C1 Module 4: The Science of Learning

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Project 2021-1-SE01-KA220-HED-000023166

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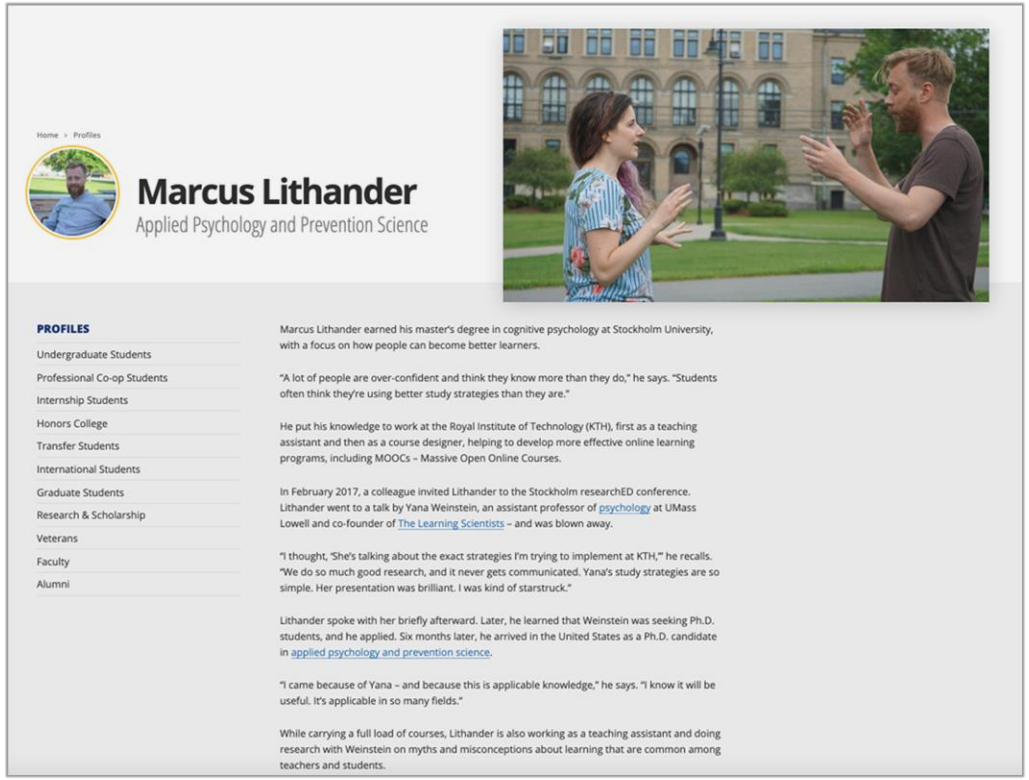
Me: Marcus Lithander, Ph.D.

Applied Psychology and Prevention Science

Cognitive Psychology

University of Massachusetts

- How can we help students to study better?
- How can teachers become better at designing courses that promote student learning?
- Why do students use sub-optimal learning strategies?



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Marcus Lithander

Applied Psychology and Prevention Science

PROFILES

- Undergraduate Students
- Professional Co-op Students
- Internship Students
- Honors College
- Transfer Students
- International Students
- Graduate Students
- Research & Scholarship
- Veterans
- Faculty
- Alumni

Marcus Lithander earned his master's degree in cognitive psychology at Stockholm University, with a focus on how people can become better learners.

"A lot of people are over-confident and think they know more than they do," he says. "Students often think they're using better study strategies than they are."

He put his knowledge to work at the Royal Institute of Technology (KTH), first as a teaching assistant and then as a course designer, helping to develop more effective online learning programs, including MOOCs – Massive Open Online Courses.

In February 2017, a colleague invited Lithander to the Stockholm researchED conference. Lithander went to a talk by Yana Weinstein, an assistant professor of psychology at UMass Lowell and co-founder of The Learning Scientists – and was blown away.

"I thought, 'She's talking about the exact strategies I'm trying to implement at KTH,'" he recalls. "We do so much good research, and it never gets communicated. Yana's study strategies are so simple. Her presentation was brilliant. I was kind of starstruck."

Lithander spoke with her briefly afterward. Later, he learned that Weinstein was seeking Ph.D. students, and he applied. Six months later, he arrived in the United States as a Ph.D. candidate in applied psychology and prevention science.

"I came because of Yana – and because this is applicable knowledge," he says. "I know it will be useful. It's applicable in so many fields."

While carrying a full load of courses, Lithander is also working as a teaching assistant and doing research with Weinstein on myths and misconceptions about learning that are common among teachers and students.

Lab to Classroom approach

Controlled experiments in the lab.

Do findings hold up in real-world settings?

Implement in broad scale. Are effects generalizable and do they hold up over time?

How do we learn?
And what does it all mean?

- *Learning should neither be too difficult nor too easy.*
- *Learning should be adapted to student's current state of development and knowledge.*
- *Learning is social*
- *Everybody learns differently*
- *Knowledge is constructed*
- *Learning is natural*

Teaching the Science of Learning

”Applying research on cognition to education requires focusing on the system level — on the relationship between courses, on instructional activities and requirements, and so forth — as well as on what students can and should do on their own to enhance learning.”

1. *Promote student learning during classes, before classes and after classes*
2. *Communicate to promote good behaviors*
3. *Help student learn how to learn – metacognition*

Kornell & Bjork, 2007

What works?

"Teacher candidates should get a good overview of research-proven instructional strategies."

- Pomerance et al., 2016

Weinstein et al. Cognitive Research: Principles and Implications (2018) 3:2
DOI 10.1186/s41235-017-0087-y

Cognitive Research: Principles and Implications

Open Access

TUTORIAL REVIEW

Teaching the science of learning

Yana Weinstein[1*], Christopher R. Madan[2,3] and Megan A. Sumeracki[4]

Abstract

The science of learning has made a considerable contribution to our understanding of effective teaching and learning strategies. However, few instructors outside of the field are privy to this research. In this tutorial review, we focus on six specific cognitive strategies that have received robust support from decades of research: spaced practice, interleaving, retrieval practice, elaboration, concrete examples, and dual coding. We describe the basic research behind each strategy and relevant applied research, present examples of existing and suggested implementation, and make recommendations for further research that would broaden the reach of these strategies.

