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TEACHER-READY RESEARCH REVIEW

Practice Tests, Spaced Practice, and Successive Relearning: Tips for Classroom Use and for Guiding Students' Learning

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Several techniques have been identified that can help students of all ages and abilities learn, understand, and retain materials across a wide variety of classes. Although these techniques are not the panacea for all the learning hurdles that students must overcome, they do offer an easy and low-cost solution to boosting student achievement in many classes. Thus, in this teacher-ready research review, we provide some pointers about how to use two particularly potent techniques—practice testing and spaced practice—to improve student learning in the classroom and on how another technique—successive relearning—can be used by your students to guide their learning outside of the classroom.

Keywords: learning techniques, testing, spaced practice, successive relearning

Fostering student learning and success is arguably one of the most important goals of teaching. As teachers, we often try to discover ways to improve our teaching, whether it includes revamping a presentation to more clearly describe a concept or trying out a new demonstration that shows promise for capturing students' interest. These classroom innovations will typically target specific content, such as finding a better way to describe an action potential in hopes that every student will understand it or developing a demonstration that makes the principles of reinforcement and punishment perfectly clear. Much headway can be made by improving instruction of particular concepts in this manner, and we applaud teachers who continue to search for the best ways to present difficult-to-grasp concepts. To support such efforts, we describe a complementary approach that involves using content-general techniques that promise to help students learn a wide variety of content across many different classes.

Of course, an all-purpose technique that will solve every problem that struggling students have is not currently available, and we suspect it never will be, because even the most versatile techniques have limitations. Nevertheless, several low-cost techniques have demonstrated generality in their effects on student learning and can be widely applied. Some of these techniques are listed in Table 1, and in a recent review (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), we evaluated the evidence pertaining to how well they really work—do they improve student learning across a wide variety of domains, do they help students of different ages and abilities, and have they been shown to work when tested with actual classes? Our intent in that review was to provide enough details about relevant evidence for each technique so that readers could decide for themselves whether a particular technique meets their instructional or learning goals. Nevertheless, on the basis of how well each technique faired with respect to the size and generalizability of their effects—across different learners, materials, criterion tasks, and whether they worked in educational settings—we also assigned each technique a utility rating. A high rating indicated that positive evidence (i.e., that the technique boosted performance) has been consistently found with regard to the dimen-

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Table 1
Learning Techniques

Technique	Utility	Description
1. Elaborative interrogation	Moderate	Generating an explanation for why an explicitly stated fact or concept is true
2. Self-explanation	Moderate	Explaining how new information is related to known information or explaining steps taken during problem solving
3. Summarization	Low	Writing summaries (of various lengths) of the to-be-learned texts
4. Highlighting	Low	Marking (potentially important) portions of to-be-learned materials while reading
5. Keyword mnemonic	Low	Using keywords and mental imagery to associate verbal materials
6. Imagery for text	Low	Attempting to form mental images of text materials while reading or listening
7. Rereading	Low	Restudying text material again after an initial reading
8. Practice testing	High	Self-testing or taking practice tests over to-be-learned material
9. Spaced practice	High	A schedule of practice that spreads out study activities over time
10. Interleaved practice	Moderate	A schedule of practice that mixes different kinds of problem (or study of different kinds of material) within a single study session

Note. Table adapted from Dunlosky, Rawson, Marsh, Nathan, and Willingham (2013).

sions above, with lower ratings (moderate or low) indicating either that negative evidence was found or that sufficient evidence was currently unavailable. The utility assessment for each technique is presented Table 1, and although interested readers will need to refer to the original review for details (Dunlosky et al., 2013), we explain some of the evidence leading to these ratings next.

First, research indicates that highlighting and rereading texts does not offer much in terms of learning benefits. Sure, it is fine if students highlight what they believe are the most critical concepts in a textbook or in their notes, but doing so is only the beginning of the learning journey. It is how students subsequently study those important concepts that matters most, and merely rereading the material does not offer a lot. Second, whereas highlighting and rereading received lower marks because they do not appear to be that effective, other techniques received a low or moderate rating because not enough research is currently available to know whether they will benefit students' learning and performance in actual classrooms. For instance, self-explanation and elaborative interrogation benefited students' learning of some materials and boosted their performance on some tasks (e.g., Pressley, McDaniel, Turnure, Wood, & Ahmad, 1987; Rittle-Johnson, 2006), but more psychological research—especially in the classroom—needs to be conducted before we could endorse these techniques with full confidence. The same held for interleaving practice, although this technique may quickly be on its way to earning a high rating, given exciting new evidence indicating that interleaving math practice improves students' performance in a classroom context (Rohrer, Dedrick, & Burgess, 2014; Rohrer, Dedrick, Stershic, in press). With such caveats in mind, however, persuading students to use techniques that would foster deeper processing of course materials—such as self-explaining—is likely to be an improvement over rereading.

