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ARENA OF SCHOOLING

Becoming Better Learners, Becoming Better Teachers: Augmenting Learning via Cognitive and Motivational Theories

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Abstract
The answer to improving student learning cannot be to simply spend more time studying (more time in school, more homework, more after-school programs, more summer school, etc.). Decades of cognitive psychology research have shown that classroom instructional time and student self-regulated learning time could be used more efficiently if they incorporate spaced and interleaved retrieval practice. But it is not always easy to translate research to real-life practice. In this paper, we outline the barriers and potential pitfalls in the implementation of time-saving and memory-enhancing strategies in the classroom. We suggest ways to implement these effective strategies, both in instructional design and in students' own self-regulated study. In particular, we focus on how instructors can support students, not only by modeling effective learning practices in the classroom, but by focusing on ways to empower learners to transfer these strategies into their own study sessions. Finally, we direct researchers' and practitioners' attention to future directions that integrate cognitive, metacognitive, and motivational approaches to enhancing student learning.

Keywords Science of learning · Effective learning · Instructional practice · Desirable difficulties · Motivation

There are two general strategies for increasing educational achievement (Carroll, 1962, 1963). Either (1) a learner can spend more time learning, or (2) they can spend their time learning more efficiently (i.e., through better learning strategies, higher quality instruction). Despite the existence of the latter strategy, the former strategy seems to be the predominant reaction to any perceived underperformance of students or the educational system generally.

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For example, there has always been a great need to invest in education globally, but the COVID-19 pandemic and the lost learning time experienced across the world further underscored this need. As a result of the COVID-19 pandemic, in the USA, students were estimated to be 4 to 5 months behind where they would be expected to achieve relative to comparable pre-pandemic peers, existing inequalities widened with Black students being particularly hard hit (Dorn et al., 2021; Goldberg, 2021). Globally, students in 2022 were on average 8 months behind, though in Latin America and South Asia where schools were fully or partially closed for the longest time, students were estimated to be 9 to 15 months behind (Bryant et al., 2022).

In response to the learning losses in the USA, the *American Rescue Plan* provided $200 billion in the form of "Elementary and Secondary School Emergency Relief" money to schools. As Kuhfeld et al. (2022) note, schools primarily used these funds "designated for academic recovery on a wide variety of strategies, with summer learning, tutoring, after-school programs, and extended school-day and school-year initiatives rising to the top" (n.p.). What do all of these mitigation strategies have in common? They rely on increasing the amount of time students spend learning—increase the length of the school day, increase the number of days, increase the number of support programs. The so-called "wide variety of strategies" above is actually all a single strategy: more time in the classroom. Admittedly, we understand why policymakers, superintendents, and grant funders may tend to default to increasing time in the classroom as the policy of choice for reversing learning loss. For one, increased time is a very tractable and one-dimensional strategy. As long as adequate funds are available, it is a policy-level change that can be implemented relatively easily at a broad scale. But the problem is that time, attention, and willingness (both on the part of teachers and students) are limited. More time cannot always be the solution. In fact, the Global Education Evidence Advisory Panel (GEEAP), co-hosted by the Foreign Commonwealth & Development Office and The World Bank, specifically called out "additional inputs alone" (i.e., without changing pedagogy) as a *bad buy*, a non-cost-effective approach to improve global learning (GEEAP, 2020).

The other strategy, then, is to consider how existing time spent in education can be used more *efficiently*. This approach is necessarily more complex and multi-dimensional. Indeed, of the two main strategies for increasing student achievement, increasing the *quality* of learning (as opposed to the *quantity of time* spent learning) is potentially more complicated to achieve. Different contexts may require different types of instruction. For example, mathematics classes may require different types of learning strategies than English classes. Adaptation of effective strategies requires that teachers not only understand effective learning and motivational processes, but also how these principles can be applied into their particular contexts to students of varying levels of prior knowledge. All this requires forethought and planning to alter one's curriculum, assignments, or tests.

The potential rewards are also much greater than simply adding more time in the classroom. A small increase in the average quality of instruction on the part of the teacher and learning strategies on the part of the student offers large potential cumulative benefits over the course of a year (or 12, or 16) of education. After all, learning builds upon itself, and one of the most powerful predictors of learning is what the learner already knows (Ausubel, 1968; Hattie, 2012). For this reason, this paper is dedicated to translating research from cognitive psychology, educational psychology, and motivation science to the classroom context and highlighting some of the most interesting applications of this research in the classroom from our personal experience as university instructors and from the broader science of learning community.

