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WHAT WORKS, WHAT DOESN'T

Some study techniques accelerate learning, whereas others are just a waste of time—but which ones are which? An unprecedented review maps out the best pathways to knowledge

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Education generally focuses on what you study, such as algebra, the elements of the periodic table or how to conjugate verbs. But learning how to study can be just as important, with lifelong benefits. It can teach you to pick up knowledge faster and more efficiently and allow you to retain information for years rather than days.

Cognitive and educational psychologists have developed and evaluated numerous techniques, ranging from rereading to summarizing to self-testing, for more than 100 years. Some common strategies markedly improve student achievement, whereas others are time-consuming and ineffective. Yet this information is not making its way into the classroom. Teachers today are not being told which learning techniques are supported by experimental evidence, and students are not being taught how to use the ones that work well. In fact, the two study aids that students rely on the most are not effective. One of them may even undermine success.

One potential reason is that the huge amount of research is overwhelming, making it difficult for educators and students to identify the most practical and advantageous ways to study. To meet this challenge, we reviewed more than 700 scientific articles on 10 commonly used learning techniques. We focused on strategies that seem to be easy to use and broadly effective. We also took a closer look at a couple of methods that are very popular with students.

To receive our recommendation, a technique must be useful in a range of learning conditions, such as whether a student works alone or in a group. It must assist learners of various ages, abilities and levels of prior knowledge—and it must have been tested in a classroom or other real-world situation. Learners should be able to use the method to master a variety of subjects, and their performance should benefit no matter what kind of test is used to measure it. The best approaches also result in long-lasting improvements in knowledge and comprehension.

Using these criteria, we identified two clear winners. They produced robust, durable results and were relevant in many situations. Three more are recommended with reservations, and five—including two popular learning aids—are not advised, either because they are useful only in limited circumstances or because not enough evidence supports a higher rating. We encourage researchers to further explore some of the untested techniques, but students and teachers should be cautious about relying on them.

FAST FACTS

Rating the Best Ways to Study

1» **Some study methods work in many different situations and across topics, boosting test performance and long-term retention. Learning how to learn can have lifelong benefits.**

2» **Self-testing and spreading out study sessions—so-called distributed practice—are excellent ways to improve learning. They are efficient, easy to use and effective.**

3» **Underlining and rereading, two methods that many students use, are ineffective and can be time-consuming.**

4» **Other learning techniques need further testing and evaluation. In the meantime, students and teachers can put proved study methods to use in classrooms and at home.**

THE GOLD STAR WINNERS

1. SELF-TESTING Quizzing Yourself Gets High Marks



HOW IT WORKS: Unlike a test that evaluates knowledge, practice tests are done by students on their own, outside of class. Methods might include using flash cards (physical or digital) to test recall or answering the sample questions at the end of a textbook chapter. Although most students prefer to take as few tests as possible, hundreds of experiments show that self-testing improves learning and retention.

In one study, undergraduates were asked to memorize word pairs, half of which were then included on a recall test. One week later the students remembered 35 percent of the word pairs they had been tested on, compared with only 4 percent of those they had not. In another demonstration, undergraduates were presented with Swahili-English word pairs, followed by either practice testing or review. Recall for items they had been repeatedly tested on was 80 percent, compared with only 36 percent for items they had restudied. One theory is that practice testing triggers a mental search of long-term memory that activates related information, forming multiple memory pathways that make the information easier to access.

WHEN DOES IT WORK? Anyone from preschoolers to fourth-year medical students to middle-age adults can benefit from practice testing. It can be used for all kinds of factual information, including learning words in foreign languages, making spelling lists and memorizing the parts of flowers. It even improves retention for people with Alzheimer's disease. Short, frequent exams are most effective, especially when test takers receive feedback on the correct answers.

Practice testing works even when its format is different from that of the real test. The beneficial effects may last for months to years—great news, given that durable learning is so important.

IS IT PRACTICAL? Yes. It requires modest amounts of time and little to no training.

HOW CAN I DO IT? Students can self-test with flash cards or by using the Cornell system: during in-class note taking, make a column on one edge of the page where you enter key terms or questions. You can test yourself later by covering the notes and answering the questions (or explaining the keywords) on the other side.