Keywords: Education, Learning, Memory, Teaching

Significance

Education does not currently adhere to the medical model of evidence-based practice (Roediger, 2013). However, over the past few decades, our field has made significant advances in applying cognitive processes to education. From this work, specific recommendations can be made for students to maximize their learning efficiency (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger, Finn, & Weinstein, 2012). In particular, a review published 10 years ago identified a limited number of study techniques that have received solid evidence from multiple replications testing their effectiveness in and out of the classroom (Pashler et al., 2007). A recent textbook analysis (Pomerance, Greenberg, & Walsh, 2016) took the six key learning strategies from this report by Pashler and colleagues, and found that very few teacher-training textbooks cover any of these six principles – and none cover them all, suggesting that these strategies are not systematically making their way into the classroom. This is the case in spite of multiple recent academic (e.g., Dunlosky et al., 2013) and general audience (e.g., Dunlosky, 2013) publications about these strategies. In this tutorial review, we present the basic science behind each of these six key principles, along with more recent research on their effectiveness in live classrooms, and suggest ideas for pedagogical implementation. The target audience of this review is (a) educators who might be interested in integrating the strategies into their teaching practice, (b) science of learning researchers who are looking for open questions to help determine future research priorities, and (c) researchers in other subfields who are interested in the ways that principles from cognitive psychology have been applied to education.

While the typical teacher may not be exposed to this research during teacher training, a small cohort of teachers intensely interested in cognitive psychology has recently emerged. These teachers are mainly based in the UK, and, anecdotally (e.g., Dennis (2016), personal communication), appear to have taken an interest in the science of learning after reading *Make it Stick* (Brown, Roediger, & McDaniel, 2014; see Clark (2016) for an enthusiastic review of this book on a teacher's blog, and "Learning Scientists" (2016c) for a collection). In addition, a grassroots teacher movement has led to the creation of "researchED" – a series of conferences on evidence-based education (researchED, 2013). The teachers who form part of this network frequently discuss cognitive psychology techniques and their applications to education on social media (mainly Twitter; e.g., Fordham, 2016; Penfound, 2016) and on their blogs, such as Evidence Into Practice (https://evidenceintopractice.wordpress.com/), My Learning Journey (http://reflectionsofmyteaching.blogspot.com/), and The Effortful Educator (https://theeffortfuleducator.com/). In general, the teachers who write about these issues pay careful attention to the relevant literature, often citing some of the work described in this review.

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Photo: iStock

So, how do we learn? Tell us Marcus!

Instructional decisions are and should be based on a mix of theories–trial and error, craft knowledge, and gut instinct.

But which strategies are robust and clear enough to be implemented into classroom practice?

I will give you ***3*** examples!

