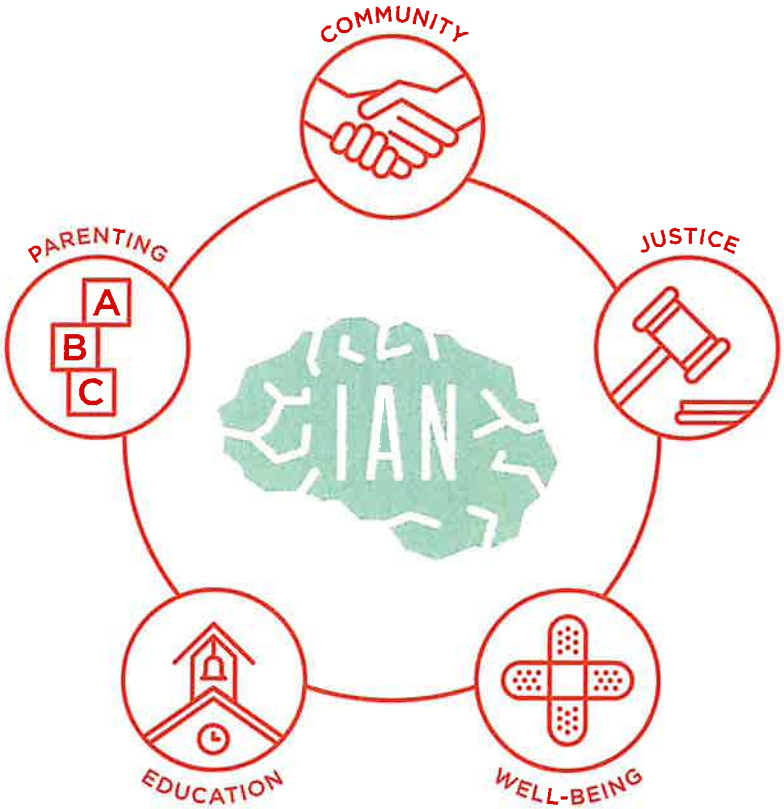
INSTITUTE FOR APPLIED NEUROSCIENCE

BRAIN SCIENCE FOR GOOD



SCIENCE OF LEARNING WORKSHOP GUIDE

WHAT DO WE KNOW ABOUT HOW THE BRAIN LEARNS?

It turns out, a LOT. There are thousands of research studies that have looked into how the brain learns best. We will discuss many of them in our Science of Learning bootcamp, along with how they might be applied to your classroom practice *today*. This guide will help you carry these discussions and practices back into your classroom so you may design your own education innovations based on science of learning principles. In this way, we hope to empower you to generate your own education innovations. Our approach is not prescriptive, but rather generative, because we recognize *how much you know* about how students learn. You are the front-lines of innovation, with boots on the ground studying how students learn in real-world environments.

While many current education initiatives encourage *student agency*, **we also believe in the power of EDUCATOR AGENCY**. This guide is designed to support you in transforming what you know and amplifying it with the science of learning to create teaching and learning practices you can test in the lab of your classroom!

Thousands of studies investigating the neuroscience, cognitive science, and behavioral science of learning have revealed insights into how the brain learns. Bi-directional dialog between researchers and educators can help us refine how to apply these insights into education innovations.

"Somewhere, something incredible is waiting to be known."

- Carl Sagan

20 INSIGHTS

INSIGHTS FROM THE SCIENCE OF LEARNING

There are many myths of learning and the brain that are perpetuated in popular culture. Here we myth-bust and reframe some of the most common myths based on current research.