Cognitive Processes Underlying Long-Term Learning and Retention

Making the Case for the Centrality of Memory

Educators may be wary of research aimed at improving students' memory. Why is memory important, when the goal is to enhance students' ability to engage with the world in a critical fashion and to be informed adults? "Rote memorization" might as well be a swear word in some education circles. To this end, op-eds are frequently published with provocative titles, such as a piece by Santens (2017) in *Education Week* titled "Stop Teaching Students What to Think. Teach Them How to Think." Indeed, many argue for the need to stop focusing on content and teach critical thinking and problem-solving instead (Snyder & Snyder, 2008). Cognitive psychologists have heard these concerns many times (cf. Willingham, 2019). Critical thinking should indeed be one of the end goals of the education system, but improving memory and enhancing critical thinking are not at odds with one another. In fact, students need a reliable base of knowledge to engage in critical thinking—improving memory is a necessary step for helping students succeed in complex reasoning tasks, requiring higher-level critical thinking.

Let's take a look at a case where prior knowledge might be helpful in evaluating whether to trust a text, in this instance, a story about Shakespeare's usage of technology:

> William Shakespeare was a world-renowned playwright, but in his day, cell phones were not yet invented. One day, Shakespeare's friend, the actor Richard Burbage, came to him with a new invention: the cell phone. At first, Shakespeare was skeptical, but after Burbage demonstrated how the phone worked, Shakespeare was amazed. He immediately began composing a new play, using the cell phone to dictate his lines to a scribe. The play was a huge success, and Shakespeare became known as the first playwright to use a cell phone in his work. From then on, he always kept his phone close at hand, using it to jot down ideas for new plays, poems, and sonnets. Thanks to the cell phone, Shakespeare's legacy has endured for centuries.

Would you trust this text? Probably not, because you know that cell phones were not invented in the 1500 and 1600 s when Shakespeare was alive. But would your students trust this text? They might—especially if they are younger and don't yet realize that the cellphone is a relatively modern invention. In fact, the above text was generated using artificial intelligence (OpenAI's GPT-3; Brown et al., 2020) and shows just how easy it is for an entirely fictional story to have just enough coherence to be dangerous to uninformed readers! The truth is, without background knowledge, it is hard to be a critical thinker. As Kumar and Geethakumari (2014) note, people are more likely to accept misinformation as true when the misinformation is consistent with their existing knowledge. When new information is fluently processed in tandem with prior knowledge, we tend to accept it as true (Reber & Unkelbach, 2010). Therefore, the richer a student's understanding and memory for correct information in the moment when they encounter a text like the Shakespeare and cell phones story above, the more likely they are to be able to detect an inconsistency and realize that the entire story is not to be believed.

But, isn't all this information available on the internet? Why do students need to memorize when a cell phone was invented, when they can just Google it? There are two major reasons why the use of the internet to engage in so-called "cognitive offloading" (Risko & Dunn, 2015; Risko & Gilbert, 2016) cannot be considered a panacea. First, as implied in the example above, students may not realize that they need to fact-check something that appears at least superficially truthful. If a text sounds plausible, why waste the time fact-checking it? This is part of why misinformation flourishes online, where people of all ages share stories first and ask questions later (Storm & Soares, in press).

Second, even if a learner knows that their knowledge is insufficient and that they need to consult online sources, they will run into the limits of working memory (Baddeley, 2006; Cowan, 2012). Knowledge that has been previously committed to memory reduces the burden of integrating new information (Reder et al., 2016). A recent thought experiment put forth by Christodoulou (2022) makes the limits of cognitive offloading via the internet even more clear. In his blog post, he shows the limits of using the internet for "just-in-time" searches to understand complex topics, by using the example of searching Wikipedia to learn quantum mechanics. If learning quantum mechanics was as simple as looking up the relevant material on the internet, we could simply (1) open up the "Quantum Mechanics" page on Wikipedia, and then (2) every time we're confused, we can click the linked page that explains whatever concept we don't already know. (3) Then, if there is a concept on *that page* we don't understand, click the relevant link and so forth. In our experience trying this learning strategy out, we quickly find ourselves five pages deep, trying to make sense of Coulomb's inverse-square law, and unable to remember what we were trying to learn in the first place. Experts, as opposed to novice learners, are much more likely to have enough background knowledge to guide their own learning (Kirschner et al., 2006). This is why, for example, a professor specializing in quantum physics would be much more likely to be able to read the Wikipedia article through, find the one concept they do not remember, and (re)learn this information (see the literature on the *expertise reversal effect*, Kalyuga et al., 2003). Hence, memory is important to critical thinking. It helps us realize when something seems off (it does not cohere with our understanding of the world) and it also enables us to integrate more and more information into this understanding of the world.

Learning Is Not "One and Done"

As a teacher, you plan your lesson. Maybe you put together some slides that integrate text and images that appear to bring a concept to life. The students nod along as they listen. Perhaps, there is a nice video or demonstration. Maybe you even have discussions or other activities during class. The students seem engaged. You check for understanding at the end of the lesson. The students answer your questions just fine. Pleased with this apparent learning, at the next class, you will move onto the topic.