Strategy 1 – Examples

Strategy 1 – Examples

Strategy 1 – Examples

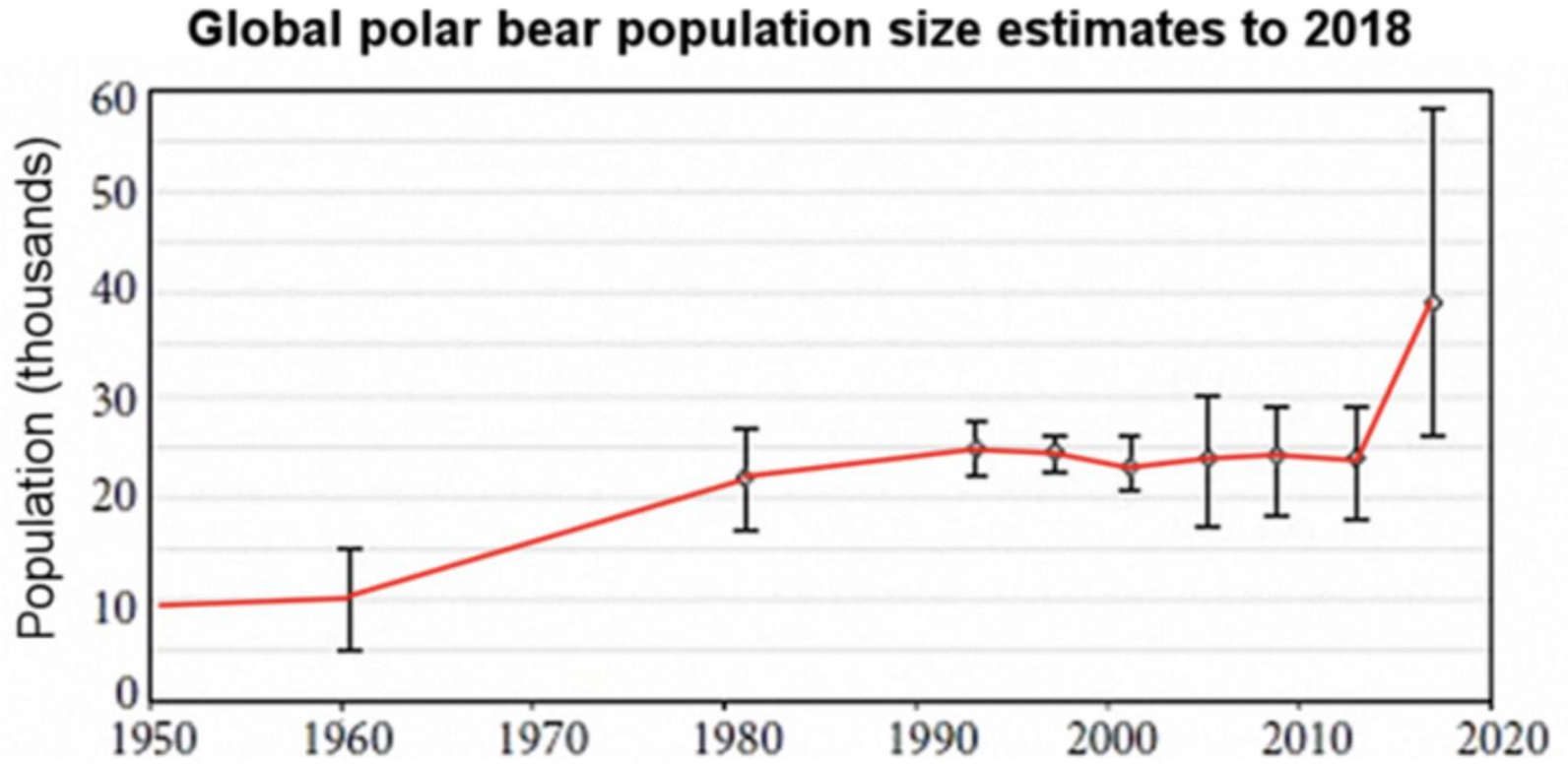


Figure 1. Global polar bear population. Source: Susan J. Crockford, The Polar Bear Catastrophe That Never Happened, Chapter 10 (London, U.K.: The Global Warming Policy Foundation, 2019).

Explanations

Have students explain concepts.

For example, you may say that you know how a zipper works. However, if someone asks you to explain how it works, it may not be as easy to explain.

This type of self-explanation has shown to promote learning and increasing metacognitive accuracy (knowing what you know and don't know).

Strategy 1 – Examples

1. Collect examples and look in your class materials for as many examples as you can find.

2. Ask students to come up with their own examples.. Have students work with each other and explain the examples to each other for added benefits.

3. Make sure your examples are correct.

Rawson, K. A., Thomas, R. C., & Jacoby, L. L. (2014). The power of examples: Illustrative examples enhance conceptual learning of declarative concepts. Educational Psychology Review, 27, 483-504

Strategy 2 – Retrieval Practice

Retrieval practice involves bringing information to mind from memory. For example, when students take practice tests or quizzes.

Use it or lose it!

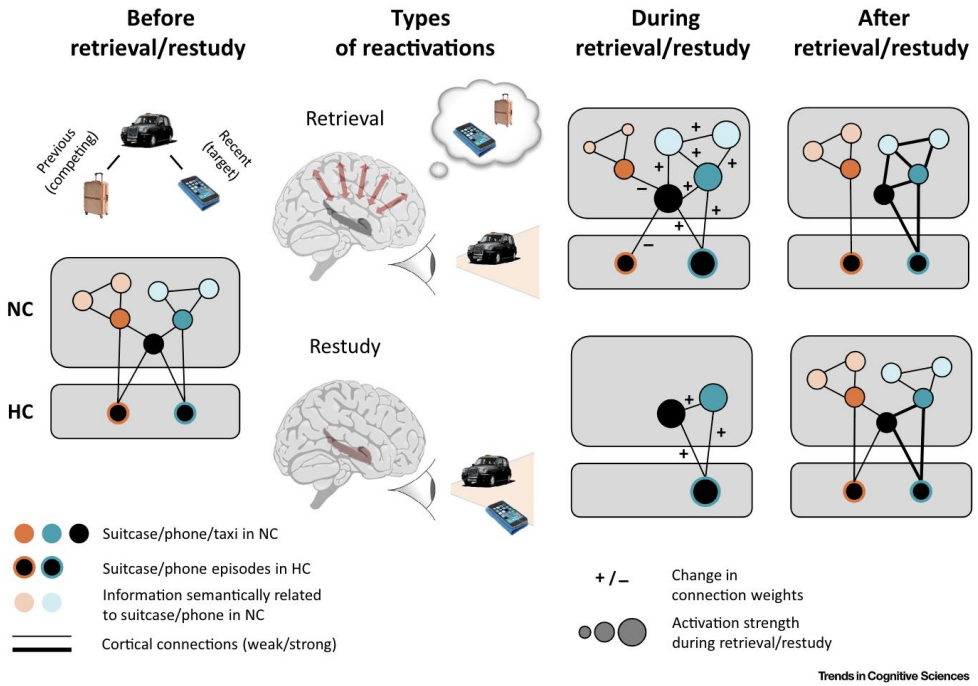
Three components of our memory system:

Encoding – Storage – Retrieval

Effortful processing

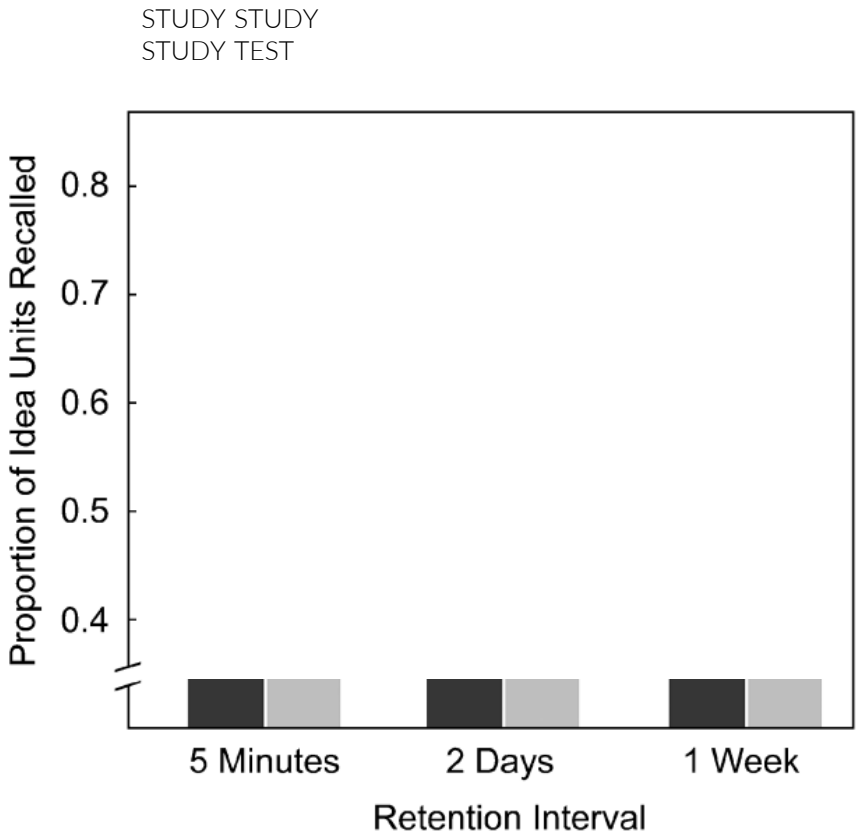
What is Retrieval Practice

- Dissociation between recognition and retrieval
- Tip of the tongue effect
- Rapid memory consolidation