RATING: High utility. Practice testing works across an impressive range of formats, content, learner ages and retention intervals.

WE REVIEWED MORE THAN 700 SCIENTIFIC ARTICLES ON 10 COMMON LEARNING TECHNIQUES TO IDENTIFY THE MOST ADVANTAGEOUS WAYS TO STUDY.

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2. DISTRIBUTED PRACTICE
For Best Results, Spread Your Study over Time



HOW IT WORKS: Students often "mass" their study—in other words, they cram. But distributing learning over time is much more effective. In one classic experiment, students learned the English equivalents of Spanish words, then reviewed the material in six sessions. One group did the review sessions back to back, another had them one day apart and a third did the reviews 30 days apart. The students in the 30-day group remembered the translations the best. In an analysis of 254

studies involving more than 14,000 participants, students recalled more after spaced study (scoring 47 percent overall) than after massed study (37 percent).

WHEN DOES IT WORK? Children as young as age three benefit, as do undergraduates and older adults. Distributed practice is effective for learning foreign vocabulary, word definitions, and even skills such as mathematics, music and surgery.

IS IT PRACTICAL? Yes. Although textbooks usually group problems together by topic, you can intersperse them on your own. You will have to plan ahead and overcome the common student tendency to procrastinate.

HOW CAN I DO IT? Longer intervals are generally more effective. In one study, 30-day delays improved performance more than lags of just one day. In an Internet-based study of trivia learning, peak performance came when sessions were spaced at about 10 to 20 percent of the retention interval. To remember something for one week, learning episodes should be 12 to 24 hours apart; to remember something for five years, they should be spaced six to 12 months apart. Although it may not seem like it, you actually do retain information even during these long intervals, and you quickly relearn what you have forgotten. Long delays between study periods are ideal to retain fundamental concepts that form the basis for advanced knowledge.

RATING: High utility. Distributed practice is effective for learners of different ages studying a wide variety of materials and over long delays. It is easy to do and has been used successfully in a number of real-world classroom studies.

THE RUNNERS-UP

Despite their promise, the following learning techniques fall short, in many cases because not enough evidence has been amassed to support their use. Some techniques, such as elaborative interrogation and self-explanation, have not been evaluated sufficiently in real-world educational contexts. Another emerging method called interleaved practice has just begun to be systematically explored. Nevertheless, these techniques show enough potential for us to recommend their use in the situations described briefly here.

3. ELABORATIVE INTERROGATION Channel Your Inner Four-Year-Old



HOW IT WORKS: Inquisitive by nature, we are always looking for explanations for the world around us. A sizable body of evidence suggests that prompting students to answer "Why?" questions also facilitates learning.

With this technique, called elaborative interrogation, learners produce explanations for facts, such as "Why does it make sense that…?" or "Why is this true?" In one experiment, for example, students read sentences such as "the hungry man got into the car." Participants in an elaborative interrogation group were asked to explain why, whereas others were provided with an explanation, such as "the hungry man got into the car to go to the restaurant." A third group simply read each sentence. When asked to recall which man performed what action ("Who got in the car?"), the elaborative-interrogation group answered about 72 percent correctly, compared with about 37 percent for the others.

WHEN SHOULD I USE IT? When you are learning factual information—particularly if you already know something about the subject. Its power increases with prior knowledge; German students benefitted from elaborative interrogation more when they were learning about German states than about Canadian provinces, for example. It may be that prior knowledge permits students to generate more appropriate explanations for why a fact is true.

PROMPTING STUDENTS TO ANSWER "WHY?" QUESTIONS, CALLED ELABORATIVE INTERROGATION, ALSO FACILITATES LEARNING.

The effects of this technique appear to be robust across ages, from fourth graders through undergraduates. Elaborative interrogation clearly improves memory for facts, but whether it also might enhance comprehension is less certain, and there is no conclusive information about how long the gains in learning persist.

IS IT PRACTICAL? Yes. It requires minimal training and makes reasonable time demands. In one study, an elaborative-interrogation group required 32 minutes to do a task that took 28 minutes for a reading-only group.