But something seems to happen once your students leave the classroom. Maybe you notice it in the next class when you check for understanding of the prior lesson and find that the students have trouble saying what they could say with ease last time. Maybe you notice it on the end-of-unit or end-of-year assessments, where the content they learned months prior has now been forgotten. Or maybe you notice it the next academic year, when you realize that you can't easily build upon the prior year's learning because your students have lost many of those foundations. What was once there is now forgotten.

The crux of the issue is that learning does not happen in a single shot and in-the-moment performance is often a poor proxy of long-lasting learning. Students and teachers alike use in-the-moment performance cues—"Does it feel easy?" or "Can I answer questions correctly right after reading the textbook or after the lesson?"—to infer that they have learned and will retain new information. The assumption is that if they know it now, they'll also know it later. For learning to be long-lasting, however, it not only needs to be connected and elaborated on during the initial lesson, but it also needs to be practiced, differentiated from other similar concepts, and maintained. In particular, we focus on three interconnected strategies for learning: retrieval practice, interleaving, and spacing.

Spaced and Interleaved Retrieval Practice

The retrieval practice effect is the finding that the act of retrieving information from memory strengthens learning substantially more than spending the same amount of time rereading the information (Roediger & Butler, 2011); retrieval practice has even been found to be superior for long-term learning to concept mapping, an elaborative strategy that is generally considered to foster deep learning (Karpicke & Blunt, 2011). In experimental settings, retrieval is often operationalized as a quiz or a test, but retrieval can be any activity that requires learners to draw upon their memories (i.e., without peeking at notes); more varied examples will be discussed in the "Implementing Effective Strategies" section. Aside from the format of the retrieval activity, the *content* of what is being retrieved and the *timing* of retrieval are also critically important.

First, with respect to the content, retrieval practice can be augmented when it consists of a mixture of several different but related concepts. The mixing up of different concepts is referred to as *interleaved* practice (contrasted with one-at-a-time *blocked* practice). Interleaving has been shown to be particularly effective when it involves the juxtaposition of related and confusable concepts (Brunmair & Richter, 2019; Carvalho & Goldstone, 2019; Yan & Sana, 2021a, b). For example, instead of practicing one type of math problem at a time, studies have found that mixing up the practice enhances the discrimination of problem types (Rohrer, 2012) and the ability to more flexibly apply different math strategies (Nemeth et al., 2019).

Second, with respect to timing, retrieval practice is more effective when it incorporates spacing. Spacing refers to the revisiting of previously taught material at a delay or distributed across time. Spaced repetitions strengthen long-term retention and make knowledge more resistant to forgetting (Carpenter, 2017). For example, quizzing students at the end of a class in which the concepts were just taught is not as effective for strengthening learning when compared to a quiz that occurs in the next class or at the end of the week. Indeed, what the spacing literature has also highlighted is the importance of revisiting concepts multiple times and at longer intervals (particularly if the goal is long-term retention, Cepeda et al., 2008). In other words, a concept that is taught in the first week of September might be revisited a few times in that first week (initially in class and then in homework), but also, the concept should continue to be refreshed and maintained even after the class has moved on to the next unit and throughout the rest of the year.

Note that in the vast majority of studies that compare retrieval practice to rereading, spacing to massing, and interleaving to blocking, total study time is held constant. That is, these are not learning strategies that take more time; they are strategies that are both more effective and efficient. Taken together, spaced and interleaved opportunities for retrieval practice can be powerful tools for enhancing learning. This claim is borne out in a number of classroom studies at both secondary and post-secondary education levels (see Hopkins et al., 2016; Rohrer et al., 2020b; Samani & Pan, 2021; Sana & Yan, 2022). In these studies, the manipulation added no extra time to normal instruction (e.g., through modifying existing homework assignments) or added time was minimal (e.g., taking only 12 additional minutes per week to add in a quiz), yet, the effect sizes are substantial (e.g., $d = 0.40$–0.83). For reference, the average effect size found in educational experiments is in the realm of 0.16 standard deviation differences (Kraft, 2020), which speaks to the potential utility and cost-effectiveness of designing targeted curriculum-specific interventions based on cognitive psychology principles.

If you are interested in more details, we suggest that you consult the many well-written reviews and meta-analyses about the benefits and boundary conditions of retrieval practice, interleaving, and spacing (Agarwal et al., 2021; Brunmair & Richter, 2019; Carpenter, 2012, 2017; Carpenter et al., 2022; Cepeda et al., 2006, 2008; Dunlosky & Rawson, 2015; Kang, 2016; Yang et al., 2021).

Barriers to Implementing Effective Strategies

If these methods are so effective, why isn't everyone using them? Students and instructors alike might be resistant to implementing spaced and interleaved retrieval practice for a number of reasons. Here, we focus on metacognitive and motivational barriers: lack of metacognitive knowledge, lack of resources, high perceived time and effort costs, or perceived emotional or motivational costs.