Finally, and most important, two techniques—*practice testing* and *spaced practice*—received the highest marks because the evidence consistently demonstrated benefits to students' learning across a wide variety of materials and for learners of different ages and abilities. These techniques really work (for in-class demonstrations, see McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011; McDermott, Agarwal, D'Antonio, Roediger, & McDaniel, 2014; Roediger, Agarwal, McDaniel, & McDermott, 2011), and they work particularly well when combined in a technique called *successive relearning*. Although successive relearning is not listed in Table 1 because it was not included in the Dunlosky et al. (2013) review, it is based on combining practice testing with spacing across multiple sessions, which we describe further below. Given that these techniques do work, how can we, as teachers, use them to help students achieve their learning goals? In the next two sections, we offer some possible answers to this question for classroom use and for supporting students' self-regulated learning.

Using Practice Testing and Spacing While Teaching

Practice tests can help students in two ways (Roediger & Karpicke, 2006). Taking a practice test can directly benefit learning. That is, taking practice tests can boost students' learning of the tested information, which in turn may enhance performance on higher stakes exams. Taking practice tests can also indirectly benefit learning by helping students figure out what they do versus do not know, so that they can focus subsequent efforts on learning content that is less well known. In fact, this indirect effect of practice tests is largely why students report using them in the first place (Kornell & Bjork, 2007; for a review, see Bjork, Dunlosky, & Kornell, 2013)—and tests do provide a metacognitive tool that improves students' ability to accurately identify what they have not yet learned. Fortunately, when practice tests are administered and followed by feedback, students can reap both their direct and indirect benefits. Moreover, practice tests do more than just improve students' memory for the tested information; they also improve performance on transfer tests that tap students' ability to use and comprehend the practiced content (for a recent review, see Carpenter, 2012).

Here are a few pointers on how to use practice tests while teaching. One is to select the most important concepts, ideas, and content for practice tests. It makes no sense to choose content willy-nilly for practice testing, because limited time is available for testing during a class period. Instead, we must decide what is most important for our students to learn and then emphasize these decisions by testing them on this content prior to higher stakes exams. To get the most out of these practice tests, make sure that they are delayed sometime after the content is covered, so that students must retrieve (or construct) the answers from long-term memory (Cull, 2000; Pavlik & Anderson, 2005). In line with this recommendation, practice tests that require reconstruction of correct answers from long-term memory tend to produce larger benefits than those that require recognizing the answers (Carpenter & DeLosh, 2006; Glover, 1989). So, if possible, it is better to use free recall or short-response formats than those based on recognition, such as some multiple-choice questions do. Do not rule out using multiple-choice practice tests, however, because multiple-choice questions can be written that still require retrieval from long-term memory, and using a few at the end of each class (with feedback) or during a preexam review can improve students' performance on the tested content on later exams (McDaniel, Agarwal, Huelser, McDermott, & Roediger, 2011; McDermott et al., 2014; Roediger et al., 2011).

Providing students with feedback about the correct answers is beneficial, and the timing of the feedback can matter, too. In contrast to our intuitions, it appears that *delaying* feedback is best in that it can lead to greater gains than providing feedback immediately after students answer a practice question (for a recent review and demonstration of the benefits of delaying feedback in an engineering course, see Mullet, Butler, Verdin, von Borries, & Marsh, 2014). Based on these recommendations, one option is to begin each class with a brief practice test that covers the most important concepts from the prior class and then end the class with feedback. Doing so will ensure that students must construct answers from long-term memory and that they receive delayed feedback to promote learning and retention of the material. Your students will benefit even more from feedback when you explain why answers are correct or incorrect (Butler, Godbole, & Marsh, 2013; Moreno, 2004; Moreno & Mayer, 2007). Such explanatory feedback may not only enhance performance compared to providing corrective feedback alone (i.e., indicating whether an answer is correct or not) but also increases the chances that students will perform better on transfer tests of the content—a major educational goal for almost any domain.