RATING: Moderate utility. The technique works for a broad range of topics but may not be useful for material more complex than a factual list. Benefits for learners without prior knowledge may be limited. More research will be needed to establish whether elaborative interrogation generalizes to various situations and different types of information.

4. SELF-EXPLANATION How Do I Know?



HOW IT WORKS: Students generate explanations of what they learn, reviewing their mental processing with questions such as "What new information does the sentence provide for you?" and "How does it relate to what you already know?" Similar to elaborative interrogation, self-explanation may help integrate new information with prior knowledge.

WHEN SHOULD I USE IT? It benefits kindergartners to college students and helps in solving math problems and logical reasoning puzzles, learning from narrative texts and even mastering endgame strategies in chess. In younger children, self-explanation can help with basic ideas such as learning numbers or patterns. The technique improves memory, comprehension and problem solving—an impressive range of outcomes. Most studies, however, have measured effects within only a few minutes, and it is not known whether the technique is more lasting in people of high or low knowledge.

IS IT PRACTICAL? Unclear. On the one hand, most students need minimal instruction and little to no practice, although one test of ninth graders showed that students without training tended to paraphrase rather than generate explanations. On the other, a few studies report that this technique is time-consuming, increasing time demands by 30 to 100 percent.

RATING: Moderate utility. Self-explanation works across different subjects and an impressive age range. Further research must establish whether these effects are durable and whether the time demands make it worthwhile.

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5. INTERLEAVED PRACTICE
Mixing Apples and Oranges



HOW IT WORKS: Students tend to study in blocks, finishing one topic or type of problem before moving on to the next. But recent research has shown benefits for interleaved practice, in which students alternate a variety of types of information or problems. In one study, for example, college students learned to compute the volumes of four different geometric shapes. In a so-called blocked-practice condition, they finished all the problems for one shape before moving on to the next. In interleaved practice, the problems were intermixed. When tested one week later, the interleaved

What Doesn't Work

These techniques were rated as low utility because they are inefficient, ineffective or beneficial only for certain types of learning and for short periods of retention. Most students report rereading and highlighting, yet these techniques do not consistently boost performance, and they distract students from more productive strategies. Other methods mentioned below are just too time-consuming.



HIGHLIGHTING

Students commonly report underlining, highlighting or otherwise marking material. It is simple and quick—but it does little to improve performance. In controlled studies, highlighting has failed to help U.S. Air Force basic trainees, children and remedial students, as well as typical undergraduates. Underlining was ineffective regardless of text length and topic, whether it was aerodynamics, ancient Greek schools or Tanzania.

In fact, it may actually hurt performance on some higher-level tasks. One study of education majors found that underlining reduced their ability to draw inferences from a history textbook. It may be that underlining draws attention to individual items rather than to connections across items.

WHAT YOU SHOULD DO INSTEAD: Highlighting or underlining can be useful if it is the beginning of a journey—if the marked information is then turned into flash cards or self-tests. Given that students are very likely to continue to use this popular technique, future research should be aimed at teaching students how to highlight more effectively—which likely means doing it more judiciously (most undergraduates overmark texts) and putting that information to work with a more useful learning technique.

REREADING

In one survey of undergraduates at an elite university, 84 percent said they reread textbooks or notes during study. It requires no training, makes modest demands on time, and has shown some benefits on recall and fill-in-the-blank-style tests.

Yet the evidence is muddy that rereading strengthens comprehension, and whether its effects depend on knowledge level or ability is also woefully underexplored. Most of the benefit of rereading appears to accrue from the second reading, with diminishing returns from additional repetitions. No experimental research has assessed it using materials from actual courses—ironic, given that this strategy is the one most commonly reported by students.

WHAT YOU SHOULD DO INSTEAD: Don't waste your time—in head-to-head comparisons, rereading fares poorly against more active strategies such as elaborative interrogation, self-explanation and practice testing.

Three less commonly used study techniques also fared poorly in our assessment. "Imagery for text learning" needs more evidence before it can be recommended, whereas "summarization" and "keyword mnemonic" appear to be ineffective and time-consuming.