Lack of Declarative Metacognitive Knowledge

Teachers and students might not know what strategies are effective for long-term learning. If they don't know what is effective, then they are not likely to incorporate effective practices into their own instruction or their own study behaviors. People's own past experiences and heuristics can lead them to develop inaccurate models of their own learning and memory (Bjork et al., 2013; Pan & Bjork, in press).

One way that people's mental models may be misled by experience is that they frequently conflate immediate performance with long-term learning (Bjork, 2018; Soderstrom & Bjork, 2015). People often use immediate performance—Can I do it right now? Am I recalling the information correctly right now?—as an indication of long-term learning. However, there are many reasons why someone is able to recall or perform well in the moment that are unrelated to long-lasting learning. For example, if a student can immediately repeat back what the teacher is saying, does that mean they have learned? Maybe not, as the student may simply be relying on their short-term memory to parrot back what they just heard. On the other hand, if the student can still recall the concepts correctly the next day (spaced retrieval), one might be more confident that the learning resides somewhere other than in short-term memory. If a student answers ten "calculate the area of the triangle" questions correctly in a row, does that mean they have learned? Maybe not, as the student might be mindlessly plugging numbers from the problems into a formula. But if the student can switch back and forth between different types of problems (interleaved practice), then one might be more confident that the student is thinking more deeply about the concept(s) they are learning. There are many empirical examples in the cognitive psychology literature in which the study strategy that leads to better initial performance does not lead to better long-term learning; and conversely, there are many empirical examples where learners may appear to be making more mistakes and making "slower progress" initially, but in fact, are learning more deeply (Soderstrom & Bjork, 2015).

This discrepancy between initial performance and long-term learning is not always apparent for another reason: In many educational settings, it is possible to get away with only focusing on short-term performance. For example, although the research reveals robust spacing benefits, the fact that students can and often do cram for high-stakes exams means that those who do not space their learning can often appear to be doing just fine. In other words, learners can enjoy apparent academic "success" by using the less effective strategies.

Moreover, people often rely on heuristics to make judgments about their learning and the effectiveness of various strategies. In particular, people often associate ease with effectiveness. This association is a natural one. After all, the things a person knows well are the things that can now be recalled or applied easily. It is easy then to create a heuristic that flips the causal association between ease and retention: that if something is easily learned, then it will be easily remembered. Indeed, studies have shown that people often use an "ease-of-processing" heuristic, judging items feel more difficult or take more time or effort, to be learned more poorly (Begg et al., 1989; Dunlosky & Metcalfe, 2008; Koriat, 2008; Undorf & Erdfelder, 2011). In a similar vein, strategies such as retrieval practice and interleaving feel more effortful and, hence, are judged to be less effective for learning (Kirk-Johnson et al., 2019; Macaluso et al., 2022).

Indeed, studies have shown that students and instructors alike commonly misjudge the efficacy of different learning strategies and endorse the myth of individual learning styles (Kornell & Bjork, 2007; McCabe, 2011, 2018; Morehead et al., 2016; Yan et al., 2014). For example, Morehead and colleagues (2016) found that both college students and college instructors believed that blocking was better than interleaving (only 13–16% indicated that interleaving would lead to better learning in a described scenario based on an empirical study by Kornell & Bjork, 2008). Less than half (49%) of students recognized that testing would be better than rereading (62% of instructors recognized the benefits of testing). More optimistically, 69% of students and 74% of instructors endorsed the benefits of spacing over massing. However, both students (58%) and instructors (a worrying 91%) endorsed the myth of individual learning styles.

McCabe (2018) surveyed the heads of academic support centers in 77 higher education institutions. These are the people in a college or university who should be the most knowledgeable about the strategies that support student success. The findings were more positive than the prior studies, but still revealed some misconceptions. When asked to list their top three study strategy recommendations, time-management (a self-regulation strategy) came in first and self-testing second (23% of participants). Spacing was the fourth most common response (15% of participants). When asked to rate the effectiveness of different strategies, they rated interleaving as more effective than blocking. However, 9% also mentioned learning styles. When making predictions about learning outcomes in scenarios representing evidence-based strategies, only 59% correctly endorsed testing over rereading and only 23% correctly endorsed interleaving over blocking.

Lack of Procedural Metacognitive Knowledge

Though a potential barrier, lack of knowledge about the cognitive literature on effective learning may be less common these days. There are now a number of popular psychology books about metacognitive knowledge (e.g., Brown et al.'s, 2014 *Make it Stick*), the "How to Learn" course on Coursera is very popular, and the benefits of spaced retrieval practice are often increasingly referred to and built into various learning applications (e.g., Anki, Duolingo). Recent studies examining what learners understand about effective learning are finding that students know more than the past literature would suggest. Undergraduate students, for example, acknowledge that testing and self-explanation are more effective than passive strategies such as rereading, highlighting, and listening to others' explanations (Biwer et al., 2020; Blasiman et al., 2017; Rea et al., 2022) and that spacing out study is more effective than massing it (Biwer et al., 2020).