Healy, Jones, Lalchandani, & Tack, 2017, Abel & Bäuml, 2020

What is Retrieval Practice



Roediger III, H. L., & Karpicke, J. D. (2006). The power of testing memory: Basic research and implications for educational practice. Perspectives on psychological science, 1(3), 181-210.

Retrieval Practice and Metacognition

Indirect effect. Knowing what you know and what you don't know.

Helps both students and teachers.

Re-focusing on what needs to be studied further/more

What about multiple choice tests?

As a teacher I would use multiple-choice tests to promote student learning.

Overall, taking a multiple-choice test is an effective way of studying and boosts performance on later tests. Although studying using self-testing can be hard, effortfully processing study material often enhances learning. Practicing retrieval using multiple-choice tests is a good way to study (Marsh, Roediger, Bjork & Bjork 2007).

Also, do you think I would include a multiple-choice test in this course if it wasn't an effective way of learning? :)

Implementing Retrieval Practice

1. Use tests or quizzes that are “low” or “no-stakes”
2. Provide feedback on students’ test performance
3. Allow students to freely produce answers or practice “writing down everything they know”
4. Providing feedback can increase student motivation

Healy, Jones, Lalchandani, & Tack, 2017, Abel & Bäuml, 2020

Implementing Retrieval Practice

5. If possible, use an open-ended question first, then a multiple-choice question.

6. 6. Having students first trying to retrieve information without cues can enhance the “retrieval-effect”. Don’t worry. Using Multiple choice quizzing is also effective.

7. Yes. Students will probably think It’s harder. But remember Effortful processing benefits learning and long-term retention.

Spacing

Why it works:

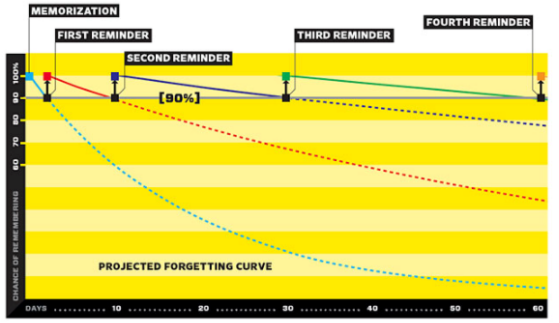
Spacing or spreading out learning session over time improves learning compared to cramming.

Ebbinghaus forgetting curve

Students will learn and retain more information if they study 60 minutes a a day in a week instead of studying for 5 hours all on one day.

How Supermemo Works

SuperMemo is a program that keeps track of discrete bits of information you've learned and want to retain. For example, say you're studying Spanish. Your chance of recalling a given word when you need it declines over time according to a predictable pattern. SuperMemo tracks this so-called forgetting curve and reminds you to rehearse your knowledge when your chance of recalling it has dropped to, say, 90 percent. When you first learn a new vocabulary word, your chance of recalling it will drop quickly. But after SuperMemo reminds you of the word, the rate of forgetting levels out. The program tracks this new decline and waits longer to quiz you the next time.



However, this technique never caught on. The spacing effect is "one of the most remarkable phenomena to emerge from laboratory research on learning," the psychologist Frank Dempster wrote in 1988, at the beginning of a typically sad encomium published in *American Psychologist* under the title "The Spacing Effect: A Case Study in the Failure to Apply the Results of Psychological Research."

From Wired, 2008

Spaced Practice… in Practice

Use multiple low-stake or no-stakes quizzes throughout the course. Low-stake quizzes have shown to better promote learning than graded quizzes.

Help students to space out their studying by splitting up exams in smaller chunks.

Kang, S. H. (2016). Spaced repetition promotes efficient and effective learning: Policy implications for instruction. *Policy Insights from the Behavioral and Brain Sciences*, *3*(1), 12-19.

Spaced Practice in Practice

Use effective strategies when going studying the material.

Don’t go back and just re-read notes or the text book as it may create a fluency/recognition bias.

Why aren’t we using this strategy?

Students are aware that spaced (rather than massed) study benefits learning

Students may feel that massed practice lead to knowing the material well. Student may become overconfident in that they will be able to retrieve the material in the future.

And what about teachers? What do you say?

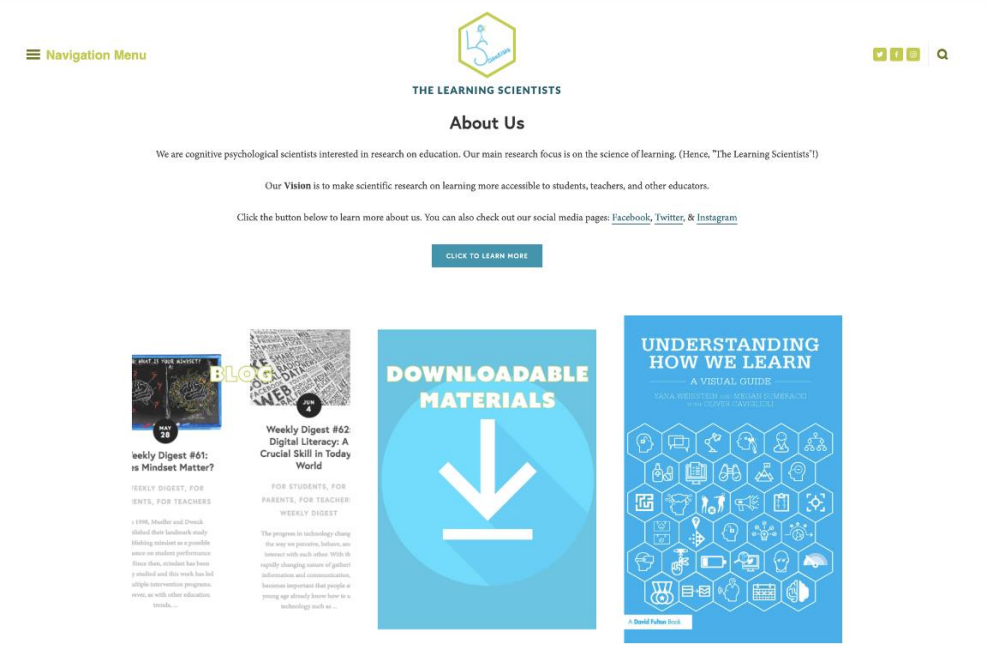
Three “Take away strategies”

