The Science of Learning: Research Meets Practice

Six Research-Based Teaching Practices Are Put Into Practice

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THE LEARNING AGENCY

Introduction

For years, centuries really, educators have experimented with different learning tools, techniques, and curricula. Some efforts have been more successful than others, of course. But how many of them are based on science with a robust body of research behind them?

The short answer is: not all educational approaches have had the backing of research. For example, for decades, the notion of “learning styles” has been prevalent. This is the idea that when instruction is tailored to an individual’s learning style, they learn better. But no rigorous evidence supports this view.

For the nation’s education system, though, the bigger question is: How do we best educate our children so that they learn better, and learn **how** to learn, in addition to learning **what** to learn? Additionally, and arguably just as challenging, is: How do we translate this body of research into classroom practice effectively?

Enter the “Science of Learning: Research Meets Practice.” The goal of the project is to get the science of learning into the hands of teaching professionals as well as to parents, school leaders, and students.

What is the Science of Learning?

Experimental research into how people learn first began over a century ago. In the decades following World War II, cognitive psychologists became more and more interested in how people remember incoming information, the differences between novices and experts, the course of expertise development, and the development of reasoning in children.

As researchers consolidated this knowledge in the 1980s and 90s, there was a growing interest in applying this knowledge to classroom settings. Especially since the mid-2000s, collaborations between teachers and researchers have validated many of the central ideas first explored in the 1970s and early 80s. These collaborations have also often led to fruitful teaching innovations.

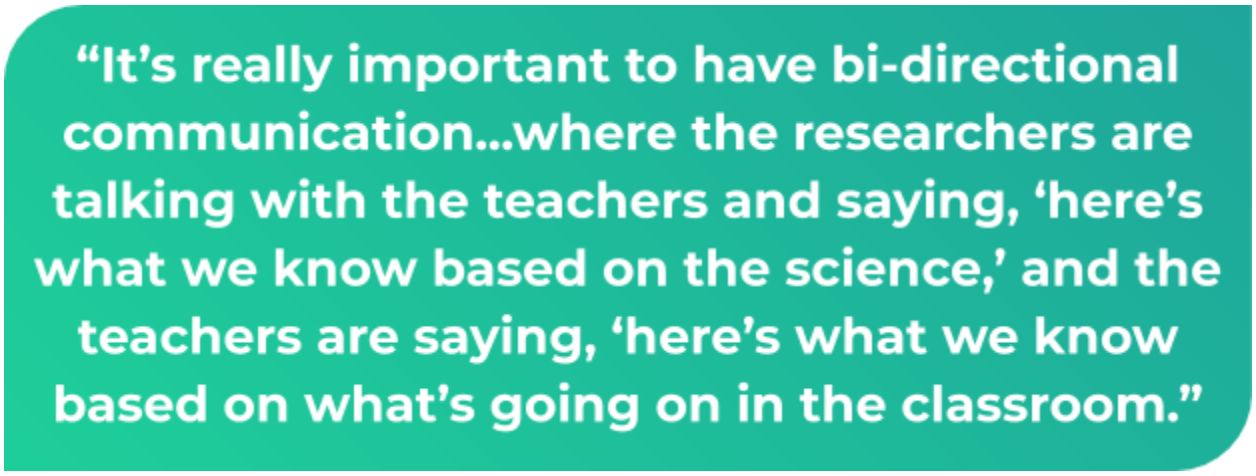
We still have a long way to go, however. For example, many still use misguided study practices like blocked approaches to studying, where one concept is studied repeatedly before a new concept is explored. Instead, people should use interleaving — or mixed practice — which is far more effective.

Project Goals

*The goal was to **bring the science of learning into the classroom** and kickstart the development of easy-to-use professional development materials. We also wanted to collaborate with teachers, and **learn from them what was effective, or not**, when implementing science-based practices. In other words, we were interested in **listening to teachers about implementing the research**, rather than telling them what they "should do."*

What would happen, for instance, if learning scientists met with experienced classroom teachers, and had a conversation about how concepts in cognitive science could possibly translate into the classroom?

As learning scientist Megan Sumeracki explains,



We selected schools with a wide range of student and teacher profiles, racial, ethnic, and socioeconomic backgrounds. Project partners included Leading Educators, Teaching Lab, and Wellington Road Productions.

