  + The subsequent 30% is lost at a slower rate
* The key is to **interrupt the forgetting process** 
  + This can be accomplished with testing or self-assessment tools
* Practicing retrieval makes learning stick far better than re-exposure to original material
  + Must be spaced out to prevent mindless recitation- must require some cognitive effort
* Testing is a powerful learning tool, but seldom utilized that way

Testing Effect

* Testing effect “in the wild,” Brown, et al. 2005
* 6th grade social studies class at Columbia Middle School (IL)
* Used existing curricula, textbooks, lesson plans, teaching formats
  + Topics included ancient Egypt, Mesopotamia, India, and China
* Study ran over the course of 3 semesters (1.5 years)

Testing Effect

* A series of quizzes were given to the students on 1/3 of the course material (administered by a research assistant)
* Teacher blinded to the tested material
* Quizzes were not counted for a grade
* Questions were projected on a screen, students responded with handheld remotes
* When all had responded, the correct answer was revealed
* Non-quizzed material was interspersed with the questions as restated facts
* Students scored a full grade higher on the quizzed material during their units examination

Testing Effect

* In 2007, the process was repeated with an 8th grade science class
* At the end of 3 semesters…
  + Averaged 92% on quizzed material
  + Averaged 79% on non-quizzed material
* The testing effect persisted eight months later on the end-of-year exams

Feedback

* Getting feedback strengthens retention more than testing alone
* Briefly delaying the feedback produces a better retention and immediate feedback
* Example: Students read prose passages on science topics
  + Group A was given questions and allowed to answer them with an “open-book” format
  + Group B took the test without the material, afterward were given the passages to check their work
  + Group A performed better on the immediate test, Group B performed better on a repeat test the following day

Format

* The type of test matters
  + Short answers are more powerful than recognition tests (e.g. MCQ, T/F)
  + Learner engagement is important, may respond best to automated clickers…
* Does not need to be instructor driven
  + Flashcards can be an effective self-assessment tool
  + Retrieval is two-fold; the act of making the cards followed by their use

Benefits

* Direct effect of retrieval practice on learning
* Increased attentiveness during presentation of the material
* More accurate sense of what they know in what they don’t
  + Prevents a false sense of mastery
* Allows for the instructor to make changes in the curriculum

Testing as a Tool

* Frequent
* Low stakes
* Readily available (but delayed) feedback

Chapter 3: Mix Up Your Practice

The myth of massed practice:

* High quantity repetition done in a single way or “mass practice” leads to is easily done but easily forgotten: *easy come, easy go*.
* Many people employ this method because it *feels* like they are learning and you can cover more material more quickly.
* Spaced, variable practice, while more effortful, is more *lasting*.

Spaced practice:

* Surgical resident study on suturing vessels
  + Group 1: finished 4 sessions in a day
  + Group 2: finished 4 sessions with a week inbetween
  + Results:
    - Group 2 scored higher in all measures.
    - 16% of group 1 participants damaged the vessel beyond repair during testing on the aorta of rats.
* Memory consolidation takes place over hours to days, which helps explain why Group 2 was more successful.

Interleaved practice

* College students taught to find volumes of geometric objects (wedges, spheroid, cone, half cone)
  + Group 1: massed practice
    - Got 89% correct initially, but only 20% correct 1 week later.
  + Group 2: interleaved practice
    - Only 60% correct initially, but later got 63% right.
  + Conclusion: interleaved practice may even inhibit learning initially, but performs better long term.

Developing discrimination skills

* several studies have demonstrated that interleaved practice helps develop improved powers of discriminations
* 2 examples:

1. Learning to identify artists work using interleaved vs mass practice
2. Learning to identify birds

* In both above cases, the interleaved practice group did better.
* Interleaved practice helps develop *“conceptual knowledge”*; that is knowledge about the relationships between things.
* ‘C*onceptual knowledge*” is a higher level of knowledge than “f*actual knowledge*”, which is essentially recall and recognition.

Improving complex mastery for medical students

* “practice like you play and you will play like you practice”; the most effective retrieval practice is the one that reflects what you will be doing with that knowledge later.
* this idea supports broad use of simulators
* this section uses the “Resident teaching conferences” as an example of time that is not optimally utilized.
  + without reinforcement, the topics presented at these conferences are easily forgotten.

These principles are broadly applicable

* uses the example of college football as a model for interleaved practice.
* each practice is spaced repetition
* different plays and scenarios offer sense of variation and practice with discrimination

Chapter 4: Embrace Difficulties

* Short-term impediments that make for stronger learning are called desirable difficulties
  + Example of Jump School where each step become more and more difficult
* How learning occurs
  + Encoding – converting sensory perceptions into meaningful representations in the brain
  + Consolidation – strengthening the mental representations by making connections to past experiences/prior knowledge (thus prior knowledge is a pre-requisite to making sense of new learning); sleep helps!
  + Retrieval – Associating the material with a diverse set of cues making us adept at recalling the knowledge later
    - The situational learning; e.g. learning how to tie knots becomes more important when you’re on a boat than just hanging around in a park
    - How readily you can recall knowledge depends on context, recency, number and vividness of cues
* Inverse relationship of ease of retrieval practice and consolidation
  + E.g. baseball example (15 in a row of curveballs v mixing it up)
  + Effort requires you to reconstruct the components of a skill or material anew from a long-term memory. This is stronger than mindlessly repeating from a short-term/working memory (e.g. beanbag toss)
  + Doing this enough allows you to create a mental model
  + Retrieval practice (different contexts and interleaving with different issues) permits new associations and broadens the mental model
  + We learn by differences as much as by similarities (consider paintings, dog breeds and even disease processes)
  + When asked to solve a problem BEFORE being shown how to solve it, the solution is better learned (again, the boat and knot-tying example)
    - How can we use this for MS3s when sending to see a consult? Chart review? Chief complaint only? Some helpful tips on what to ask for in a headache patient?
* Other learning strategies incorporating desirable difficulties
  + Presenting lecture in different format from textbook and making students reconcile the two
  + Using odd font or deleting letters to make them slow down and process (but no comic sans! Or bad spelling!)
  + Generation – the act of attempting to solve a problem rather than being presented a solution; i.e. free form answers is better strategy for learning than multiple choice. This can be utilized in ‘pimping’. Perhaps we should be asking to verbalize the thought process? Some attendings ascribe to the “Don’t guess” philosophy and perhaps that should be changed
  + Reflection – mixture of retrieval, elaboration, generation that is done independently and reinforces learning. One example is “write to learn”
    - Intro psych lectures. Write down key concepts v showing a summary slide. Guess who did better?
    - Is there a role for this in weekly conferences? Or perhaps the summer lecture series?
    - The generative learning example about the Minnesota gardener. She embraced the difficulties and wrote about them in a blog. Perhaps a role for M&M?
* Errorless learning is no longer desirable
  + However, it is prized in Western society. And perhaps reinforced by some educators who worry students will remember the mistakes and NOT the correct answers!
    - Consider the typical MS3 who excelled in high school, college, MCAT and is now excelling/expecting to excel on the wards?!
    - Obsessing over this occupies working memory which means one has less space/RAM for trying to solve a complex problem (like a test!)
    - Trying to change the philosophy with “Festival of Errors” and “FailCon”
* Undesirable Difficulties
  + One must be able to overcome the difficulty with increased EFFORT, thus, if one lacks the pre-requisite knowledge or skills, learning cannot happen