Powerful Teaching: Unleash the Science of Learning

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Dave's Reading Highlights

The science of learning sits dormant in academic journals, rather than easily accessible in pre-service textbooks and professional development materials.

By drawing on empirical research by fellow cognitive scientists and practical strategies from educators around the world, we focus on four powerful teaching strategies based on the science of learning: retrieval practice, spaced practice, interleaving, and feedback-driven metacognition. Retrieval practice boosts learning by pulling information out of students' heads (e.g., quizzes and flashcards), rather than cramming information into students heads (e.g., lectures). Retrieval practice is a no-stakes learning opportunity that increases student performance, beyond formative and summative assessments. Spaced practice boosts learning by spreading lessons and retrieval opportunities out over time so learning is not crammed all at once. By returning to content every so often, students' knowledge has had time to rest and be refreshed. Interleaving boosts learning by mixing up closely related topics and encouraging discrimination. For example, learning increases when students practice addition, subtraction, multiplication, and division problems all mixed up, rather than one type of problem at a time. Feedback boosts learning by providing the student the opportunity to know what they know, and

know what they don't know. This increases students' metacognition or understanding about their own learning progress.

Encoding is when we get information in and absorb knowledge, almost like a sponge. Storage is where we hope that once we encode information, our knowledge sticks around. Retrieval is when we reach back and bring something we previously learned into mind.

Retrieval practice is the same thing as the retrieval stage of the learning process: It's when we practice bringing information to mind. We tend to think that most learning occurs during the encoding stage, but a wealth of research demonstrates that learning is strengthened during retrieval.

In contrast, researchers have demonstrated that the opposite is true: When information feels fluent, we forget it. In other words, just because we learn something easily does not guarantee we'll remember it. As Anne Agostinelli, a math teacher from Illinois, put it, “I thought my students learned it, but then they forgot it. Which makes me wonder: Did they ever really know it in the first place?”

In other words, we typically focus on getting information into students' heads. On the contrary, one of the most robust findings from cognitive science research is the importance of getting information out of students' heads. Based on a century of research, in order to transform learning, we must focus on getting information out – a strategy called retrieval practice.

Consider it this way: In the span of one week, when students re-read passages, they forgot more than half of what they once knew! On the other hand, when students engaged in a simple, quick retrieval method, they forgot a little bit (which is expected), but they forgot much less over the one-week delay.

On a 0–7 point scale, students said they'd remember more after re-reading (a rating of 4.8) than after retrieval (a rating of 4.0) – the opposite from the actual results. Time and time again, cognitive scientists find this same pattern or illusion of fluency, where students

think they'll remember something well after re-reading, but that's actually when they forget the most.

Doug Lemov, author of Teach Like a Champion 2.0, defines retrieval practice as follows: Retrieval practice occurs when learners recall and apply multiple examples of previously learned knowledge or skills after a period of forgetting.

If we want students to think on a higher-order level, then we should make sure our retrieval questions are basic and higher-order.

You're probably familiar with these two forms of assessment: Formative assessment is when we check on and monitor students' progress. Kind of like inserting a toothpick into a cake to see how it's doing while baking, formative assessment is a strategy to see if things are on track. Summative assessment is when we discover what students have learned through various forms of measurement. This is when we get to celebrate accomplishments, perhaps like enjoying a cake after baking, while also noticing what could be done differently next time.

Retrieval practice is a learning strategy, not an assessment strategy.

For our first retrieval practice strategy, here's a small technique that makes a big impact on student learning: Brain Dumps. Pause your lesson, lecture, or activity. Ask students to write down everything they can remember. Continue your lesson, lecture, or activity. Yes, it's that simple! Simply ask students to Brain Dump and write down what they remember individually, then move on. How do we know that Brain Dumps improve learning? Research, of course! In scientific lingo, writing down what you remember is called free-recall, and it's a common retrieval strategy in laboratory studies because of its simplicity and opportunity for open-ended responses. In fact, scientists have demonstrated that Brain Dumps: Boost students' learning of past and future content3 Boost students' organization of knowledge4 Boost students' inferential reasoning

What should students do after a Brain Dump? Simply move on with your lesson! No collection of papers, no grading, no class discussion, other than acknowledging students' engagement in retrieval practice, of course.

Provide the opportunity for peer feedback. Ask students to swap their Brain Dump with a neighbor for 1–2 minutes, have them add something new that wasn't already written down, and pass back the Brain Dump. This is quick and instant feedback, but it could also be followed with extended discussion. Use Think-Pair-Share following a Brain Dump. Students have already completed the think stage individually. During the pair stage, here are some questions you can ask to prompt discussion: Is there anything in common that both of us wrote down? Is there anything new that neither of us wrote down? Did either of us write down any misinformation? Why do you think you remembered what you did?

How can we turn note-taking into retrieval practice? We call it Retrieve-Taking! Here are the steps: Teach your lesson as usual. Students listen and participate, but they can't take notes (yet!) Pause your lesson. Students write down important topics they want to study. Give students quick feedback about important topics or facilitate a discussion where students share what they wrote down. Continue with your lesson.