1. Use multiple examples when lecturing and give students time to create their own examples
   - Use different examples to explain a general concept, for example solving a math problem in different ways.

2. Include quizzes or use interactive polls
   - If possible, provide feedback
   - Keep assignments “low-stake”

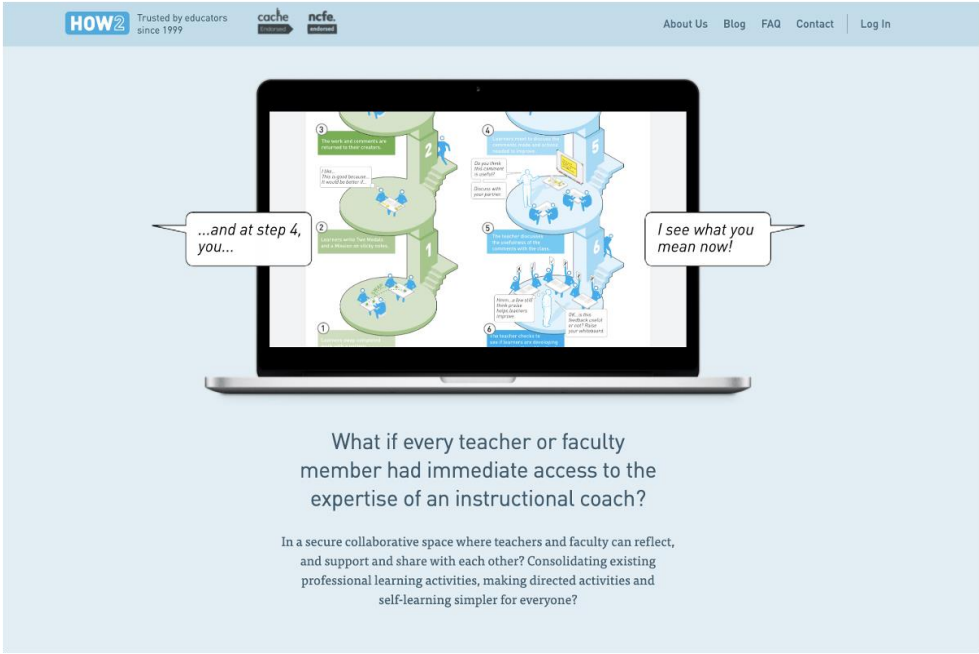
3. Split up assignments/tasks and interleave between topics
   - Return to previous material, and interleave different topics
   - Design the course so students have a chance to practice on previously taught material

Recommended blogs and websites



https://www.learningscientists.org/

Excellent material and blogs on how to apply cognitive science in the classroom.



https://teachinghow2s.com/

Beautiful infographics and excellent summaries of recent findings from cognitive and educational psychology.

The Learning Scientist

THE SCIENCE OF LEARNING

Navigation Menu

THE LEARNING SCIENTISTS

About Us

We are cognitive psychological scientists interested in research on education. Our main research focus is on the science of learning. (Hence, "The Learning Scientists"!)

Our **Vision** is to make scientific research on learning more accessible to students, teachers, and other educators.

Click the button below to learn more about us. You can also check out our social media pages: Facebook, Twitter, & Instagram

CLICK TO LEARN MORE

BLOG

MAY 28

Weekly Digest #61: ...s Mindset Matter?

...EEKLY DIGEST, FOR ...ENTS, FOR TEACHERS

...1998, Mueller and Dweck ...blished their landmark study ...blishing mindset as a possible ...ence on student performance ...Since then, mindset has been ...y studied and this work has led ...ultiple intervention programs. ...ever, as with other education trends, ...

JUN 4

Weekly Digest #62: Digital Literacy: A Crucial Skill in Today World

FOR STUDENTS, FOR PARENTS, FOR TEACHERS WEEKLY DIGEST

The progress in technology chang... the way we perceive, behave, an... interact with each other. With th... rapidly changing nature of gatheri... information and communication, ... becomes important that people a... young age already know how to u... technology such as ...

DOWNLOADABLE MATERIALS

UNDERSTANDI... HOW WE LEA...

A VISUAL GUIDE

YANA WEINSTEIN AND MEGAN SP... WITH OLIVER CAVIGLIOL...