1. **We use 100% of our brain, 100% of the time!** *We DON'T only use 10% of our brain!*
2. **Students are whole-brain learners,** *NOT left-brained or right-brained learners!*
3. **There is no evidence that students learn best visually, auditorily, or kinesthetically**. *Rather, a better way to think about how students learn differently is to understand how they MAKE MEANING out of the material*
4. **Students' brains stay teachable (plastic) throughout life, with a second window of plasticity in adolescence.** *The first 3 years of a child's life are important, but do not determine their ultimate success. Don't give up on them! Likewise, adolescence is a second window of opportunity (and vulnerability)*
5. **Highly decorated classrooms may be distracting from learning.** *Be mindful of the amount and type of info you place on classroom walls; use to cue retrieval of learnings*
6. **Sunlight or short wavelength light is good for learning.** *Blue LED or full spectrum bulbs do the trick too! They tell the hypothalamus that it is time to be alert!*
7. **Nature and views of nature are good for learning.** *Even simulated views of nature can improve focus*
8. **Sleep is good for learning.** *Sleep is like putting jello in the refridgerator, it 'consolidates' learning and makes it stronger*
9. **Glucose is good for learning.** *The brain is by far the biggest consumer of glucose in the body. Glucose comes from starches*
10. **Exercise is good for learning.** *Aerobic exercise stimulates growth factors that make learning stronger, and increases size of the hippocampus (a brain structure critical for learning)*
11. **Students who multitask heavily with media tend to be BAD at multitasking.** *They also tend to be more distractible and have poorer memory. But we don't yet know if it's the media multitasking that is CAUSING the cognitive differences, or vice versa*
12. **Kids who play action video games are learning-to-learn**. *They seem to pick up patterns better, so encourage students to recognize patterns in their learning material*
13. **Autism is caused by differences in the 'social brain'**, *NOT vaccines!*
14. **Boys are NOT inherently better at math than girls.** *Gender gap appears due to cultural beliefs about ability and NOT biology; girls perform better in countries where gender equality is higher*
15. **Learning physically changes the brain.** *Learning strengthens connections between neurons*
16. **Praise the effort, not the person.** *'Growth mindset' can be cultivated by praising a student for their hard work, trying of new strategies, and using failure as fodder for learning*
17. **Ask students to answer questions before teaching the lesson.** *Will boost learning, even if they get the answer WRONG! Builds a scaffold for learning*
18. **Teaching kids delayed gratification/self-regulation leads to better academic and life outcomes.**
19. **Stress can help learning.** *A healthy 'stress mindset' can change how you respond to stress*
20. **Peer tutoring benefits the TUTOR most.** *Encourage struggling students to be the TUTOR, not the tutee*

10 KEY PRACTICES

PRACTICAL APPLICATIONS OF SCIENCE OF LEARNING

Research findings are converging to identify many practices that inform an evidence-based understanding of how the brain learns and functions. **Use these as guiding principles to generate your own education innovations**. And don't forget to use your life as your lab! Test how well these work for you and your students.

1. **Don't make learning as easy! ('Desirable Difficulties')** *When learning is easy, it is soon forgotten. One of the best ways to foster long-lasting learning is to make it a little difficult for your students. It may seem frustrating at first, but it carves deep pathways in the brain for long-lasting learning.*

2. **Retrieval strengthens learning. ('Retrieval Practice')** *Anything that asks the student to practice remembering the information (like self-testing and low-stakes quizzing) actually changes the nature of the memory, strengthening the path to memory and enriching the memory itself. Both lead to stronger and more enduring learning.*

3. **Spacing out learning strengthens learning. ('Spaced Practice')** *The same amount of learning, spaced over time, can dramatically improve learning and retention. A relatively small shift in strategy that can lead to big learning gains.*

4. **Don't suppress the social brain--use it! ('Social Learning')** *Students are highly tuned to social dynamics, and the 'social brain' is a powerful learning asset. Teach content with social narratives in mind, and utilize the power of learning-to-teach (even if the students don't end up teaching the material, they will learn it better!).*

5. **Teach with the end in mind. ('Interleaved Learning')** *If you want your student to be able to flexibly access the learning in unpredictable environments, teach them to retrieve it in unpredictable environments! To do so, interleave different learning topics and practice retrieving in an interleaved way.*

6. **Reframe failure. ('Failure as Fodder')** *When students see failture as an opportunity to find out what they don't know in order to adjust their learning strategies (like they do in video games) rather than seeing failure as an indication of self-worth, they are more likely to perservere in the learning task.*

7. **Keep them at the edge of their mastery. ('Leveling-Up')** *A form of desirable difficulty, and consistent with principles of game design, the ability to find the edge of their mastery so they can surpass their current level of ability engages the brain deeply and builds strong memories.*

8. **Be transparent about why difficulties are necessary. ('Learning Mindset')** *Framing desirable difficulties as a way to grow your students' brains can promote 'growth mindset', and foster a healthy 'stress mindset'.*

9. **Don't forget about exercise, sleep, and music! ('Non-cognitive Support')** *Aerobic exercise can increase a growth factor ('BDNF') that improves the brain's plasticity for at least a short while, and increases hippocampal volume (a key part of the brain that allows us to learn new information). Sleep is critical for consolidating (solidifying) learning from the day (so put some sleep between learning and the test!). Musical training has been shown to increase attention abilities, reduce the impact of distraction, and increase verbal and nonverbal skills.*

10. **Ineffective learning techniques: Highlighting and Re-reading.** *While these are the most popular study techniques, they are very ineffective, fostering only short-term learning. Students get trapped in the myth of fluency, where they feel fluent with the information in the short term, but cannot access it later.*

THE INSIGHTS, IN PRACTICE

In the following sections, we dive more deeply into the science behind each practice, and give examples of how you may use them in your classroom today.