In summarization, students identify a text's main points, excluding unimportant material. Whether it works is difficult to answer, as it has been implemented in many different ways. It is unknown whether summarizing small pieces of a text or large chunks of it works better or whether the length, readability or organization of the material matters.

With keyword mnemonics, imagery is used to enhance memory; for example, a student learning the French word *la dent* ("tooth") might use the similar-sounding English word "dentist" to form a mental image of a dentist holding a large molar. Mnemonics do seem to help with foreign-language vocabulary, word definitions and medical terminology, but the effects have not been shown to endure, and in the end the effort involved in generating keywords may not be an efficient use of time.

Another technique that uses mental pictures is imagery for text learning, in which students are told to create images for every paragraph they read. Research has revealed a patchwork of inconsistent results that have not been shown to last over the long term. Teachers may consider instructing students to attempt using this technique with image-friendly texts, but further demonstrations of its usefulness are necessary.

» See the *Psychological Science in the Public Interest* article "Improving Students' Learning with Effective Learning Techniques: Promising Directions from Cognitive and Educational Psychology," on which this story for *Scientific American Mind* is based, at the Association for Psychological Science's Web site: **www.psychologicalscience.org**

practice group was 43 percent more accurate. Interleaving allows students to practice selecting the correct method and encourages them to compare different kinds of problems.

WHEN SHOULD I USE IT? When the types of problems are similar, perhaps because juxtaposing them makes it easier to see what is different about them. Blocked practice—doing all the items from one category in a row—may be more effective when the examples are not very much alike because it highlights what they have in common.

It is possible that interleaved practice benefits only those who are already reasonably competent. Outcomes are also mixed for different types of content. It improves performance on algebra problems and was effective in a study that trained medical students to interpret electrical recordings to diagnose cardiac disorders. Yet two studies of foreign-vocabulary learning showed no effect for interleaved practice. Nevertheless, given how much difficulty many students have in mathematics, it may still be a worthwhile strategy for that subject.

STUDENTS ARE NOT BEING TAUGHT THE BEST STRATEGIES, PERHAPS BECAUSE TEACHERS THEMSELVES ARE NOT SCHOOLED IN THEM.

IS IT PRACTICAL? It seems to be. A motivated student could easily use interleaving without any instruction. Teachers could also use the technique in the classroom: After one kind of problem (or topic) is introduced, practice first focuses on that problem. Once the next kind of problem is introduced, it is mixed in with examples of earlier subjects. It may take a little more time than blocking practice, but such slowing most likely is worthwhile, reflecting cognitive processes that boost performance.

RATING: Moderate utility. Interleaved practice improves learning and retention of mathematical knowledge and boosts other cognitive skills. The literature on interleaved practice is small, however, and includes enough negative results to raise concern. It may be that the technique does not consistently work well, or perhaps it is not always used appropriately—topics for future research.

What We Have Learned

Why don't students use more effective study techniques? It seems they are not being taught the best strategies, perhaps because teachers themselves are not schooled in them. In our survey of six educational-psychology textbooks, only one technique—"keyword mnemonics"—was covered in every book. None offered much guidance on the use, effectiveness or limitations of different ways of studying.

A second problem may be that in the educational system, the emphasis is on teaching students critical-thinking skills and content. Less time is spent on teaching them how to learn. The result can be that students who do well in their early years, when learning is closely supervised, may struggle once they are expected to regulate their own learning in high school or college.

Some questions, such as the best age for students to start using a technique and how often they will need to be retrained or reminded, still require further research. But even now teachers can incorporate the most successful approaches into lesson plans so that students could adopt them on their own. For instance, when moving to a new section, a teacher can start by asking students to do a practice test that covers important ideas from the previous section and providing immediate feedback. Students can interleave new problems with related ones from preceding units. Teachers can harness distributed practice by reintroducing major concepts during the course of several classes. They can engage students in explanatory questioning by prompting them to consider how the information is new to them or why it might be true.

These learning techniques are no panacea. They benefit only those who are motivated and capable of using them. Nevertheless, we expect that students will make meaningful gains in classroom performance, on achievement tests and during their lifetime. M

(Further Reading)

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