During longer classes, we know that students' minds will wander, and even teachers may need a break to refocus from time to time. To alleviate these problems, consider inserting a few test questions throughout a class. These questions could focus on content covered earlier in that class or can even be repeats of questions used in prior classes. By using these interim tests, you can break the monotony a bit, reduce students' mind wandering, and improve their learning. These benefits of interim tests were recently demonstrated by Szpunar, Khan, and Schacter (2013), who interpolated tests during videos of online lectures. They also found that the interpolated tests reduced students' anxiety about the final cumulative tests, which is an added bonus of practice testing that should be further investigated.

What about spaced practice? One of the most powerful ways to enhance students' retention of important concepts is to return to those concepts across time (for an extensive review, see Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). You can space exposure to content in numerous ways, such as reviewing a few of the most important concepts from a lecture at the end of each class or reviewing those concepts at the beginning of the next class. The former involves spacing within a class, and the latter involves spacing across classes. Both should enhance students' learning of the repeated content, but the longer interval between classes will likely work better for enhancing long-term retention. You can combine the benefits of both spaced practice and testing—a powerful duo in the fight to improve student achievement—by repeating some of the practice test questions across classes. Besides directly enhancing students' learning, we suspect that reviewing some content across classes will also have an indirect benefit, because it will further emphasize the importance of the content. Doing so may encourage students to study those materials even more as they study outside of the classroom, which we consider next.

Supporting Students' Use of the Techniques to Learn Course Content

Why Students Need Instruction on Effective Learning Techniques

Students can use practice tests and spaced practice to their advantage as well, but most students will likely need some encouragement and support to use these techniques effectively. One difficulty is that most students commonly use poor strategies such as rereading and also cram for tests (Karpicke, Butler, & Roediger, 2009; Kornell & Bjork, 2007; Taraban, Maki, & Rynearson, 1999), and even worse, many also believe that these approaches for exam preparation are the best ones. Consider results from Gurung, Weidert, and Jeske (2010), who developed an easy-to-use survey of study behaviors that can be adapted for any course. For this survey, students endorsed statements such as "I attended every class" or "I highlighted the most important information in each chapter to review later" on a 5-point scale, with 1 indicating that the behavior is *not at all like me* and 5 indicating that is *exactly like me*. Students' endorsements of the behaviors varied considerably, and in some cases, this variability was related to exam performance. For instance, attending class was positively related to performance ($r = .24$), and consistent with the review discussed above (Dunlosky et al., 2013), highlighting was negatively related ($r = -.23$). Most relevant to the use of practice testing, the average rating for "I used practice exams to study" was 3.8 with a standard deviation of 1.4, indicating that some students endorsed using practice exams, whereas others did less so. The reported use of practice exams also predicted class performance ($r = .24$), a key outcome that was replicated in a large-scale study involving 454 students enrolled in an introductory psychology course (Gurung, Daniel, & Landrum, 2012).

Other research has asked students to note which study techniques they regularly use, and such checklist surveys again reveal that although some students endorse using effective strategies such as self-testing, some students also fail to use them and also perform more poorly in classes (Hartwig & Dunlosky, 2012). In a recent survey of this sort (Morehead, Rhodes, & DeLozier, 2015), not only did students from a large state college endorse the use of relatively ineffective strategies (such as rereading), but the college professors endorsed them, too. Thus, many students are not equipped with effective techniques, so using some class time to discuss which techniques work (and which do not) could pay off, and it may even be worthwhile to inform your colleagues about the best techniques as well. To work, however, this instruction may need to go beyond merely telling the students about what works best, because they may need scaffolding to use them effectively.

One reason why scaffolding may be needed is that to use spacing, students should stop cramming and begin studying earlier and regularly for class exams. To do so, students need to develop a study schedule that minimally includes the dates of the class exams and several weekly study sessions for each class. For these sessions, we encourage students to begin by studying their notes and text from the immediately prior class, with an eye toward making sure they understand their notes and the concepts discussed in class. Afterward, they should then restudy material from prior classes (such as by self-testing with feedback), so they can reap the benefits of spaced practice. When we have students develop these study schedules for all of their courses, such as using a paper or electronic calendar, it becomes apparent that many students will need to use their time wisely each week to succeed. You can still encourage students to study some the night before an exam, such as to ward off some anxiety and to review the most important and difficult concepts. Although we are unaware of any large-scale evaluation of whether using these scaffolds (e.g., training students to schedule time to incorporate spaced practice and testing) will improve student achievement, the outcomes from many investigations (Cepeda et al., 2006) suggest that if they use spaced practice throughout a course, they should be already set for success the evening before each exam.