A David Fulton Book

PERVASIVE MISUNDERSTANDINGS ABOUT LEARNIN... CHAPTER 1 2 3

Rank	Misunderstanding	% who believe it
1	Individuals learn better when they receive information in their preferred learning style (e.g., auditory, visual, kinesthetic)	93%
2	Environments that are rich in stimuli improve the brains of pre-school children	89%
3	Short bouts of coordination exercises can improve integration of left and right hemisphere brain function	76%
4	Exercises that rehearse coordination of motor-perception skills can improve literacy skills	74%
5	Differences in hemispheric dominance (left brain, right brain) can help explain individual differences among learners.	74%
6	It has been scientifically proven that fatty acid supplements (omega-3 and omega-6) have a positive effect on academic achievement	61%
7	Emotional brain processes interrupt those brain processes involved with reasoning	60%
8	We only use 10% of our brain	49%
9	Memory is stored in the brain much like as in a computer: each memory goes into a tiny piece of the brain	48%
10	Children are less attentive after consuming sugary drinks and/or snacks	47%

The data in this table have been aggregated from the following studies: Deligiannidi and Howard-Jones (2015); Dekker, Lee, Howard-Jones, and Jolles (2012); Dündar and Gündüz (2016); Ferrero, Garaizia, and Vadillo (2016); Gleichgerrcht, Luttges, Salvarezza, and Campos (2015); Herculano-Houzel (2002); Hermida, Segretin, Soni García, and Lipina (2016); Macdonald, Germine, Anderson, Christodoulou, and McGrath (2017); Karakus, Howard-Jones, and Jay (2015); Papadatou-Pastou, Haliou, and Vlachos, (2017); and Pei, Howard-Jones, Zhang, Liu, & Jin (2015). Note that not all of the studies mentioned included each statement.

Shannon Rowley & Marcus Lithander

1) "ENVIRONMENTS THAT ARE RICH IN STIMULI IMPROVE THE BRAINS OF PRE-SCHOOL CHILDREN"

This belief describes the idea that young children should be exposed to many interesting things to see and explore, and often manifests itself as gaudy, "visually noisy" classrooms (Erickson, 2017).

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THE SCIENCE OF LEARNING

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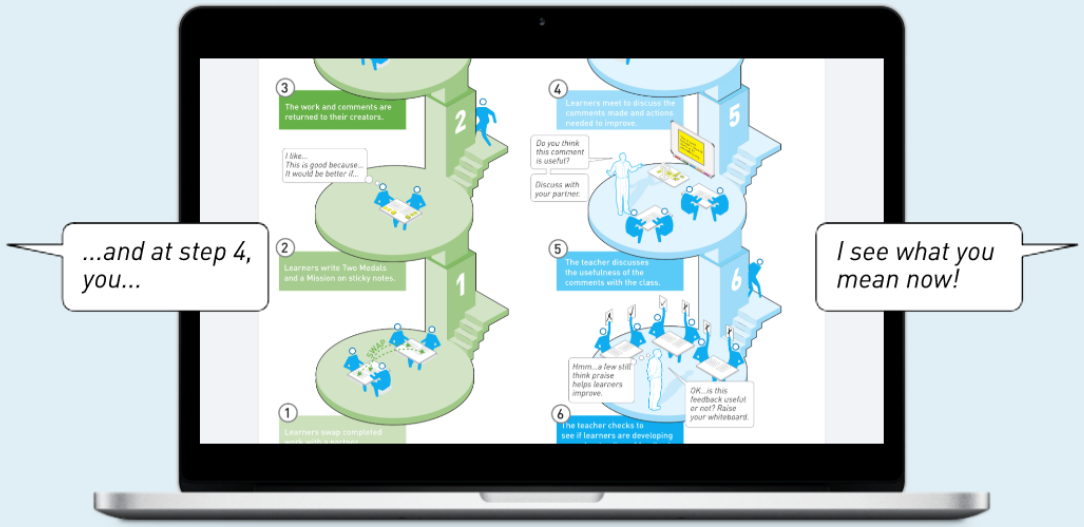

What if every teacher or faculty member had immediate access to the expertise of an instructional coach?

In a secure collaborative space where teachers and faculty can reflect, and support and share with each other? Consolidating existing professional learning activities, making directed activities and self-learning simpler for everyone?

What works?

THE SCIENCE OF LEARNING

Weinstein et al. Cognitive Research: Principles and Implications (2018) 3:2
DOI 10.1186/s41235-017-0087-y

Cognitive Research: Principles and Implications

TUTORIAL REVIEW Open Access

Teaching the science of learning

Yana Weinstein[1*], Christopher R. Madan[2,3] and Megan A. Sumeracki[4]

Abstract

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Significance

Education does not currently adhere to the medical model of evidence-based practice (Roediger, 2013). However, over the past few decades, our field has made significant advances in applying cognitive processes to education. From this work, specific recommendations can be made for students to maximize their learning efficiency (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger, Finn, & Weinstein, 2012). In particular, a review published 10 years ago identified a limited number of study techniques that have received solid evidence from multiple replications testing their effectiveness in and out of the classroom (Pashler et al., 2007). A recent textbook analysis (Pomerance, Greenberg, & Walsh, 2016) took the six key learning strategies from this report by Pashler and colleagues, and found that very few teacher-training textbooks cover any of these six principles – and none cover them all, suggesting that these strategies are not systematically making their way into the classroom. This is the case in spite of multiple recent academic (e.g., Dunlosky et al., 2013) and general audience (e.g., Dunlosky, 2013) publications about these strategies. In this tutorial review, we present the basic science behind each of these six key principles, along with more recent research on their effectiveness in live classrooms, and suggest ideas for pedagogical implementation. The target audience of this review is (a) educators who might be interested in integrating the strategies into their teaching practice, (b) science of learning researchers who are looking for open questions to help determine future research priorities, and (c) researchers in other subfields who are interested in the ways that principles from cognitive psychology have been applied to education.

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Lessons for learning:

How cognitive psychology informs classroom practice

Laboratory science and classroom observation reveal four simple strategies that can promote learning.

by **Pooja K. Agarwal and Henry L. Roediger, III**

Because learning is an incredibly complex behavior, the science of learning includes many topics: how we learn and remember information in school, how we learn from the environment around us, how our actions influence what we remember, and so on. With this in mind, it's useful to think of *learning science* as an umbrella term that spans many research fields including psychology, computer science, and neuroscience. Our own research sits in the field of cognitive science or, more specifically, cognitive psychology. The word *cognition* comes from the Latin word for "to know," and cognition refers to "behind-the-scenes" behaviors like perceiving, attending, remembering, thinking, and decision making. In cognitive psychology, we typically examine mental operations, or behaviors occurring *inside* our heads.