But there's another aspect of metacognitive knowledge: procedural metacognitive knowledge (Schraw & Moshman, 1995). A student might know the theory that spaced and interleaved retrieval practice is good, but not know how to apply the strategies to their own learning. Rereading is simple—you pick up whatever text you have and start at the first line on the first page. There are a limited number of ways to reread something. But if a student wanted to incorporate retrieval practice, what does that look like? Retrieval practice can take many different forms. Do they take a practice test? What if the teacher hasn't provided any? Do they make flashcards? It takes time to make them and takes extra knowledge to make and use them *well* (Lin et al., 2018). Of course, retrieval can be as simple as writing down everything one can remember (with or without additional supporting structures, such as concept maps; Blunt & Karpicke, 2014; O'Day & Karpicke, 2021), but our conjecture is that students need practice even with this simple strategy. Similarly, it is not always easy to know how exactly to interleave practice. How does a learner identify which concepts or skills would benefit most from interleaving (Brunmair & Richter, 2019; Yan & Sana, 2021a, b; also see Foster et al., 2019)? To what extent is blocked practice still useful (Carvalho & Goldstone, 2015)? Does interleaving have to consist of alternating on every trial or can it be done in other ways (Yan et al., 2017)?

One of the studies reported by Rea and colleagues (2022) focused on undergraduate students who were enrolled in a course that taught about effective learning strategies (spacing, retrieval practice, interleaving, as well as elaboration). They were given summative exams four times across the semester, and at the end of each exam, they were asked about their study strategies and the barriers to using the strategies they had been taught. On the first exam, one of the more commonly reported barriers was a lack of self-efficacy (with 23% reporting it as a barrier), meaning that students did not know if they would be able to use the strategies effectively. The bright side, however, is that with additional opportunities to practice using these strategies—some built directly into the course—the report of self-efficacy as a barrier decreased across the subsequent exams (with only 7% reporting it as a barrier by the end of the semester).

Lack of Resources and Time and Effort Costs

Students and instructors have many demands on their time. Students' choices of study strategies, for example, are often driven by their most pressing deadline (Kornell & Bjork, 2007; Yan et al., 2014), not by some master plan of study that will best help them learn and retain information. Therein lies the challenge. We need to first make sure that students and instructors receive pedagogy training (i.e., declarative and procedural metacognitive knowledge), and then that they have the resources needed to effectively implement them.

Sana and Yan (2022) created weekly retrieval quizzes for Canadian high-school teachers to administer to their students. These quizzes only took 12 min of class time each week, but revealed substantial benefits: Compared to questions about the not-quizzed concepts (control condition), questions about the interleaved and retrieved concepts were answered 0.71 standard deviations better after a 1- to 2-month delay. These results were presented to the teachers. However, casual communications with some of them a few months later showed that despite knowing the benefits, none of the teachers we spoke to had continued to give those quizzes. One reason was that they did not have the time to create the quizzes. Teaching platforms that provide a ready supply of interleaved assignments would go a long way in supporting instructors like these.

Similarly, students may perceive time and effort costs in using effective learning strategies. In the studies reported by Rea and colleagues (2022), time was easily the most commonly reported barrier to implementing effective strategies. Cognitive psychologists point out, of course, that these strategies should in fact *save* time. By making learning more efficient, one can reach one's learning goals in less time. However, qualitative analysis of students' explanations about time costs revealed that time concerns were not mainly about the time needed to implement the strategies themselves. Rather, students perceive time as an issue for different reasons. To engage in spacing, for example, students must start studying earlier than usual, not the day before an exam. When students said that they didn't have time to use effective strategies, sometimes, they meant that they simply did not start thinking about studying early enough.

The students also pointed out that they had too many other demands on their time—assignments and exams in other classes, part-time jobs, social responsibilities, and so on. One way to interpret these explanations is that students were saying that they did not have time to study at all, let alone use the more effective strategies. However, another way to interpret it—and this is something that several students stated explicitly—is that when they felt that time was running short, they fell back on their old habits of studying. In other words, under time pressure, students may not feel as though they can afford to try out new strategies, even if they know those strategies are supposed to be more effective. Under such pressure and competing demands, students may also feel as though they do not have the mental energy to use the more effective strategies. Retrieval practice takes more effort than rereading; interleaving study of related concepts requires more effort than studying one concept at a time. No wonder effort costs were another commonly reported barrier to the use of these strategies (Rea et al., 2022).