Seven schools were chosen for the project, from urban Memphis, Tennessee and East Baton Rouge, Louisiana, to suburban Kenner, Louisiana, Leominster, Massachusetts, and rural Medomack, Maine. With project partner Leading Educators, who helped with the selection of teachers in the Memphis and East Baton Rouge/Kenner Louisiana areas, 16 different teachers were invited to participate.

The conversation with teachers included an initial interview to learn about their teaching experiences, what they felt they knew about the science of learning concepts that they'd be working with, as well as a meeting with their learning scientist. The teachers and researchers would then check in a few times during the duration of the project. The interaction culminated in a final filming of teachers in the classroom, and a debriefing among the teachers and learning scientists about what worked and what didn't when trying out specific teaching strategies.

Additionally, teachers were asked to tape themselves in at least one self-reflection piece and send it to our videographer. All of these elements were included in the final product: a video on the specific science of learning strategy that could be disseminated to decision-makers, classroom teachers, parents and students alike.

The Strategies

We focused on six distinct strategies; although they can be used in relation to one another, and often lend themselves to specific subjects and concepts, they can all be adapted to a wide variety of classroom settings, grades, and subject areas.

Retrieval Practice

"Retrieval practice boosts learning by pulling information out of students' heads, rather than cramming information into students' heads," according to cognitive scientist and author, Dr. Pooja Agarwal.

"For example, simply asking students, 'What did we do in class yesterday?' rather than telling them 'Here's what we did in class yesterday' significantly boosts long-term learning."

Frequent low-stakes quizzing is the signature example of retrieval practice.

Dual Coding

"Dual coding is about combining images or visual representations with words. When used well, combining those can provide two ways of remembering information," states learning scientist Dr. Megan Sumeracki.

But, not all graphic representations are created equal, and likewise, just creating a picture is not enough. According to researchers, visuals must be directly linked to the text without many distractions.

Spacing

Spacing is “coming back to information that was learned previously in order to refresh it,” states learning scientist, Dr. Yana Weinstein-Jones.

In short, spaced practice is the opposite of cramming, and experts like Weinstein-Jones recommend that learning is stretched out over time, optimally over the course of a number of sessions.

Teachers should intentionally bring up skills and concepts, strategically spaced, to improve how well students grasp the material.

Interleaving

Interleaving is studying different problem sets, “or mixing up different types of problems or…different concepts that you’re trying to learn,” according to learning scientist Dr. Megan Sumeracki. This can help students to see links and similarities between different ideas and concepts and can improve long-term learning. Sumeracki adds that when a teacher introduces interleaving into the classroom, “there might be some struggle early on, but over time the students will probably get more used to it, and then those successes will be really exciting.”

Metacognition

Metacognition is most often defined broadly as, “thinking about thinking.” However, what we know, via the cognitive sciences, includes a much more specific notion of metacognition. The Center for Teaching at Vanderbilt University describes the value of planning, monitoring and assessing one’s own learning.

According to learning scientist Dr. Regan Gurung, “The more we can make the thinking process visible, the better we can understand how to make it more effective. That’s what metacognition is all about.”

Elaboration

In everyday contexts, we often use “elaborate” to mean “describe in more detail.” But psychologists mean something a little different by the word “elaboration.” In this context, elaboration is fundamentally about “making meaningful associations to a

particular concept...it's the opposite of just rote memorization," states. Dr. Stephen Chew, learning scientist.

Chew adds, "what elaboration does is **it increases the number of ways of accessing information.**" For example, when teaching students about the topic of variation in statistics, asking the students to come up with an example from their lives of high variation and low variation would be a good way to encourage elaboration.

Retrieval Practice

School: **Greenlawn Terrace Elementary - Kenner, Louisiana (urban)**
Teachers: **Anedra Robertson, Rebekah Haynes, Troy Hobson**
Researcher: **Yana Weinstein-Jones**

When it comes to learning, people are often focused on getting information into our brains or helping our students put information into their brains.

Retrieval practice is different. It is the concept of retrieving or getting information out of our brains. For example, says Pooja Agarwal, "if you think about your very first childhood friend, you probably weren't thinking about them until right this moment...Going back and thinking of something and sort of bringing it up - that's what scientists call retrieval."

