

the same knowledge but were not identical.) Most impressive, the gains lasted to cumulative semester and end-of-year tests.

It's *trying to remember* that drives the practice-testing effect. Although there are different ways to prompt that effort, a quiz is probably the most straightforward way to get students to probe their memories, so that's the most commonly used technique in the classroom. Whether you use a quiz or something else, it helps if you provide feedback. That is, if the student searches memory for a fact and can't find it, you should make that fact available.

You can also encourage students to use this strategy themselves if they're studying on their own. Testing yourself (using flash cards, for example) is not only an efficient way to ensure that memory is robust and long-lasting, but also a reliable way of evaluating whether you know something well enough or need to continue studying. If rereading is the main study activity, it's all too easy for the student to become convinced that she knows the material; after rereading a chapter several times, it will all seem quite familiar.

For example, a student studying biology may feel that the phases of meiosis are very familiar when he reads about them in a textbook, but when pressed, he can't describe them. It's only when he looks away from the text and tries to reproduce the information that he realizes he's stuck.

A Sensible Caveat

Each of these techniques has been studied, not only in the laboratory, but also in classrooms (see Brown, Roediger, & McDaniel, 2014; Carey, 2014). They've been tested with a variety of subject matters and across different age groups, so there's good reason to think they'll work for you.

Still, memory is just one part of what happens in a classroom. The

**Rooting around in
memory, trying
to remember
something, is a
great way to
ensure that the
memory sticks.**

techniques described here are useful additions to a teacher's toolbox, but using them could also have unforeseen consequences on other student outcomes. To use an extreme example, constant quizzing might be good for memory, but it would be detrimental to motivation. As always, teachers can capitalize on research findings to improve their practice, but they should temper those findings with professional experience for use in the classroom. **E**

References

- Agarwal, P. K., Bain, P. M., & Chamberlain, R. W. (2012). The value of applied research: Retrieval practice improves classroom learning and recommendations from a teacher, a principal, and a scientist. *Educational Psychology Review*, 24(3), 437-448.
- Brown, P. C., Roediger, H. L., & McDaniel, M. A. (2014). *Make it stick*. Cambridge, MA: Harvard University Press.
- Callender, A. A., & McDaniel, M. A. (2009). The limited benefits of rereading educational texts. *Contemporary Educational Psychology*, 34(1), 30-41.
- Carey, B. (2014). *How we learn*. New York: Random House.
- Craik, F. I. M., & Tulving, E. (1975). Depth of processing and the retention of words in episodic memory. *Journal of Experimental Psychology: General*, 104(3), 268-294. Retrieved from <http://psycnet.apa.org/journals/xge/104/3/268>
- Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, 14(1), 4-58.
- Hartwig, M. K., & Dunlosky, J. (2012). Study strategies of college students: Are self-testing and scheduling related to achievement? *Psychonomic Bulletin and Review*, 19(1), 126-134.
- Kornell, N., & Bjork, R. A. (2007). The promise and perils of self-regulated study. *Psychonomic Bulletin and Review*, 14(2), 219-24. Retrieved from www.ncbi.nlm.nih.gov/pubmed/17694904
- Kornell, N., & Bjork, R. A. (2008). Learning concepts and categories: Is spacing the "enemy of induction"? *Psychological Science*, 19(6), 585-592.
- Markman, E. M. (1979). Realizing that you don't understand: Elementary school children's awareness of inconsistencies. *Child Development*, 50(3), 643-655.
- McDaniel, M. A., Agarwal, P. K., Huelser, B. J., McDermott, K. B., & Roediger, H. L. (2011). Test-enhanced learning in a middle school science classroom: The effects of quiz frequency and placement. *Journal of Educational Psychology*, 103(2), 399-414.
- Rawson, K. A., Dunlosky, J., & Sciarcelli, S. M. (2013). The power of successive relearning: Improving performance on course exams and long-term retention. *Educational Psychology Review*, 25(4), 523-548.
- Rohrer, D., & Taylor, K. (2006). The effects of overlearning and distributed practise on the retention of mathematics knowledge. *Applied Cognitive Psychology*, 20(9), 1209-1224.
- Rosenshine, B., Meister, C., & Chapman, S. (1996). Teaching students to generate questions: A review of the intervention studies. *Review of Educational Research*, 66(2), 181-221.
- Taylor, K., & Rohrer, D. (2010). The effects of interleaved practice. *Applied Cognitive Psychology*, 24, 837-848.

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