Luckily, students can swap note-taking with Retrieve-Taking outside of class, too! Students read their book. Every so often, students close their book. Students engage in Retrieve-Taking. Students open the book. Voila!

Here are some examples of my short-answer questions: Describe one of the 10 psychology myths we learned about last week. Are all humans scientists? Why or why not? What are Two Things you learned from your book reading this week? Be specific. How would a scientist conduct an experiment to see which type of shoe makes people jump higher, Nike or Adidas?

Just because something seems “active” doesn't mean that learning sticks. The key question to ask is this: Are students engaging in retrieval practice during “active” instruction?

When students are retrieving, they're also encoding. So yes, start with encoding – presenting material, discussion, videos, etc. But try to intersperse retrieval during encoding, not just after everything has been crammed in. Here's another way to think about it: Retrieving helps students encode. In other words, when students are retrieving, they're also encoding.

Our second Power Tool is what cognitive scientists call spaced practice, or simply spacing. In a nutshell, spacing is a combination of engaging in retrieval practice multiple times, while also engaging in those retrievals over time. In contrast, when students engage in retrieval practice but it's crammed all at once, learning isn't nearly as robust.

As shown in Figure 4.1, after one week, the cramming condition led to slightly higher exam performance compared to the spacing condition. After four weeks, however, performance in the cramming condition dropped by more than half, while exam performance for the spacing condition decreased only a little bit, from 70% to 64%. In other words, simply completing 10 math problems spaced out over two weeks instead of one week dramatically reduced forgetting.

Just because something boosts learning in the short term doesn't mean learning will stick around over the long term. Remember the study we discussed in Chapter 2 by Roddy Roediger and Jeff Karpicke on retrieval practice? The graph in Figure 4.1 shows the exact same pattern: What's good for learning in the short term, like re-reading and cramming, leads to a huge drop-off in learning over the long term when compared to challenging strategies like retrieval practice and spacing. 2 Cramming works, but only in the short term.

It may sound counterintuitive, but a little forgetting is the key to spacing: When we let time pass and space things out, students' knowledge has time to solidify and “simmer.”4 We know from

experience that by taking a step back and letting things settle, we have a better understanding of what we're trying to learn.

In other words, student performance increased the more the space between the lesson and the quiz increased, even with just one quiz. Note that this doesn't mean that pre- and post-quizzes are ineffective – they boosted learning more than zero quizzes. But when it comes to the “biggest bang for your buck,” quizzes that are spaced and delayed a few days after initial learning are the most powerful for long-term learning.

Based on Pooja's classroom research, we recommend spacing retrieval practice at least a few days after a lesson. Why? Again, the more challenging the retrieval, the better; so the more spacing, the better. Yet any schedule of retrieval practice is better than none at all. As a very simple example of spacing, don't give students homework on what they learned in class earlier that day; challenge them by providing homework on content learned last week. In other words, focus more on the amount of spacing, and less on when it should occur.

This strategy of mixing things up during spacing is called interleaving. Years of cognitive science research have established that interleaving – simply re-arranging the order of retrieval opportunities during spacing without changing the content to be learned – can increase (and even double) student learning.

As shown in Figure 4.3, student performance immediately after practice was higher for the blocked condition, but then students showed a giant drop-off in learning after 24 hours. When completing interleaved math problems, students had nearly double the exam performance after 24 hours (77%) compared to students who initially completed blocked problems (38%).

Why does interleaving help our students remember songs and civilizations? There are two reasons why interleaving is powerful: Interleaving promotes students' discrimination. Interleaving increases students' learning of information in the middle of a unit.

Second, interleaving helps students learn the middle of a unit. As we know from decades of cognitive science research – and from everyday life – we tend to remember things at the beginning and end of a movie, song, or textbook unit, but not the middle. For example, retrieve and write down a list of all the US presidents. Which ones do you remember? Which ones have you forgotten? Most likely, you are experiencing what scientists call the serial position effect16 – you remember the first few presidents and the most recent ones, but you've probably forgotten the presidents in the middle (aside from Abraham Lincoln!).17 By interleaving and spacing throughout the semester, students learn and remember what we teach them in the middle of the school year in November or February, not just information taught in September or May. Retrieving after forgetting and thinking while discriminating are desirable difficulties that dramatically boost learning.

But can you spot the difference between spacing and interleaving? This is a tough question, and rightfully so! Spacing is how we spread out content over time, whereas interleaving is how we mix things up. The critical difference is that interleaving refers to what happens in between spacing. When you're spacing content, you could fill the gap with unrelated content (this would be spacing) or highly related content (this would be interleaving).

This should not be competitive. As we mention throughout the book, by using low- and no-stakes retrieval practices, you emphasize that retrieval, spacing, and interleaving are learning strategies, not assessment strategies.

Power Tool #4 is feedback-driven metacognition. When students engage in retrieval, they are able to reflect on what they know and what they don't know – what cognitive scientists call metacognition.

It is quite common for students to study what they already know; it is powerful and builds confidence. In my class, however, it is my duty to teach students how to learn. I teach them how to differentiate between what they know and what they don't know. I urge them to

remember the feeling of “not knowing” with my Lady Murasaki Shikibu example. There was no shame; instead, I emphasize the attitude of “I don't know that yet.”