DON'T MAKE LEARNING AS EASY

DESIRABLE DIFFICULTIES, PRODUCTIVE STRUGGLE

INSIGHT

When learning is easy, it is often forgotten easily. One of the best ways to foster long-lasting learning is to make it a little difficult for your students to learn the information. The more effort required, the more the brain is engaged, and the better your students will learn the information.

We are actually quite poor at judging how deeply we are learning material, and therefore tend to use practices that feel fruitful but in fact only lead to temporary learning (the 'myth of fluency'). Making learning a little more difficult may seem frustrating at first, but it carves deep pathways in the brain for long-lasting learning.

IN PRACTICE

- Instead of trying to teach students in their preferred 'learning style' (which we know is not supported by empirical research), it's more helpful to challenge them to learn in many different ways, drawing on their many abilities. This can increase the challenge of learning and engage the brain more robustly, leading to more enduring learning.
- We learned that practicing retrieving what you've learned is one of the best ways to strengthen learning (see more in next section), but don't make it too easy! Allow some forgetting to happen before practicing retrieval, to deepen learning. In other words, don't practice retrieving the same thing 10x in rapid-fire because little effort is required to do this, and thus very little long-term benefit will accrue. Instead, practice retrieving many times over a few days, weeks, or months. You'll get much more bang for your buck.

YOUR TURN

What are some other ways you could use the principle of **Desirable Difficulties** or **Productive Struggle** in your teaching practice?

RETRIEVING STRENGTHENS LEARNING

INSIGHT

Anything that asks the student to practice remembering the learned information, like self-testing and low-stakes quizzing, not only deepens learning, but actually **changes the nature of the memory**. Retrieval practice strengthens the path to the memory and enriches the memory itself. Both lead to stronger learning.

The key insight here is that the expression of learning is the ability to access the learned information later, when the students need it (during the test and in real-life). The more often they practice retrieving the information (but only after it's been forgotten a bit; see Key Practice #1), the more pathways they build to the memory. Thus, the more likely they will be to find the memory later, when they need it. In parallel, the process of retrieving the memory actually changes the memory itself, strengthening neural connections within the memory. Stronger connections result in more enduring memory.

IN PRACTICE

- Self-testing. Flashcards and self-quizzing are some of the best study habits around. Flashcards aren't restricted to rote memorization of facts only, but could also be used to cue the student to retrieve and elaborate on deeper concepts. The important things about self-testing are to (1) allow some forgetting to happen between testings, and (2) use self-tests to assess what knowledge is not easily retrieved, to flag for more retrieval practice. And continue to self-test in regular intervals to interrupt forgetting and add more consolidation. Also, pausing during studying of notes or textbooks to test on key ideas is another powerful way to practice retrieval.
- Low-stakes quizzing. There are several ways to leverage the benefits of quizzing while making amenable to both teachers and students: make quizzes low-stakes, predictable (not pop quizzes), simple and quick with no negotiating make-ups. Asking students to generate questions for quizzes can be doubly beneficial!

YOUR TURN

What are some other ways you could use the principle of **Retrieval Practice** in your teaching practice?

SPACING OUT LEARNING STRENGTHENS LEARNING

SPACED PRACTICE

INSIGHT

The same amount of learning, spaced over time, can dramatically improve learning and retention. Decades of research shows that if students spread out their learning over multiple sessions, rather than cramming into a short study session, they can remember the information better. While cramming may lead to better short-term gains, if we want students to remember the information in an enduring way, we can encourage ways to distribute the learning over time, returning to it periodically.

Spaced practice allows the learned information to 'consolidate' or solidify in the brain. Then when the student returns to learning the information again, after a bit of time, he or she will be practicing retrieval of what they learned before (thus engaging the principle of Retrieval Practice, and strengthening the routes to memory as well as enriching the nature of the memory).

IN PRACTICE

- Break up the teaching of concepts over multiple classes, reloading the key concepts during subsequent sessions.
- Reach back to prior concepts when you teach new ones. This confers the benefits of retrieval practice, and allows a richer scaffold of learning to develop over time. Building a scaffold to hang new information on fosters more enduring memory than building new scaffolding each time.
- Encourage your students to break up their studying of a topic into multiple days/weeks, studying the information more than once, and allowing a good amount of time in between study sessions.

