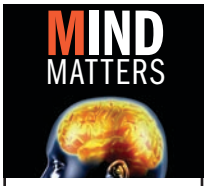


Each week in Mind Matters, www.ScientificAmerican.com/mind-and-brain, researchers explain their disciplines' most notable recent findings. Mind Matters is edited by Jonah Lehrer, the science writer behind the blog The Frontal Cortex, http://scienceblogs.com/cortex

The Pluses of **Getting It Wrong**

New research makes the case for difficult tests in schools and suggests an unusual technique that anyone can use to learn

By Henry L. Roediger and Bridgid Finn

For years many educators have championed "errorless learning," advising teachers (and students) to create study conditions that do not permit errors. For example, a classroom teacher might drill students repeatedly on the same multiplication problem, with very little delay between the first and second presentations of the problem, ensuring that the student gets the answer correct each time.

The idea is that students who make errors will remember the mistakes and will not learn the correct information (or will learn it more slowly, if at all). Recent research shows that this worry is misplaced. Pupils actually learn better if conditions are arranged so that they *have* to make errors. Specifically, people remember things better and longer if they are given tests so challenging that they are bound to fail. This phenomenon has obvious applications for education, but the technique could be useful for anyone who is trying to absorb new material of any kind.

Test First, Study Later

Evidence for the effect comes from a new study by psychologists Nate Kornell, Matthew Hays and Robert Bjork, then at the University of California, Los Angeles, which showed that trying and failing to retrieve the answer help in learning. As the researchers report in the July 2009 issue of the *Journal of Experimental Psychology: Learning, Memory and Cognition*, students who make an unsuccessful attempt to answer a test question before receiving the correct answer remember the material better than if they simply study the information.

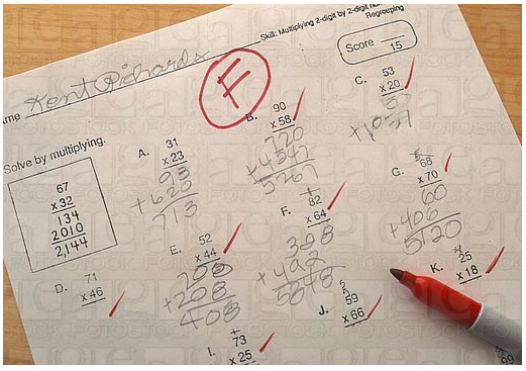
In one of the experiments, students were required to learn pairs of "weak associates"—loosely related words, such as star-night or factory-plant. The associations are weak because students who are given the first word and asked to generate an associate have only a 5 percent probability of coming up with the target word. Students who took a pretest were given the first word of each pair (star-???) and told to try to produce the second member that they would have to later remember. They had eight seconds to do so. Of course, almost by definition,

FAST FACTS

Test First, Learn Later

1» **Students who take tests on material before studying it remember the information better and longer than those who study without pretesting.**

2» **Anyone can use this technique to enhance recall of new information.**



Failing a test may not be all bad. If students learn the correct answers soon after they get the questions wrong, they will retain the information better in the long run.

with probability against them, they nearly always failed to think of the correct answer—they might say "bright" or "sun" in the case of star-???. After their attempt, they were given the target pair (star-night) and allowed to study the pair for five seconds. Another group of students got 13 seconds to study each pair. Thus, in both conditions, students had a total of 13 seconds of study time for each pair.

The team found that students remembered the pairs much better when they first tried to guess the answer before it was shown to them. In a way, this pretesting effect is counterintuitive: studying a pair for 13 seconds is less effective than studying the pair for five seconds if those five seconds of study follow eight seconds of trying to guess the answer. But the pretesting effect produced about 10 percent better recall when the students were tested both immediately after study and after a delay averaging 38 hours.

Memory Boost

Using word pairs is a favorite tactic of psychologists, but it may seem a far cry from a real classroom test. In a paper from the *Journal of Experimental Psychology: Applied,* psychologists Lindsey E. Richland, Nate Kornell and Liche Sean Kao investigated the same phenomenon, but they used more educationally relevant material: an essay on vision from Oliver Sacks's book *An Anthropologist on Mars* (Vintage, 1996), commonly used in college classrooms. Some students were asked to read the essay and prepare for a test on it. Others were given a pretest: they were asked questions about a passage before reading it, such as, "What is total color blindness caused by brain damage called?"