One of the easiest ways to incorporate retrieval practice into learning and teaching is via low-stakes tests or quizzes. According to learning scientist Yana Weinstein-Jones, "simply the effect of bringing information to mind from memory...is going to increase learning."

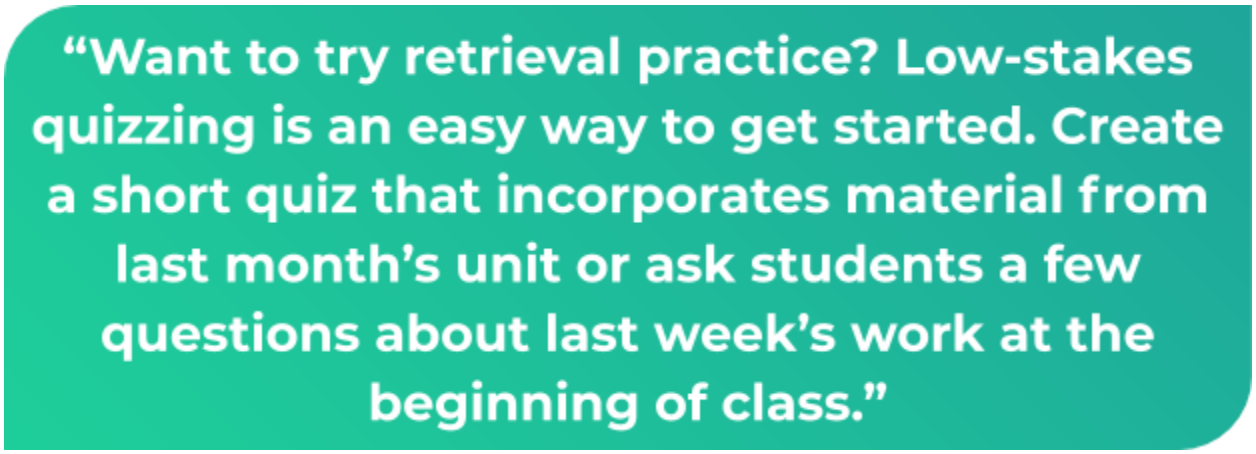
Retrieval practice is one of the most well-researched learning strategies. The most basic research approach explores how well people can remember a list of words, for example. In a typical study, psychologists had one group read (or "study") a word list for a period of time, so they could try to remember as much as they could. Another group practiced remembering the words through testing (cover the list up, try to remember all they could, see what they missed, do it again). **Those who practiced retrieval (or self-testing) remembered more words than those who merely re-read or studied.**

The rationale behind retrieval practice is twofold. First, actively trying to remember something or perform some skill is a more effective way of learning than passively

reading or hearing about how to do something. Second, retrieval practice provides students with better ways of monitoring what they know. The act of re-reading a textbook can't tell you what you don't know or where you should focus your efforts, but a test can.

Greenlawn teachers Troy and Anedra both made adjustments to their classroom practices to increase retrieval practice. For example, Troy adapted his "Jeopardy" game to allow all students to jot down their answers before the problem was solved. Anedra realized that giving students the opportunity to solve different problems increased their ability to retrieve "old" learning. Weinstein-Jones notes, "taking that diagnostic test, or doing the problem of the day...that's not a check. That's when the learning is actually happening."

"I've been cycling more of those skills and then using them more often," adds Troy, giving students more opportunities to practice retrieval. For her part, Anedra states that adding low-stakes tests to her classroom confused some students. "I had to let them know, no, it's not a test... I just want to know what you know."



Dual Coding

School: **Douglass High School, Memphis TN**
Teachers: **Lauren Mueller and LaShaundra Cox**
Researcher: **Dr. Megan Sumeracki**

*Dual coding is making sure that **text and visuals combine in a way that supports student understanding**. "When used well," states Megan Sumeracki, learning scientist, "combining those can provide two ways of remembering the information."*

*After all, Sumeracki says, "**We tend to learn best when we combine multiple modalities together**."*

The combination of verbal and visual presentation of information helps students learn new concepts. Numerous lab studies illustrate the potential of dual coding to enhance learning in a variety of domains. Classroom studies have further substantiated the idea that combining visuals and verbal information in the right way enhances learning overusing either alone.

