

## A MIND FOR NUMBERS

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### ***Understand the paradoxes of learning***

The very thing we need in order to learn impedes our ability to learn. We need to focus intently to be able to solve problems—yet that focus can also block us from accessing the fresh approach we may need. Success is important, but critically, so is failure. Persistence is key—but misplaced persistence causes needless frustration.

### ***Mistakes are inevitable***

*We learn a great deal from our failures.* Know that you are making progress with each mistake you catch when trying to solve a problem—finding errors should give you a sense of satisfaction. Edison himself is said to have noted, “I have not failed. I’ve just found 10,000 ways that won’t work.”

### ***Take responsibility for your own learning***

Research has shown that students learn best when they themselves are actively engaged in the subject instead of simply listening to someone else speak. A student’s ability to grapple personally with the material, sometimes bouncing it off fellow learners, is key.

### ***Prime your mental pump***

As you first begin looking at a chapter, it helps to take a “picture walk” through the chapter, glancing not only at the graphics, diagrams, and photos, but also at the section headings, summary, and even questions at the end of the chapter. You’ll be surprised at how *spending a minute or two glancing ahead before you read in depth will help you organize your thoughts*. You’re creating little neural hooks to hang your thinking on, making it easier to grasp the concepts.

### ***What to do when you’re really stumped***

When you’re genuinely stuck, nothing is more helpful than getting insight from classmates or the instructor. Ask someone else for a different perspective on how to solve the problem or a different analogy to understand the concept; however, it’s best that you first wrestle with the problem yourself *before* you talk to anyone else, because it can embed the basic concepts deeply enough that you become receptive to the explanation. Learning often means making sense of what we’ve ingested, and for that, we need to have ingested something. And don’t wait until the week before midterms or final exams for this assistance. Go early and often. The instructor can often rephrase or explain in a different way that allows you to grasp the topic.

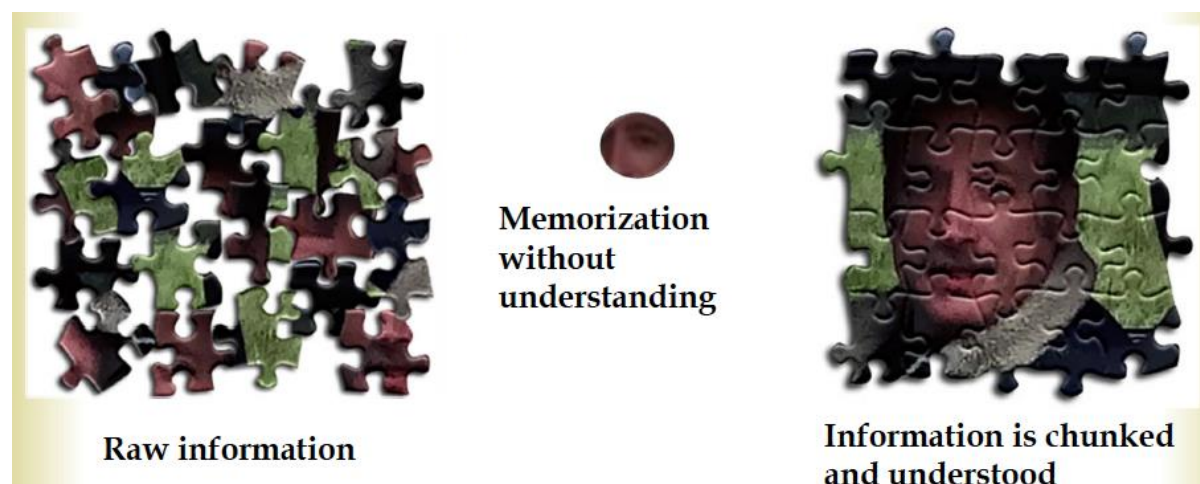
### ***The value of studying with friends***

Friends can serve as a sort of ever-questioning, larger-scale diffuse mode, outside your own brain, that can catch what you missed, or what you just can’t see. And of course, explaining to friends helps build your own understanding.

Those you study with should have, at least on occasion, an aggressively critical edge to them. Research on creativity in teams has shown that nonjudgmental, agreeable interactions are *less* productive than sessions where criticism is accepted and even solicited as part of the game. If you or one of your study buddies thinks something is wrong in your understanding, it’s important to be able to plainly say so, and to hash out why it’s wrong without worrying about hurt feelings. Of course, you don’t want to go about gratuitously bashing other people, but too much concern for creating a “safe environment” for

criticism actually kills the ability to think constructively and creatively, because you're focusing on the other people rather than the material at hand. Criticism, whether you are giving or receiving it, isn't really about you. It's about what you are trying to understand.