Cognitive psychology examines processes we engage in every day without stopping to reflect on the complex series of behaviors that determine our success or failure. For example, have you ever talked on a cell phone while driving a car? Many complex cognitive operations are involved in both of these activities (and there's plenty of research demonstrating it's dangerous to attempt both at once!). Another example: You meet someone at a party and later you remember details about your new friend — where they live, where they work, and so on — but you struggle to remember their name.

POOJA K. AGARWAL (pooja@poojaagarwal.com) is an assistant professor at the Berklee College of Music in Boston, an adjunct professor at Vanderbilt University in Nashville, and founder of RetrievalPractice.org, a hub of resources for teachers based on the science of learning. Her upcoming book, coauthored with Patrice M. Bain, a veteran K-12 teacher, is *Powerful Teaching: Unleash the Science of Learning* (Jossey-Bass, Spring 2019). **HENRY L. ROEDIGER, III** (roediger@wustl.edu) is the James S. McDonnell Distinguished University Professor at Washington University in St. Louis. His most recent book, coauthored with Peter Brown and Mark McDaniel, is *Make it Stick: The Science of Successful Learning* (Harvard University Press, 2014).

Photo: iStock

...that teachers could coach students to use without sacrificing ... student could use. We excluded

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Psychological Science in the Public Interest
14(1) 4–58

DOI: 10.1177/1529100612453266
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Improving Students' Learning With Effective Learning Techniques: Promising Directions From Cognitive and Educational Psychology

John Dunlosky[1], Katherine A. Rawson[1], Elizabeth J. Marsh[2], Mitchell J. Nathan[3], and Daniel T. Willingham[4]
[1]Department of Psychology, Kent State University; [2]Department of Psychology and Neuroscience, Duke University; [3]Department of Educational Psychology, Department of Curriculum & Instruction, and Department of Psychology, University of Wisconsin–Madison; and [4]Department of Psychology, University of Virginia

Summary

Many students are being left behind by an educational system that some people believe is in crisis. Improving educational outcomes will require efforts on many fronts, but a central premise of this monograph is that one part of a solution involves helping students to better regulate their learning through the use of effective learning techniques. Fortunately, cognitive and educational psychologists have been developing and evaluating easy-to-use learning techniques that could help students achieve their learning goals. In this monograph, we discuss 10 learning techniques in detail and offer recommendations about their relative utility. We selected techniques that were expected to be relatively easy to use and hence could be adopted by many students. Also, some techniques (e.g., highlighting and rereading) were selected because students report relying heavily on them, which makes it especially important to examine how well they work. The techniques include elaborative interrogation, self-explanation, summarization, highlighting (or underlining), the keyword mnemonic, imagery use for text learning, rereading, practice testing, distributed practice, and interleaved practice.

To offer recommendations about the relative utility of these techniques, we evaluated whether their benefits generalize across four categories of variables: learning conditions, student characteristics, materials, and criterion tasks. Learning conditions include aspects of the learning environment in which the technique is implemented, such as whether a student studies alone or with a group. Student characteristics include variables such as age, ability, and level of prior knowledge. Materials vary from simple concepts to mathematical problems to complicated science texts. Criterion tasks include different outcome measures that are relevant to student achievement, such as those tapping memory, problem solving, and comprehension.

We attempted to provide thorough reviews for each technique, so this monograph is rather lengthy. However, we also wrote the monograph in a modular fashion, so it is easy to use. In particular, each review is divided into the following sections:

1. General description of the technique and why it should work
2. How general are the effects of this technique?
   2a. Learning conditions
   2b. Student characteristics
   2c. Materials
   2d. Criterion tasks
3. Effects in representative educational contexts
4. Issues for implementation
5. Overall assessment

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Question 1

As a teacher I would switch and interleave between different types of problems and topics to promote as it can promote student learning.

Question 1 - Feedback

As a teacher I would switch and interleave between different types of problems and topics to promote as it can promote student learning.

Interleaving or switching between topics while studying or teaching is beneficial for learning. Switching between different ideas will help make links between concepts to strengthen understanding of information and is helpful for the learning process (Rohrer, 2012).

Question 2

As a teacher I would include extra time for students to reread the textbook before final exams as it can help students to become aware of what they know and don’t know (enhance metacognitive accuracy).

Feedback Question 2

As a teacher I would include extra time for students to reread the textbook before final exams as it can help students to become aware of what they know and don't know (enhance metacognitive accuracy).

Students can learn more by rereading, however, rereading is not a very effective way of studying. Also, when rereading notes, students may become familiar with the text, a familiarity that often creates an illusion of fluency. Therefore, rereading can lead people to wrongly believe they can recall the material without notes (Dunlosky et al., 2013).

Question 3

As a teacher I would match may teaching to students preferred learning styles (e.g., auditory, visual, kinesthetic) as it can promote student learning.

Feedback Question 3

As a teacher I would match may teaching to students preferred learning styles (e.g., auditory, visual, kinesthetic) as it can promote student learning.

Although the concept of learning styles is widespread, individuals do not learn better when they receive information in their preferred learning style. It is true that students have personal preferences for different ways of learning, however, the matching hypothesis of learning styles does not hold up. For example, students classified as "auditory learners" do not learn better by studying auditory material compared to visual material (see Pashler et al., 2008).