The Power of Successive Relearning

If you can convince your students to develop a study schedule that involves studying for each course at least a couple times each week, they can further boost their success by using practice tests during these spaced study sessions. Doing so involves one of the most potent ways to capitalize on testing, which is called *successive relearning* (Bahrick, 1979). Successive relearning involves self-testing until you can correctly recall the target information from memory and, critically, *doing so in more than one practice session.* For instance, students could use a version of the Cornell note-taking system in which they write down key words in the margins of their notes that refer to each of the to-be-learned concepts and then go through each key word and attempt to retrieve and write down the correct concept from memory. You could also encourage students to use flashcards for the most important concepts. Importantly, for successive relearning, after they attempt to retrieve each concept, they should check the correct answer to evaluate whether they have it or not. If they do not have it, then they should mark that concept and return to it again later in the study session. In addition, they should continue doing so until they can correctly retrieve it. Once they do correctly retrieve it, then they can remove the concept from further practice during that particular session. The critical aspect of successive relearning is that all the old concepts are relearned during the next study session (and ideally in three to four different study sessions). It sounds like a great deal of work, and admittedly, it will take students a large chunk of time to learn difficult concepts well enough to retrieve them during the first session that they are practiced, but relearning them in later sessions becomes a breeze—that is, students will quickly relearn what they correctly retrieved in prior sessions.

Does successive relearning really work? We had students use successive relearning with a virtual flashcard program to learn fundamental concepts in an introductory psychology course (Rawson, Dunlosky, & Sciartelli, 2013). Students in this class used the program to successively relearn key concept definitions that the instructor chose as being most important from different chapters (e.g., confirmation bias, IQ, zone of proximal development). Importantly, for each student, half of the concepts was assigned to receive successive relearning during practice and the other half was assigned to a baseline, “business-as-usual” control condition (where students studied them on their own as per usual). The concepts assigned to each condition were counterbalanced across students (i.e., the use of successive relearning was experimentally manipulated), so that we could evaluate the degree to which successive relearning boosted performance above the baseline. In the successive relearning condition, students practiced the concepts in synchrony with their introduction in lectures. Students had two study sessions a week using the successive-learning program in the laboratory (Experiments 1 and 2) or unsupervised on their own outside of the lab (Experiment 2).

Performance on the in-class exams for both successively relearned (SR) and baseline control concepts are presented in Figure 1. Across both

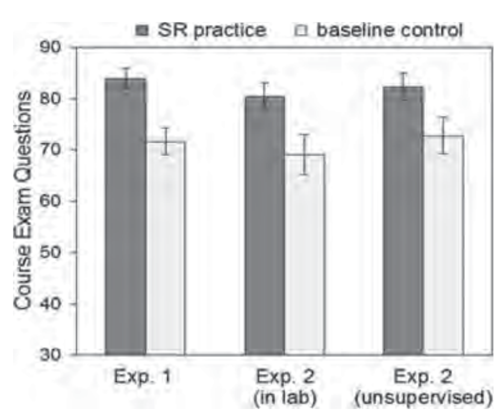

Figure 1. Percentage performance on exam. SR = successive relearning. Adapted from data reported by Rawson, Dunlosky, and Sciartelli (2013).

experiments and regardless of whether students used the program in the laboratory or on their own, they enjoyed more than a letter-grade boost from using successive relearning while studying concepts that were fundamental to the course. In this and other studies, we have also shown that successive relearning substantially improves long-term retention up to several months later (Rawson & Dunlosky, 2011, 2013). As an anecdote, we even had students in the laboratory tell us that they were shocked about how well they could learn all the definitions and asked whether their friends could be part of the experiment! Most important, you can encourage your students to use this easy technique, and all they need to do is to make some flashcards and develop a schedule to study and relearn them a couple times each week.

Future Directions and Closing Remarks

The three techniques we discussed here—practice testing, spaced practice, and successive relearning—are powerful and proven. Although some of our specific recommendations for usage above were motivated by relevant evidence, much of this evidence was collected in laboratories using relatively limited materials and methods. So, there is still much to be discovered about how to best take advantage of these techniques in the classroom. As teachers and psychological scientists (and we suspect many readers of this journal will be both), we view this limitation in our knowledge as an opportunity, because as we all are trying out these techniques, we can conduct relatively straightforward investigations to evaluate their efficacy. For instance, you probably cannot include all the most important concepts on practice tests, which affords the possibility of examining gains for tested (vs. nontested) concepts or comparing different schedules of practice testing across classes for different subsets of concepts. So many possibilities present themselves for the use of these techniques, and we hope that this brief article will inspire you to try them out and even evaluate their efficacy as you do so.

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