Emotional Costs

Finally, there may be anxiety associated with using these strategies. Doing so can increase the experience of effort and difficulty, reveal gaps in knowledge, and increase the number of mistakes made during learning. Instructors may worry about the effects of such experiences on their students' motivation and morale. Students do not want to face the gaps in their knowledge—many students only test themselves when they feel they have "learned" everything through repeated rereading, treating tests as mere metacognitive checks, not learning events (Rivers, 2021). In the study of undergraduates enrolled in a class that directly taught students about effective strategies, the second most commonly reported barrier to using those strategies is that they make them feel "nervous, worried, or anxious" (Rea et al., 2022).

For many students, these emotional costs outweigh the incentives to switch strategies, particularly if they perceive their current habits as meeting their needs. If studying with more passive strategies (e.g., cramming, rereading, highlighting, etc.) are sufficient for passing their exams and achieving the grades they want, why should they change their approach to a more effortful one? When students are already struggling, it can be anxiety provoking to abandon the strategies that appeared to have worked in the past in favor of new strategies, especially ones that require ignoring the immediate experience of increased difficulty, effort, and mistakes in the hope of realizing longer-term benefits.

Implementing Effective Strategies

Augmenting Classroom Structures and Activities

There are undoubtedly many ways in which instructors already engage in spacing, interleaving, and retrieval practice in their teaching. Each of these "strategies," as we have been referring to them up until now, is not just a single "strategy" per se. Rather, they reflect types of cognitive processing that support long-term learning: returning to previously learned content repeatedly over time, juxtaposing related and confusable concepts, and retrieving knowledge or skills from memory.

Exit tickets—short, usually low-stakes questions at the end of a class—are commonly used to assess what students have learned from a lesson. These activities might appear to engage retrieval. They certainly are good for assessing in-the-moment comprehension, but successful answering of exit ticket questions can be a misleading indicator of learning. Students may be able to answer exit tickets simply because the content is still fresh on their minds, and hence, they do not truly afford a retrieval practice opportunity. Rather, the same type of questions might be better asked as part of warm-up activities at the beginning of subsequent classes. If students are asked to recall what they had learned in a previous lesson, then this engages spaced retrieval practice. If warm-up activities help students to compare and contrast related concepts (either those that were learned in previous classes or that connect the previous class to the current class), these activities can also leverage the benefits of interleaving.

Asking students to discuss and answer questions during class can also help students to engage in effective learning processes. Teachers often pose questions to the class. However, as almost every teacher has also experienced, this comes with its own problems: it is often the same few students who answer. In these cases, it is only those few students who are getting retrieval practice. But this practice can be augmented in multiple ways to encourage all students to engage in retrieval. For example, cold-calling procedures, where the teacher poses a question, pauses (to give students time to think), and then selects a student name at random to give an answer, can encourage all students to at least covertly retrieve their knowledge (Sumeracki & Castillo, 2022). Or, a modified method might ask all students to first individually record their own answers and then discuss their answers with peers (especially those who gave different answers) before the instructor provides feedback (Deslauriers et al., 2011; Schell & Butler, 2018). This kind of peer instruction is often facilitated by technology (e.g., portable "clickers" through which students can answer multiple-choice questions or websites that record student answers via their laptops or smartphones) that enables all students to try answering the question on their own first.

Of course, simply changing classroom activities may not be sufficient. We also encourage instructors to examine the structure of their broader curriculum, homework, and project assignments. For any given concept or skill, how often does it appear across the semester or year? If we know that learning is not "one-and-done," what spaced practice opportunities are afforded by the assignments? Homework might be considered to be spaced practice—students are asked to answer questions days after it has been taught—but are there repeated opportunities for practice beyond that initial spaced practice? Are the knowledge and skills maintained after weeks or months?

Moreover, do the assignments allow for interleaved practice of related concepts or do they focus on just one concept at a time? Rohrer et al. (2020a) examined the practice problems in six of the most popular middle-school mathematics textbooks in the USA. They found that of the 13,505 practice problems contained in these books, only 9.7% were interleaved—defined as either being the first question in an assignment that is not solely focused on content from the immediately preceding lesson or as being a problem that is not based on the same skill or concept as the immediately preceding problem. Introducing interleaved and spaced retrieval practice can be as simple as making sure that practice and homework assignments include a mixture of different skills and concepts.

Time and effort costs, however, are often more significant barriers. Creating assignments and activities that integrate past content with new content, interleave related concepts, and provide spaced practice to maintain learning across the academic year takes both time and effort. This is challenging for individual teachers to accomplish on their own, especially if the school district has competing guidelines (e.g., about what material must be covered and when) or a fixed schedule of standardized testing. More effective solutions to these challenges might therefore require department- or district-level support as well as support from textbook publishers and educational technology platforms that can build spaced and interleaved retrieval practice directly into educational materials.