## CHUNKING



When you first look at a brand-new concept, it sometimes doesn't make much sense, as shown by the puzzle pieces above on the left.

Just memorizing a fact (*center*) without understanding or context doesn't help you understand what's really going on, or how the concept fits together with the other concepts you are learning—notice there are no interlocking puzzle edges on the piece to help you fit into other pieces.

Chunking (*right*) is the mental leap that helps you unite bits of information together through meaning. The new logical whole makes the chunk easier to remember, and also makes it easier to fit the chunk into the larger picture of what you are learning.

## PROBLEM SOLVING

It is key that you are the one doing the problem solving, not whoever wrote the solution manual. If you work a problem by just looking at the solution, and then tell yourself, "Oh yeah, I see why they did that," then the solution is not really yours—you've done almost nothing to knit the concepts into your underlying neurocircuitry. Merely glancing at the solution to a problem and thinking you truly know it yourself is one of the most common illusions of competence in learning.

## TESTING

Attempting to *recall* the material you are trying to learn—retrieval practice—is far more effective than simply rereading the material. Most students "repeatedly read their notes or textbook (despite the limited benefits of this strategy), but relatively few engage in self-testing or retrieval practice while studying." When you have the book open right in front of you, it provides the illusion that the material is also in your brain. *But it's not.*

In the same amount of time, *by simply practicing and recalling the material*, students learned far more and at a much deeper level than they did using any other approach, including simply rereading the text a number of times. This improved learning comes whether students take a formal test or just informally test themselves.

When we retrieve knowledge, we're not being mindless robots—the *retrieval process itself enhances deep learning and helps us begin forming chunks*.

Research has shown that testing isn't just a means of measuring how much you know. Testing in itself is a powerful learning experience. It changes and adds to what you know, also making dramatic improvements in your ability to retain the material. This improvement in knowledge because of test taking is called the *testing effect*. It seems to occur because testing strengthens and stabilizes the related neural patterns in your brain.

## INTERLEAVING

Interleaving means practice by doing a mixture of different kinds of problems requiring different strategies. When you are learning a new problem-solving approach, you tend to practice it over and over again during the same study session. The reality is, mastering a new subject means learning to select and use the proper technique for a problem. The only way to learn that is by practicing with problems that require different techniques. Once you have the basic idea of a technique down during your study session, start interleaving your practice with problems of different types. You want your brain to become used to the idea that just knowing *how* to use a particular problem-solving technique isn't enough—you also need to know *when* to use it.

Too many students do homework just to get it done. They finish a problem, check their answer in the back of the text, smile, and go on to the next problem. I suggest that they insert a step between the smile and going on to the next problem—asking themselves this question: “How would I know how to do the problem this way if I saw it on a test mixed together with other problems and I didn't know it was from this section of the text?” Students need to think of every homework problem in terms of test preparation and not as part of a task they are trying to complete.

## SHARING

Next time you are with a family member, friend, or classmate, relate the essence of what you have been learning in regard to a class you are taking. Retelling whatever you are learning about not only helps fuel and share your own enthusiasm, but also clarifies and cements the ideas in your mind, so you'll remember them better in the weeks and months to come. Even if what you are studying is very advanced, simplifying so you can explain to others who do not share your educational background can be surprisingly helpful in building your understanding.

You may think you really have to understand something in order to explain it. But observe what happens when you are talking to other people about what you are studying. You'll be surprised to see how often understanding arises as a *consequence* of attempts to explain to others and yourself, rather than the explanation arising out of your previous understanding. This is why teachers often say that the first time they ever really understood the material was when they had to teach it.