When visualizations and text are presented separately, the student has to already know how to integrate the text and visualization on his or her own. This might happen when students read a paragraph about a concept and see a separate visualization of the concept, at a different time than the reading and with no direct connection made between the text and the visual aid. **By integrating the text and the visualization together, the student can focus more on the underlying concept and less on mapping the text to the visualization.**

When integrating visuals and verbal information, care has to be taken not to overwhelm the learner. So ten new vocabulary words on a complex diagram they've never seen before is going to make it harder to understand (not easier), even if the visuals and text are integrated. Realistic depictions are often not necessary; **simplified depictions that convey the essential meaning are more effective**. Any irrelevant information can distract the learner.

LaShaundra Cox, a biology teacher at Douglass, observed, "So, it's better when they have to produce the visual rather than using the visual that's already made." But, as Dr. Sumeracki points out, "if they're not there yet, if they just stare at a blank piece of paper," it's better to have simple diagrams or visuals provided. Cox noted, "dual coding works, if you use the strategy the right way and you use it intentionally."

Both teachers found the strategy to be helpful. Lauren Mueller, an English teacher at the school used dual coding by modifying her use of graphic organizers. "It's fun to see kids who maybe struggle in other areas feel like, 'Yes, let me tell you what I think," and Mueller adds, "It has not taken much for me to implement dual coding, and that is so refreshing as a teacher."

"If students are struggling to understand a visualization, can you integrate descriptive text or simplify to make the visualization more clear? For advanced students, you might try asking them to express an idea or a process through a visualization, which can be used as a springboard for further discussion."

Spacing

School: **Medomak Valley High School, Medomak, Maine**
Teachers: **Bill Hinkley, Heather Webster**
Researcher: **Dr. Yana Weinstein-Jones**

If students do well on a test, teachers often assume that the knowledge or skills are now perfected. However, because someone performed or studied well once doesn't mean that they will continue to remember and apply the material correctly.

*Spacing helps promote **long-term retention** and, "in order to stop the forgetting process...**spacing enables additional opportunities to retrieve or remember** that information," states Yana Weinstein-Jones, learning scientist.*

The idea that "cramming" is bad is essentially correct: if you test someone who has crammed for a test, they will likely perform well, maybe even as well as someone who has consistently studied a little bit at a time. But a student who crams will quickly forget the information.

Educators can incorporate spacing into the classroom in several ways. Rather than having two large exams during the school year, for example, teachers can have routine tests with lower stakes.

Teachers can also include prior material on the tests to promote long-term memory. Further, at the beginning of class, teachers can have students address a question related to material from a week or two (or longer) before.

Medomak teachers Bill Hinkley and Heather Webster both realized how to adjust existing spacing strategies to improve learning. “I think my expectations were really high for what they should be able to retrieve, or what they would remember...(I) try to get into the kids' perspective a little bit...how is their brain processing the information that I’m saying?”

Understanding that teachers are experts, and have practiced their subject matter for many years, whereas the students have not, helps explain why students “forget” so much; “I find it to be a relief knowing that...we just have to keep hitting it time and time again,” noted Heather.

How long should we wait between spaced sessions? While any amount of spacing is better than none, **the most efficiently spaced sessions will occur when students are on the cusp of forgetting what they did before**. This strengthens the memory the most. Spacing pairs well with retrieval practice: it’s the act of temporarily forgetting and then trying to remember that strengthens memories the most.

Bill restructured his class so that review happened at the beginning of each class before he introduced anything new. Heather identified key skills to spaced practice. For example, character studies were done only once a year, but the skill of backing up findings with evidence could be practiced throughout the school year.

“Challenge students to do something that they haven’t done in several weeks or to return to material they may have forgotten. Students may be frustrated if they thought they could do something before and are struggling to do it again. You can remind them of how this kind of practice benefits long-term learning.”

Interleaving

School: **Sky View Middle School, Leominster, MA**
Teachers: **Dr. Kim Kelly, Shannon Payette**
Researcher: **Dr. Megan Sumeracki**

Interleaving, or "mixing it up," is a way to increase learning potential. For example, instead of studying 10 multiplication problems, then 10 division problems, and then 10 addition problems, mixing those problems up helps students find and see similarities and differences between the different types of problems. It also **helps to review older concepts and hone the skills needed to choose correct strategies** for solving problems.