Asking these kinds of questions before reading the passage obviously focuses students' attention on the critical concepts. The psychologists used several methods to control this "direction of attention" issue. Students who read the essay without a pretest were given additional time to study, or else the students' attention was focused on the critical passages in one of several ways: by italicizing the critical section or by making the key term that would be tested bold, or by a combination of strategies. In all the experiments, however, the researchers found an advantage in having students first guess the answers. The effect was about the same magnitude, around 10 percent, as in the previous set of experiments.

The authors took care to show that the beneficial effect from pretesting did not result from simply having seen the test questions before reading the essay but rather from attempting to answer the questions. In one of the experiments they describe in the paper, they studied a third group of students in addition to the pretested group and the extended study group. Prior to testing, this new group was asked to study the test questions carefully, try to memorize the questions and then write them down on a sheet of paper—ostensibly so they could test other students on the reading material at a later time. These question-memorizing students also performed better on the final test than the group who studied the essay without seeing the test questions, but they did not do as well as the students who attempted to answer the test questions before reading the essay.

In other words, the learning boost from pretesting seems to truly come from the attempt to answer a question and the subsequent failure to call up the information. The researchers even suggest that perhaps the enhanced retention in the memorization group was a result of the students' mental attempts to answer the questions, even though they were not instructed to do so.

Useful Techniques

This new work could be seen as an extension of the "testing effect," a well-established psychological phenomenon whereby testing students on previously learned material causes them to retain the material better than continued study does. For example, a 2006 study by one of us (Roediger) and Jeffrey D. Karpicke of Washington University in St. Louis showed that taking a memory test enhances later retention. In two experiments, students first studied prose passages. Then one group took one or three immediate free-recall tests, without feedback,

(The Authors)

HENRY L. ROEDIGER III is James S. McDonnell Distinguished University Professor at Washington University in St. Louis. BRIDGID FINN earned her Ph.D. in cognitive psychology at Columbia University. She is now working as a postdoctoral research fellow at Washington University.

People studying any material can benefit from asking themselves questions about the information they have not yet learned.

whereas another group restudied the material the same number of times as the students who received tests. On tests later, at two days and at one week, there was a substantial difference between the groups—students who had been tested remembered around 60 percent of the material, whereas students who restudied remembered only about 40 percent of the material. The benefits of testing as a learning strategy are clear, and now the new papers from Kornell and his colleagues add to this idea the fact that testing *before* learning can improve later recall as well.

Although researchers do not yet know the neural mechanisms responsible for the testing effect, the implications of this work are obvious—rather than aiming at "errorless learning," teachers should challenge their students to try to answer questions about a subject before they study the material (a tactic bound to produce many errors). And even if this strategy is not employed in the classroom, students could use it on their own to improve their learning. Look at the questions in the back of each textbook chapter and try to answer them before reading the chapter. If there are no questions, convert the section headings to questions. For instance, if the heading is "Pavlovian conditioning," ask yourself, "What is Pavlovian conditioning?" Then read the chapter and answer the questions while reading it. When the chapter is finished, go back to the questions and try answering them again. For any you miss, restudy that section of the chapter. Then wait a few days and try to answer the questions again (restudying when you need to). Keep this practice up for an entire course, and you will have learned the material in a durable manner—you will be able to retrieve it long after you have left the course.

Of course, these are general-purpose strategies that work for any type of material, not just textbooks. By challenging ourselves to retrieve or generate answers, we can improve our recall. Keep that in mind next time you turn to Google for an answer. You might want to give yourself a little more time to come up with the answer on your own. And remember, even if you get the questions wrong as you self-test yourself during study, the process is still useful, indeed much more useful than just studying alone. Getting the answer wrong is a great way to learn—as long as you receive the correct answer shortly afterward. **M**

(Further Reading)

- **Test-Enhanced Learning: Taking Memory Tests Improves Long-Term Retention.** Henry L. Roediger III and Jeffrey D. Karpicke in *Psychological Science,* Vol. 17, No. 3, pages 249–255; March 2006.
- **Unsuccessful Retrieval Attempts Enhance Subsequent Learning.** Nate Kornell, Matthew Hays and Robert Bjork in *Journal of Experimental Psychology: Learning, Memory and Cognition,* Vol. 35, No. 4, pages 989–998; July 2009.
- **The Pretesting Effect: Do Unsuccessful Retrieval Attempts Enhance Learning?** Lindsey E. Richland, Nate Kornell and Liche Sean Kao in *Journal of Experimental Psychology: Applied,* Vol. 15, No. 3, pages 243–257; September 2009.