Augmenting Self-regulated Study

Most college students will readily tell you that they engage in self-testing (i.e., retrieval practice) frequently, albeit often after rereading and other passive strategies, as a way of checking on their learning progress (Rivers, 2021). However, as the research shows, the very act of retrieval *is* a potent method for strengthening learning, so students ought to jump into self-testing far earlier in their study process. Furthermore, a problem with rereading right before self-testing is that it can circumvent the retrieval processes that strengthen long-term learning. Instead, it is better to attempt retrieving information first, and then reread to check what one has retrieved and fill in knowledge gaps.

Physical and online flashcards are some of the most popular forms of self-testing, but these are often used in suboptimal ways. The problem is that flashcards most often focus on the rote memorization of details, vocabulary terms, and simple facts (e.g., names and key dates; Wissman et al., 2012; Zung et al., 2022). However, if the goal is to develop conceptual understanding and the ability to apply concepts, students should be practicing this application process (Agarwal, 2019). In a direct comparison of flashcards that focused on details versus concepts, Lin and colleagues (2018) showed a benefit of conceptually oriented flashcards over details-oriented flashcards on short-answer questions, especially for learners who do not spontaneously focus on structure-building. Even more worrying, in a survey of undergraduates, Zung and colleagues (2022) found that, more than 40% of the time, students reported using flashcards as their basic reading material rather than as opportunities for retrieval practice. In other words, when learners use flashcards, they may not be self-testing, and when they do use them to self-test, the flashcards are often not oriented so as to deepen conceptual learning. If their existing flashcards focus on vocabulary terms, students should be encouraged to use those cards to go deeper—for example, by picking up one card and trying to generate a real-life example of the concept shown, or choosing two cards and trying to retrieve the ways in which they are related, or taking a whole set of cards and laying them out as a conceptual map.

Implementation of effective learning processes, of course, is not limited to flashcard use. Students can take a blank piece of paper and write as much information as they can recall, use chapter or slide headings to guide recall, they can make sure they are returning to concepts taught earlier in the year to create spacing, they can identify concepts that are related as a way of interleaving practice, and so on. These strategies can be interspersed in small ways throughout one's day, both individually and in interactions with others—for example, writing notes at the end of each day about what was learned that day, retrieving the main concepts of a course while commuting to school or work, describing what was covered in class to a willing roommate or family member, and explaining concepts to classmates in study groups.

Motivating Engagement and Use of Effective Strategies

As past research has shown, just telling learners what strategies are effective is insufficient to change their behaviors because as we have seen, there are metacognitive and motivational barriers to overcome. The next step in research in this area should therefore focus on how to support and motivate the use of effective strategies.

McDaniel and Einstein (2020) set out a framework for developing student-focused interventions that integrate cognitive and motivational perspectives. It includes four integral components: Knowledge, Belief, Commitment, Planning. First, learners must have the metacognitive knowledge about what strategies are effective for learning. Second, they must believe that these strategies can be useful for them in their own lives. This may involve demonstrations or activities in which learners directly experience and understand how the strategy can benefit their own learning. Direct experience can be effective (Bugg et al., 2008) but it does have the potential for learners to focus on the wrong cues (e.g., experiences of ease and difficulty; Kirk-Johnson et al., 2019; Yan et al., 2016). Third, learners should commit to using the strategy or, in other words, be motivated to use it. Motivational research highlights many ways in which incentive structure and language can influence learners' willingness to engage in important but difficult tasks, so that research can and should be leveraged to influence learners' willingness to engage in effective but effortful strategies too (see Zepeda et al., 2020 for an overview). For example, motivating the use of effective strategies might involve increasing the perceived value of the strategy (together with a shift toward mastery goal orientations for learning), reducing the perceived costs of engaging with the strategies, and supporting self-efficacy in using the strategies. Finally, learners should have concrete plans for implementing the strategies (e.g., setting implementation intentions that concretely link an external cue to the initiation of behavior, Gollwitzer & Sheeran, 2006). Learners might have the best intentions to use a strategy but fail in the execution (Blasiman et al., 2017).

There are many ways in which instructors can support and motivate their students' engagement with and use of effective learning strategies. The following sections focus on such instructor actions. Because research on integrating cognitive and motivational approaches to enhancing the use of spaced and interleaved retrieval practice is relatively new, each section includes speculation about avenues that may prove fruitful for both researchers and instructors.

Draw Explicit Attention to Effective Learning Practices

In line with the Knowledge and Belief components of the McDaniel and Einstein (2020) framework, instructors should not only incorporate more opportunities for spaced and interleaved retrieval practice into their own instruction, but also directly explain to their students the reasons for these practices. Without explanation, students may perceive the activities as hoops they are being forced to jump through rather than as structures designed to support their learning. Explanations should be repeated throughout the course. It takes more than a single exposure to learn course content, and the same is true for learning about effective learning. Moreover, instructors should help draw learners' attention to the growth in their learning, such as when a concept that once felt difficult to understand is now clear, to the time saved during learning, and to the reduced anxiety about high-stakes exams engendered by greater confidence in content knowledge.