## TEN RULES OF GOOD STUDYING

1. **Use recall.** After you read a page, look away and recall the main ideas. Highlight very little, and never highlight anything you haven't put in your mind first by recalling. Try recalling main ideas when you are walking to class or in a different room from where you originally learned it. An ability to recall is one of the key indicators of good learning.
2. **Test yourself.** On everything. All the time. Flash cards are your friend.
3. **Chunk your problems.** Chunking is understanding and practicing with a problem solution so that it can all come to mind in a flash. After you solve a problem, rehearse it. Make sure you can solve it cold—every step. Pretend it's a song and learn to play it over and over again in your mind, so the information combines into one smooth chunk you can pull up whenever you want.
4. **Space your repetition.** Spread out your learning in any subject a little every day, just like an athlete. Your brain is a muscle—it can handle only a limited amount of exercise on one subject at a time.
5. **Alternate different problem-solving techniques during your practice.** Never practice too long at any one session using only one problem-solving technique—after a while, you are just mimicking what you did on the previous problems. Mix it up and work on different types of problems. This teaches you both *how* and *when* to use a technique. (Books generally are not set up this way, so you'll need to do this on your own.) After every assignment and test, go over your errors, make sure you understand why you made them, and then rework your solutions. To study most effectively, *handwrite* (don't type) a problem on one side of a flash card and the solution on the other. (Handwriting builds stronger neural structures in memory than typing.) Quiz yourself randomly on different types of problems.
6. **Take breaks.** It is common to be unable to solve problems or figure out concepts the first time you encounter them. This is why a little study every day is much better than a lot of studying all at once. When you get frustrated with a problem, take a break so that another part of your mind can take over and work in the background.
7. **Use explanatory questioning and simple analogies.** Whenever you are struggling with a concept, think to yourself, "How can I explain this so that a ten-year-old could understand it?" Using an analogy really helps, like saying that the flow of electricity is like the flow of water. Don't just think your explanation—say it out loud or put it in writing. The additional effort of speaking and writing allows you to more deeply encode (that is, convert into neural memory structures) what you are learning.
8. **Focus.** Turn off all interrupting beeps and alarms on your phone and computer, and then turn on a timer for 25 minutes. Focus intently for those 25 minutes and try to work as diligently as you can. After the timer goes off, give yourself a small, fun reward. A few of these sessions in a day can really move your studies forward. Try to set up times and places where studying—not glancing at your computer or phone—is just something you naturally do.
9. **Eat your frogs first.** Do the hardest thing earliest in the day, when you are fresh.
10. **Make a mental contrast.** Imagine where you've come from and contrast that with the dream of where your studies will take you. Post a picture or words in your workspace to remind you of your dream. Look at that when you find your motivation lagging.

## TEN RULES OF BAD STUDYING

1. **Passive rereading**—sitting passively and running your eyes back over a page. Unless you can prove that the material is moving into your brain by recalling the main ideas without looking at the page, rereading is a waste of time.
2. **Letting highlights overwhelm you.** Highlighting your text can fool your mind into thinking you are putting something in your brain, when all you're really doing is moving your hand. A little highlighting here and there is okay—sometimes it can be helpful in flagging important points. But if you are using highlighting as a memory tool, make sure that what you mark is also going into your brain.
3. **Merely glancing at a problem's solution and thinking you know how to do it.** This is one of the worst errors students make while studying. You need to be able to solve a problem step-by-step, without looking at the solutions.
4. **Waiting until the last minute to study.** Would you cram at the last minute if you were practicing for a track meet? Your brain is like a muscle—it can handle only a limited amount of exercise on one subject at a time.
5. **Repeatedly solving problems of the same type that you already know how to solve.** If you just sit around solving similar problems during your practice, you're not actually preparing for a test—it's like preparing for a big basketball game by just practicing your dribbling.
6. **Letting study sessions with friends turn into chat sessions.** Checking your problem solving with friends, and quizzing one another on what you know, can make learning more enjoyable, expose flaws in your thinking, and deepen your learning. But if your joint study sessions turn to fun before the work is done, you're wasting your time and should find another study group.
7. **Neglecting to read the textbook before you start working problems.** Would you dive into a pool before you know how to swim? The textbook is your swimming instructor—it guides you toward the answers. You will flounder and waste your time if you don't bother to read it. Before you begin to read, however, take a quick glance over the chapter or section to get a sense of what it's about.
8. **Not checking with your instructors or classmates to clear up points of confusion.** Professors are used to lost students coming in for guidance—it's our job to help you. The students we worry about are the ones who don't come in. Don't be one of those students.
9. **Thinking you can learn deeply when you are being constantly distracted.** Every tiny pull toward an instant message or conversation means you have less brainpower to devote to learning. Every tug of interrupted attention pulls out tiny neural roots before they can grow.
10. **Not getting enough sleep.** Your brain pieces together problem-solving techniques when you sleep, and it also practices and repeats whatever you put in mind before you go to sleep. Prolonged fatigue allows toxins to build up in the brain that disrupt the neural connections you need to think quickly and well. If you don't get a good sleep before a test, nothing else you have done will matter.