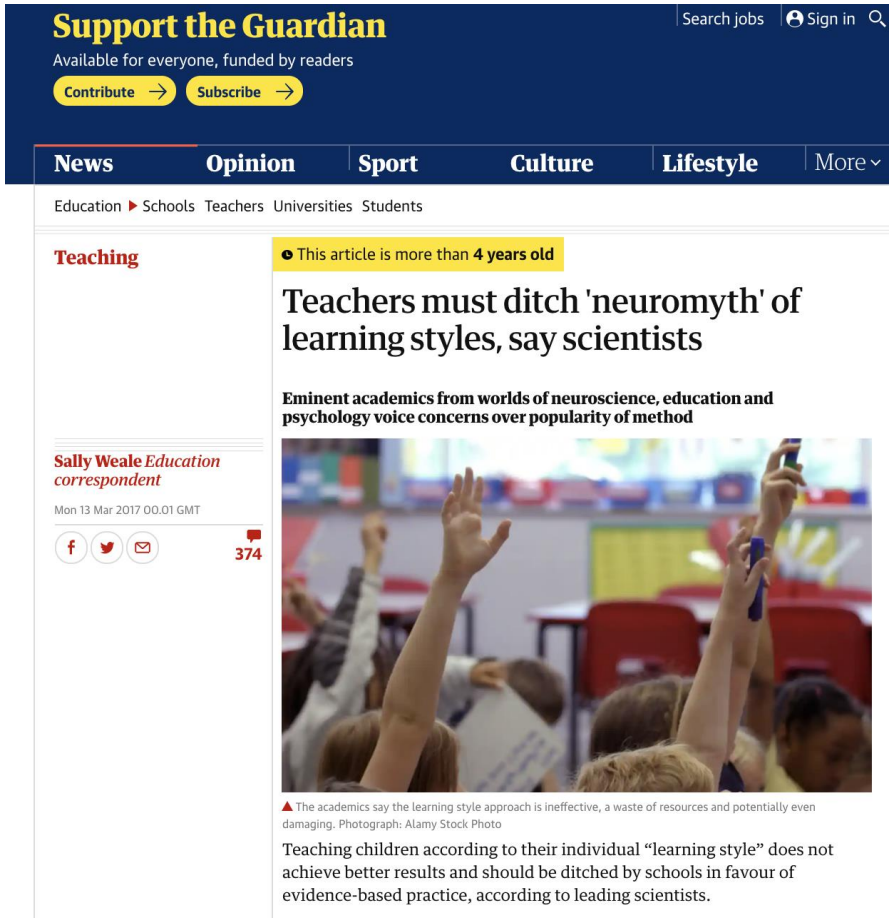
More about Learning Styles

All students are all different.

Different students have different pre-knowledge about different areas/topics.

However, so far, there is no empirical evidence for that *matching* teaching towards students preferred learning style promotes learning.

I added links to three excellent papers about learning styles below and in the comments.



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Teaching

This article is more than 4 years old

Teachers must ditch 'neuromyth' of learning styles, say scientists

Eminent academics from worlds of neuroscience, education and psychology voice concerns over popularity of method

Sally Weale *Education correspondent*

Mon 13 Mar 2017 00.01 GMT

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▲ The academics say the learning style approach is ineffective, a waste of resources and potentially even damaging. Photograph: Alamy Stock Photo

Teaching children according to their individual "learning style" does not achieve better results and should be ditched by schools in favour of evidence-based practice, according to leading scientists.

More about neuromyths in comments

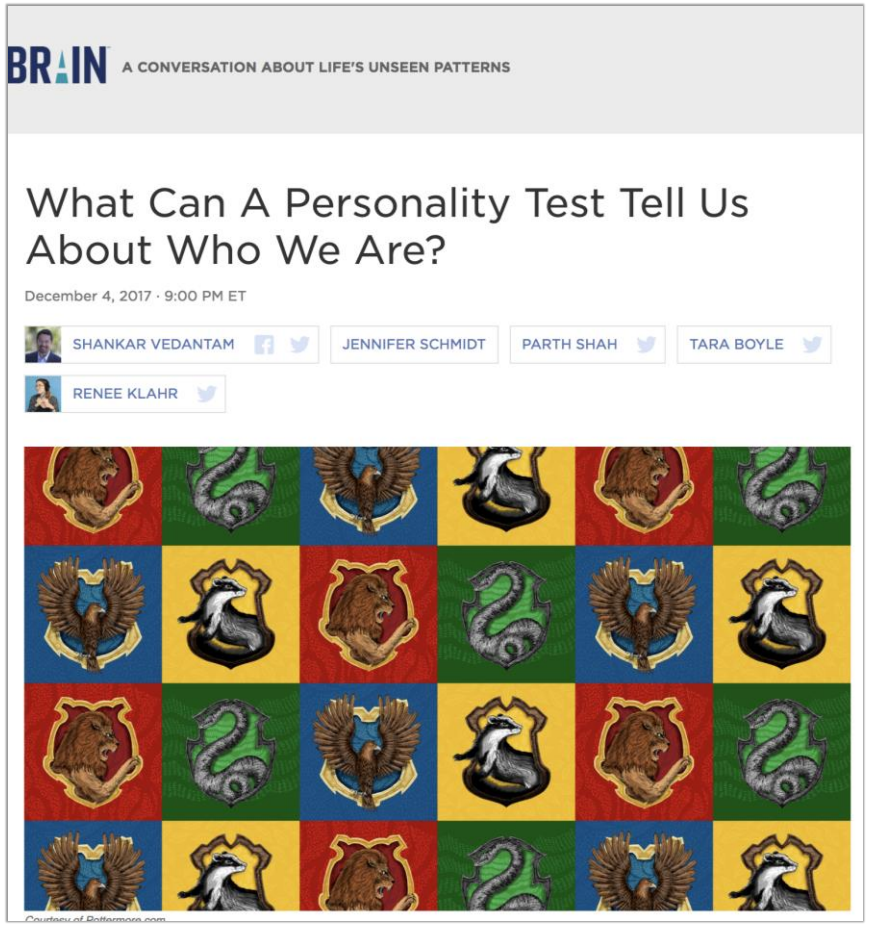
Student beliefs and Self-fulfilling prophecies

Categorization of students may lead to self-stereotypization and self-fulfilling prophesies.

Gender stereotypization in mathematics' for example.

Jane Elliott's "Blue eyes/Brown eyes" exercise is a good example of how stereotypization can affect learning.

Important! Multi modal learning can be beneficial. For everyone!



The Eye of the Storm (1970), A Class Divided (1985)

Break out Session 1

- How could you implement retrieval practice? In your field/topic?
  - Provide one concrete example
- What downsides/problems could you see in implementing retrieval practice?
- Is there a barrier or a problem in implementing Retrieval Practice?
  - E.g., time, resources, technology, priorities etc.