**BOOK**
**A Mind for Numbers: How to Excel at Math and Science (Even if you Flunked Algebra)**

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**SYNOPSIS [From the publisher]**
Whether you are a student struggling to fulfill a math or science requirement, or you are embarking on a career change that requires a new skill set, A Mind for Numbers offers the tools you need to get a better grasp of that intimidating material. Engineering professor Barbara Oakley knows firsthand how it feels to struggle with math. She flunked her way through high school math and science courses, before enlisting in the army immediately after graduation. When she saw how her lack of mathematical and technical savvy severely limited her options—both to rise in the military and to explore other careers—she returned to school with a newfound determination to re-tool her brain to master the very subjects that had given her so much trouble throughout her entire life.

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## QUOTES

"Henri Poincaré was a nineteenth-century mathematician who once described how he cracked a difficult mathematical problem that he had been intensively working on for weeks without success. He took a vacation. As he was getting on a bus in the south of France, the answer to the problem suddenly came to him, unbidden, from a part of his brain that had continued to work on the problem while he was enjoying his vacation. He knew he had the right solution even though he did not write down the details until he later returned to Paris."

"In my laboratory, for example, we have surveyed college students about their learning. They most commonly use the strategy of repeated reading—simply reading through books or notes over and over. We and other researchers have found that this passive and shallow strategy often produces minimal or no learning. We call this "labor in vain"—students are putting in labor but not getting anywhere."

"If you don't (yet) consider yourself naturally good at math and science, you may be surprised to learn that the brain is designed to do extraordinary mental calculations. We do them every time we catch a ball, or rock our body to the beat of a song, or maneuver our car around a pothole in the road. We often do complex calculations, solving complex equations unconsciously, unaware that we sometimes already know the solution as we slowly work toward it.2 In fact, we all have a natural feel and flair for math and science. Basically, we just need to master the lingo and culture."

"As you first begin looking at a chapter or section of a book that teaches concepts of math or science, 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, if the book has them. This seems counterintuitive—you haven't actually read the chapter yet, but it helps prime your mental pump. So go ahead now and glance through this

chapter and the 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."

"If you are trying to understand or figure out something new, your best bet is to turn off your precision-focused thinking and turn on your "big picture" diffuse mode"

"Creativity expert Howard Gruber has suggested that one of the three B's usually seems to do the trick: the bed, the bath, or the bus.2 One remarkably inventive chemist of the mid-1800s, Alexander Williamson, observed that a solitary walk was worth a week in the laboratory in helping him progress in his work.3 (Lucky for him there were no smartphones then.) Walking spurs creativity in many fields; a number of famous writers, such as Jane Austen, Carl Sandburg, and Charles Dickens, found inspiration during their frequent long walks. Once you are distracted from the problem at hand, the diffuse mode has access and can begin pinging about in its big-picture way to settle on a solution."

"Enlisting the diffuse mode helps you learn at a deep and creative level. There is much creativity underlying math and science problem solving. Many people think that there's only one way to do a problem, but there are often a number of different solutions, if you have the creativity to see them. For example, there are more than three hundred different known proofs of the Pythagorean theorem."

"Mistakes are inevitable. To work past them, start early on your assignments and, unless you are really enjoying what you are doing, keep your working sessions short. Remember, when you take breaks, your diffuse mode is still working away in the background. It's the best deal around—you continue to learn while you are taking it easy. Some people think they never enter diffuse mode, but that's simply not true. Every time you relax and think of nothing in particular, your brain enters into a natural default mode that's a form of diffuse thinking. Everybody does this."

"Chess players who experience Einstellung truly believe they are scanning the board for a different solution. But careful study of where their eyes are moving shows that they are keeping their focus on the original solution. Not only their eyes, but their mind itself can't move away enough to see a new approach to the problem.15 According to recent research, blinking is a vital activity that provides another means of reevaluating a situation."

"A good rule of thumb, when you are first learning new concepts, is not to let things go untouched for longer than a day."

"Learning is often paradoxical. 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."

"Criticism makes us better: By exposing our work to others, and by externalizing it so we can inspect it ourselves, we gain unique perspective and insight and develop new and improved plans for the next version. Be willing to be disagreeable. There is a negative correlation between the level of creativity and "agreeableness," so those who are the most disagreeable tend to be most creative. Looking back at the few times when I found something novel, it was because I challenged the existing answers. So I believe the creative way is advanced whenever we strip a problem back to its roots and question our own assumptions (along with assumptions suggested by others); then repeat!"

"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."

"The first step in chunking, then, is to simply focus your attention on the information you want to chunk."

"The second step in chunking is to understand the basic idea you are trying to chunk."