First, the bad news: Research confirms that students frequently think they know something, when actually, they don't. Also, students are typically overconfident when they predict or assess their own learning. Here's the good news: Cognitive scientists have developed evidence-based recommendations for improving students' metacognition by incorporating frequent feedback. In order to examine metacognition scientifically, researchers ask students to make two types of ratings: Judgments of learning, or a student's prediction of future learning or memory Confidence judgments, or a student's confidence in recent or past learning.

But keep in mind that it's not just our students who can have an illusion of fluency! As professor and host of the Teaching in Higher Ed podcast, Bonni Stachowiak, observed: We all have a tendency to miss some of these counterintuitive aspects to teaching and learning. It's really complex, and rather than see such a great distance between our learners and ourselves, we should see that we all have the potential to predict wrongly about the effects of our actions.

We know that students don't always pay attention, especially when it comes to feedback. Often, students look at their grade with delight, satisfaction, or concern; or they look through what they got incorrect, but not what they got correct. In other words, when students are “looking over” feedback, they're usually just “overlooking” it. In other words, when students are “looking over” feedback, they're usually just “overlooking” it. The best way to maintain their attention is to involve students in the process of feedback. Four Steps of Metacognition, Metacognition Sheets, Breathe and Retrieve, and Metacognition Line-Up get students actively involved in thinking about their own learning, rather than simply glossing over feedback.

Recently, a college professor was describing his typical lesson plans. He reflected and shared that he always starts class by saying, “Alright, here's what we did in class yesterday.” Take a moment.

Based on what you've learned in this book, what could he do differently? He could simply ask the students! When setting the stage for class, asking, “What did we do yesterday?” takes just as long as, “Here's what we did yesterday.” The simple swap from you reviewing to students retrieving makes a big difference.

For example, I lived in Chicago long ago and I was an avid Cubs fan. I spent many an afternoon in the bleachers at Wrigley Field. In my classroom, when we discuss World War II, I write on the board: CUBS F. Then I would ask my students, what does my being a Cubs fan have to do with the main Allies in World War II? Years later, they have no trouble remembering that the Allies were China, United States, Britain, Soviet Union, and France!

Whether you teach at an elementary school or a medical school, you've probably heard of the instructional strategy Think-Pair-Share. Here's how it typically works: Students think about a topic in response to a question or prompt. Students pair up with another student and talk about their reflection. Students share their thoughts in a larger class discussion.

If you teach 100 facts and students remember 60% without retrieval practice, that's 60 facts. If you teach 90 things and students remember 80% with retrieval practice, that's 72 facts. In this example, you're teaching slightly less, but students are remembering more. This tradeoff is small, but it can yield a large impact for student learning. Because students learn more from retrieval practice, we save time – we don't have to re-teach what students already forgot.

I also teach adult learners in my graduate-level courses (about science and education, not firefighting!). Adults, including us as educators, are always learning new knowledge and seeking ways to improve their skills. Which brings me to this question: How do we apply Power Tools outside the classroom, especially with adult learners? Based on my experience, I recommend starting a conversation with adult learners using everyday life examples beyond the classroom: What did you do last weekend? What is the name of your first childhood friend? Where did you park your car? These types

of questions get us all engaged in thinking about learning and memory in ways we don't on an everyday basis. We provide more examples of everyday learning questions (we call them Retrieval Warm-Ups) in Chapter 8, but this entry into how learning works applies for all learners – regardless of age or setting. Next, extend the conversation to a context more appropriate for adults. For example, ask adult learners, “If you just met someone new at a work event, how can you remember their name better?” or “If you're training a new employee, which Power Tools can you use to help them remember?” Engage adult learners in the conversation not just about their own learning, but about learning around them too. Also, when it comes to learning outside the classroom, we provide a number of recommendations in Chapter 6 to build on what you're already doing. Many adults use at least one Power Tool, perhaps without realizing it. With adult learners, a greater depth of conversation can be explored, and basic Power Tools work just the same for all learners.

While we can't go into an explanation for each neuromyth (that'd be a book all on its own!), we'd like to address learning styles in particular. Led by Hal Pashler from the University of California, San Diego, prominent cognitive scientists conducted a large review of research on learning styles and found no evidence that students taught in alignment with their “learning style” achieve more than students taught without designated learning styles.10 In fact, researchers have continued to demonstrate that teaching students using a variety of methods is most effective for improving learning.11 In other words, rather than concentrating on what doesn't work, focus on what does work: varying up teaching and learning using retrieval practice, spacing, interleaving, and feedback. In addition, as cognitive scientist Daniel Willingham put it, “Children are more alike than different in terms of how they think and learn.”12 Why is the learning styles myth so compelling, convincing, and controversial? As Michael Norton, manager of digital learning at KIPP Texas Public Schools, explained: Teachers want to teach students with learning styles, perhaps because they also feel they have a learning style. Teachers need to reflect on their own learning and realize they learn lots of things in lots of different styles, not just one or two ways.