Create Safe Opportunities for Failure

While learning through spaced and interleaved retrieval practice, students often make mistakes and experience difficulty and/or failure. To increase students' commitment to these practices, it is crucial that they involve no-stakes or low-stakes with respect to grades. If these activities are truly for the purpose of student learning, mistakes should not be penalized. The incentive structures should focus students on the goal of mastery, not performance (Elliot & Murayama, 2008). A learner's first try at using spaced and interleaved retrieval practice should not be in preparation for a high-stakes exam, or worse, during the high-stakes exam itself.

The messages instructors convey to their students about these learning strategies should therefore be carefully chosen. If students perceive the instructor as using these opportunities as evaluating students' abilities (even if they are not associated with course points), the students may understandably be anxious about making mistakes and less likely to offer responses (i.e., engage in retrieval practice) when they are uncertain. Thus, instructors should emphasize the pedagogical value of making mistakes and should welcome them as learning opportunities (see also growth mindset-related language; Sun, 2019; Zeeb et al., 2020). Mastery-focused learning practices can also convey instructors' belief that all their students can learn (Muenks et al., 2021). In short, the benefits for both learning and motivation may be larger when mastery-focused learning activities are combined with supportive language.

Build Self-efficacy Through Practice

Another barrier to using effective learning practices identified by Rea and colleagues (2022) was that students lacked self-efficacy. That is, they did not know if they could use the strategies effectively. This likely increases the perceived time costs of using the strategies—if there are "start-up" costs associated with figuring out how to implement them, students are less likely to engage in these strategies. They may prefer a strategy that they know is less effective (e.g., rereading), but familiar. This lack of self-efficacy presents a challenge that simply incorporating more spaced and interleaved retrieval practice opportunities into classroom instruction does not solve.

Thus, instructors might also provide opportunities for students to practice these strategies in the classroom before trying to use them outside of the classroom. For example, by starting lessons with a retrieval practice "brain dump," instructors can model for students the use of a strategy that is easily implemented on their own. Review sessions before high-stakes exams can also provide an opportunity for students to practice incorporating new strategies for themselves. For instance, students might first try to write down everything they can recall from a particular unit and then work with peers to compare notes and fill in knowledge gaps. This experience can show students how effective study strategies can be used collaboratively as well as individually.

The first author provided these practice opportunities for undergraduate students in her course, and also created a habit-formation activity aimed at encouraging students to transfer the use of these strategies outside of the classroom. What follows is a largely anecdotal account of this activity that may form the basis of a future study. In the spring semester of 2020, undergraduates enrolled in two sections of a course titled “Cognition, Human Learning, and Motivation” were taught about effective, but “desirably difficult” strategies in the first few weeks of the course and then took their first exam during week 5. That same week, the students were asked to commit to using a new study habit that would incorporate spacing and/or retrieval practice. They each generated their own habit, selecting something that would be a brief but repeated behavior (e.g., ask at least one question during every class; write examples of the main topics from each class at the end of the day; teach a roommate about something learned in class each day). They then completed weekly habit reflection check-ins for the next 5 weeks (rating habit success and anticipating potential obstacles for the upcoming week) and a final reflection at the end of the semester.

The instructor’s hope was that this habit-formation activity would help students to transfer and apply their knowledge about effective learning into their future learning practices outside of her course. And indeed, what students wrote in their final reflections suggests that, for many students, the habit activity lowered perceived barriers to using more effective learning strategies. One student put it this way: “Having a weekly habit taught me that spreading out my work will not only save me stress and time in the long run but that it will make studying in the end that much easier.” Another student, who committed to teaching a roommate about something learned in class each day, said this about how practicing retrieval increased self-efficacy, “The thing I think will carry into life and into my last year at [university] is how impactful teaching others actually is. It is something I have avoided for a while as it is often intimidating but it has shown me that if I can teach someone else the material, then I more than likely know it.”

Concluding Comments

Learning is not “one and done.” This fact applies to course-related content, and it also applies to learning about learning. Too often, instruction about effective learning strategies is treated as a single-session topic—perhaps as a single professional development workshop for teachers or as a single “study skills” session for students. Simply teaching students and instructors about effective strategies for learning is also not sufficient for transferring that knowledge into practice. Rather, students need continued support to develop better study strategies, and this support will be most beneficial when it is integrated throughout the curriculum. Instructors should be supported in modifying and augmenting existing instructional practices to incorporate spaced and interleaved practice in their courses so that they, in turn, can support their students in developing effective learning activities both in and out of the classroom.

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