"What interleaving does is force the students to figure out not just how but also when" to use a specific problem-solving strategy, explains Megan Sumeracki, learning scientist. Sky View teacher, Kim Kelly adds that **"**they can't get to the solution if they can't get to the start," pointing out that often fundamentals need a lot of support.

Part of the skill of solving math problems involves applying the right procedure to the right problem. Interleaving develops that skill. Problems can look very similar, yet require different kinds of approaches. Interleaving often results in worse performance during the practice sessions, but far higher performance on subsequent tests.

Interleaving works because it involves the right kind of practice. Blocked practice means the student never has to think about which strategy or procedure to apply; interleaved practice helps students associate the right strategy with the right problem.

To clarify, though, research doesn't support an idea like "never do blocked practice". Blocked practice is necessary for students beginning to understand a concept.

Both Kim and Shannon realized that interleaving their homework assignments and tests would require some extra time. Since most textbooks and worksheets featured blocked practice, they had to modify them. But, they both noticed the difference in their students' problem-solving abilities.

After creating an interleaved worksheet, Kelly noticed that "students (were) stopping and thinking…their brain had to shift from this topic back to some old material." Shannon saw improvements when she administered a standardized practice test. "I have a kid who has struggled. (He) did not meet expectations for math at all on his last year (state) test. He got 6 out of 6!"

"Instead of always giving students problems involving the most recent concept students have learned, try incorporating a mixture of problem types into student homework, exams, and review sessions."

Metacognition

School: **Capitol Elementary, East Baton Rouge, LA**
Teachers: **Jessica Anderson and Brittany Bush**
Researcher: **Dr. Regan Gurung**

*Metacognition refers to how students **evaluate their own knowledge** and monitor their own learning.*

Several different lines of research support the idea of teaching metacognitive strategies to students. First, students who have high levels of metacognition—who are better at monitoring their own learning and better at assessing what they know—consistently learn more, and more deeply than students with low levels of metacognition.

Additionally, the lowest-performing students also often don't know what they don't know, which can lead to overconfidence in their abilities. That is, students often think that they know the material when they don't or think they can perform a skill when they can't, which leads to frustration and poor allocation of study time. **Strategies like self-explanation and self-questioning expose these illusions when students realize they can't really explain the concept in a coherent way.**

According to learning scientist Dr. Regan Gurung, **metacognition is "broken down into three main processes. How we plan, how we monitor and then how we assess."** For example, when a student can plan out how they are going to study, and how they will tackle a complex task, their studying and learning improve, according to Gurung.

“The more we can make the thinking process visible, the better we can understand how to make it more effective - and that’s what metacognition is all about.”

“The more we can make the thinking process visible, the better we can understand how to make it more effective - and that’s what metacognition is all about,” states Gurung. **The ultimate goal of teaching metacognitive strategies is for the student to become more self-directed in their own learning.** Students, for example, should be able to figure out the areas that they are weak in and take appropriate steps to address those areas.

Teachers Jessica Anderson and Brittany Bush, like many skilled instructors, already integrated some metacognition activities in their classroom. Specifically, they both practiced the use of “exit tickets” where students could share their confidence level on a particular topic at the end of the class.

Through the project, the teachers made adjustments including having students check-in with themselves, and each other, throughout the day. Brittany states that, **at first, the change caused some confusion, but then students “realized that the ratings were for themselves and not for me…they started being more honest…they didn’t want to be overconfident any more.”**

Jessica notes, “Once they feel better about themselves, or just feel comfortable answering the questions, I find that they dig deeper and not just read and do things on the surface level.”

“When students explain a concept to themselves or evaluate how much they know about something can develop beneficial self-monitoring habits that will make students more effective learners in the future.”