"The third step to chunking is gaining context so you see not just how, but also when to use this chunk."

"Skimming through a chapter or listening to a very well-organized lecture can allow you to gain a sense of the big picture. This can help you know where to put the chunks you are constructing. Learn the major concepts or points first—these are often the key parts of a good instructor or book chapter's outline, flow charts, tables, or concept maps. Once you have this done, fill in the details. Even if a few of the puzzle pieces are missing at the end of your studies, you can still see the big picture."

"Attempting to recall the material you are trying to learn—retrieval practice—is far more effective than simply rereading the material."

"You must have information persisting in your memory if you are to master the material well enough to do well on tests and think creatively with it."

"In addition, recalling material when you are outside your usual place of study helps you strengthen your grasp of the material by viewing it from a different perspective."

"Read (but don't yet solve) assigned homework and practice exams/quizzes. With this initial step I prime my mental pump for learning new concepts—new chunks. 2. Review lecture notes (attend every lecture as much as possible). One hour of lecture is worth two hours reading the book. I learn far more efficiently if I am faithful in attending lectures and taking detailed notes—not just staring at my watch and waiting for it to be over. I review my notes the following day while the subjects are still fresh in my mind. I've also found that thirty minutes with a professor asking questions is easily worth three hours reading the book. 3. Rework example problems presented in lecture notes. It never helped me to practice problems given by either the instructor or the textbook that didn't have solutions to provide feedback. With the example problems I already had a step-by-step solution available if necessary. Reworking helps solidify chunks. I use different-colored pens when I study: blue, green, red—not just black. I found that it helps me focus on reading my notes better; things pop out more, instead of blending together into a confusing collage of inexplicable mathematical chaos on the page. 4. Work assigned homework and practice exam/quiz questions."

"Part of the reason an image is so important to memory is that images connect directly to your right brain's visuospatial centers. The image helps you encapsulate a seemingly humdrum and hard-to-remember concept by tapping into visual areas with enhanced memory abilities."

"The memory palace technique involves calling to mind a familiar place—like the layout of your house—and using it as a sort of visual notepad where you can deposit concept-images that you want to remember. All you have to do is call to mind a place you are familiar with: your home, your route to school, or your favorite restaurant. And voilà! In the blink of an imaginative eye, this becomes the memory palace you'll use as your notepad."

"Another key to memorization is to create meaningful groups that simplify the material. Let's say you wanted to remember four plants that help ward off vampires—garlic, rose, hawthorn, and mustard. The first letters abbreviate to GRHM, so all you need to do is remember the image of a GRAHAM cracker. (Retrieve your cracker from the kitchen table of your memory palace, dust off the vowels, and you're good to go.)"

"Memory Tricks Help You Become an Expert More Quickly Here's the bottom line. By using mental pictures instead of words to remember things, you can leap more easily into expert status. In other words, learning to process ideas visually in math and science is a powerful way to become a master of the material. And using other memory tricks can greatly enhance your ability to learn and retain the material."

"Good chunks form neural patterns that resonate, not only within the subject we're working in, but with other subjects and areas of our lives. The abstraction helps you transfer ideas from one area to another."

"Persistence is often more important than intelligence.1 Approaching material with a goal of learning it on your own gives you a unique path to mastery. Often, no matter how good your teacher and textbook are, it's only when you sneak off and look at other books or videos that you begin to see that what you learn through a single teacher or book is a partial version of the full, three-dimensional reality of the subject, which has links to still other fascinating topics that are of your choosing."

"In some sense, when you whiz through a homework or test problem and don't go back to check your work, you are acting a little like a person who is refusing to use parts of your brain."

"Sometimes, as we've discovered, your desire to figure things out right now is what prevents you from being able to figure things out. It's almost as if, when you reach too quickly with your right hand, your left hand automatically latches on and holds you back."

"Reshaping your brain is under your control. The key is patient persistence—working knowledgeably with your brain's strengths and weaknesses."

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—to generate the ideas from inside yourself—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 like 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 problem. 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.) You might also photograph the card if you want to load it into a study app on your smartphone. Quiz yourself randomly on different types of problems. Another way to do this is to randomly flip through your book, pick out a problem, and see whether you can solve it cold.

**6. Take breaks.**
It is common to be unable to solve problems or figure out concepts in math or science 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 math or science 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 beeps and alarms on your phone and computer and set a timer for 25 minutes. Focus intently for the 25 minutes and try to work as diligently as you can. When the timer goes off give yourself a small, fun reward.

9. **Eat your frogs first**.
Do the hardest thing early 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 are going to take you. Post a picture or words in your workspace to remind yourself of your dream. Look at this when you find motivation flagging.

"Take it. Don't settle. You're a genius and we need your contribution."