Elaboration

School: **Soulsville MS/HS Charter School, Memphis, TN**
Teachers: **Lynsey Kamine, Sanam Cotton, Jesse Finafrock (moved to Kirby Middle School), LaCardia Walker, Tatiyana Webb**
Researcher: **Dr. Stephen Chew**

Elaboration refers to the teaching and learning practice of ***making meaningful connections or associations to a particular idea or concept.*** *In other words, thinking about how other ideas, concepts, experiences or prior knowledge are related to the new lesson or idea. When that connection is made, research shows that there is a distinct learning advantage.*

Elaboration is an **encoding technique—it's a way of helping new information stick into our long-term memories**. Although almost any form of elaboration is better than none, deeper, more meaningful elaborations (e.g., elaborations based on the meaning of a new word) offer more benefits than superficial elaborations (e.g., elaborations based on the shape of the word).

Research suggests that students can learn to elaborate on their own; students who were told about several elaboration strategies (like creating a visualization, or a sentence that illustrates the concept, or make up a story) over the course of several weeks remembered more than students who were not trained on the techniques, even when the elaboration group was not specifically prompted to elaborate.

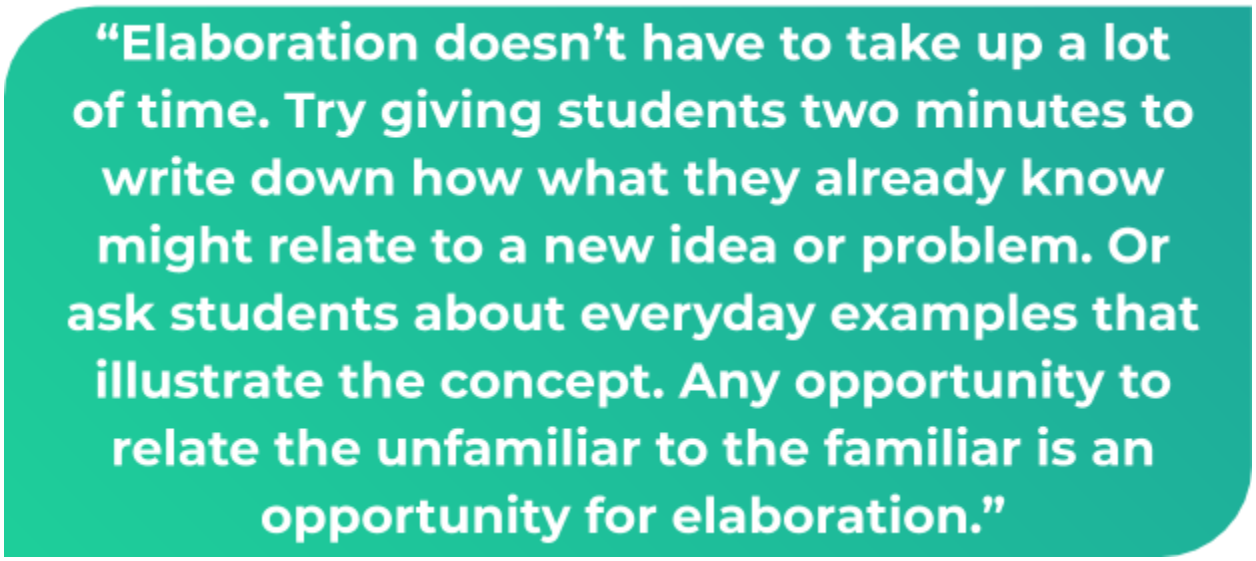
Students don't necessarily have to make their own elaborations; providing students with precise, meaningful elaborations can also improve memory for the material. **Elaboration techniques work because the approaches help people structure information**. Not only is information easier to remember when it is linked to something you already know, but elaboration that is meaningful also helps students build organized knowledge, making it easier to remember that information in the appropriate context.

Teacher Sanam Cotton had doubts about the technique, but realized that elaboration "ends up sparking a good amount of inquiry," and "becomes a tool you can use every day in your classroom."

For example, teacher Tatiyana Webb gives students more time now to elaborate, via a one-minute "Stand and Talk" time where students talk about the concept, with each other, for a minute. Jesse Finafrock observed that elaboration "helps with

engagement," noting that elaboration can be worked in almost every day, and doesn't require a self-standing lesson or lessons.

Stephen Chew, learning scientist, adds that "**elaboration…is the opposite of rote memorization.**..if you learn a web of associations about a concept, that's much more powerful in terms of learning and memory." Simple strategies like asking students to explain how a new lesson might relate to something they studied a week or two ago, or how it can relate to their own lives.



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