YOUR TURN

What are some other ways you could use the principle of **Spaced Practice** in your teaching practice?

DON'T SUPPRESS THE SOCIAL BRAIN--USE IT!

INSIGHT

Students are highly attuned to social dynamics, and the 'social brain' is one of the most powerful learning assets at our disposal. Teaching content with social narratives in mind, and utilizing the power of learning-to-teach (even if the students don't end up teaching the material, they learn it better!) are both powerful ways to harness the social brain.

Students' academic engagement decreases from elementary school to middle and high school, with a concomitant increase in social engagement. Because social motivations dramatically increase during middle and high school, the basic needs of reducing social pain and experiencing social connection can interfere with learning, if unmet. Rather than asking students to ignore the social world and focus on learning, we can take advantage of the special attention that middle and high school students pay to social environments. The social brain has evolved as a powerful learning tool to help us navigate our survival within the tribe. We can leverage this often untapped but powerful learning tool in our teaching and learning practices.

IN PRACTICE

- Adolescents' attention is highly attuned to the social world, and what they want to learn about is the social world. Instead of making this social orientation the enemy, we can use it in service of our learning goals.
- Social encoding advantage. Asking students to 'mentalize' or take the perspective of the people you are teaching about, confers deeper learning than rote memorization. Using a social narrative thread for your material can promote this benefit.
- Learning-to-teach. Preparing to teach is a powerful way to engage the social brain, whether or not the student ends up teaching the material! It often benefits the tutor more, so the lower performing student is better as the tutor rather than tutee.

YOUR TURN

What are some other ways you could use the principle of **Social Learning** in your teaching practice?

TEACH WITH THE END IN MIND

INTERLEAVED LEARNING

INSIGHT

If you want your students to be able to flexibly access their learning in unpredictable environments (e.g., the real world), teach them to retrieve the learning in unpredictable environments! To do this, interleave different learning topics.

Remember the study of baseball players, showing that players who practiced hitting three types of pitches in a random, interleaved way showed better batting averages during real-world games than their peers who got the same amount of practice, but in a blocked way. This may be because during a real game, the batters have to not only figure out how to hit the ball but also which type of pitch they are getting. This suggests we may want to **give our students practice learning and retrieving that learning in the way they will need to in the real world**, in a way that is interleaved with all the other information they have learned. This allows them to figure out what information they need in unpredictable environments.

IN PRACTICE

- A form of desirable difficulty, interleaving two or more study topics can feel frustratingly slow, like you are switching to another topic before you can gain mastery of the first. But as we learned with the first principle of Productive Struggle, because the learning and retrieval is harder, the effort produces more durable learning and allows the learning to be accessed more flexibly in later situations.
- Interleaved learning can feel frustrating to students as well as teachers, so play around/test the strategies that work for you and your classes. Perhaps start with similarly themed subjects, like teaching different artists' painting styles in an interleaved way.

YOUR TURN

What are some other ways you could use the principle of **Interleaved Learning** in your teaching practice?

REFRAME FAILURE

FAILURE AS FODDER, GROWTH MINDSET

INSIGHT

When students see failture as an opportunity to find out what they don't know in order to adjust their learning strategies (like they do in video games) rather than seeing failure as an indication of self-worth, they are more likely to perservere in the learning tasks.

Many people learn that their intellectual ability is fixed or hardwired, and that failure indicates that they are not 'built' to be able to do the thing they failed at. This 'fixed mindset' is particularly damaging when students are building their narratives about the type of learner they are: *I'm not a math person, I'm a D student.*

Researchers have revealed that intellectual ability is not actually hardwired, but rather can be improved with effort. A key understanding is for teachers and students alike to see 'failure' as a badge of effort instead of an indictment of poor ability. An important education innnovation will be to reframe how our culture views failure, celebrating it for the powerful learning tool it is. A great reframe is that 'failure' is actually iteration: a way to gather data about what you still need to learn. Students understand this in the context of video games.

IN PRACTICE

- Create a culture that celebrates failure. Silicon Valley celebrates the 'lean start-up' model of entrepeneurship, whose mantra is Fail Fast, Fail Often. This simply reflects the idea that learning requires iteration, and success requires a change in learning strategy based on what is still unknown. This model is actually quite appropriate for learning.
- Some great in-class discussion questions that help facilitate reframing failure as fodder: *Have you ever felt proud of making a mistake? How do you feel when you make a mistake? Have you ever discovered something new after making a mistake?*

YOUR TURN

What are some other ways you could use the principle of **Failure as Fodder/Growth Mindset** in your teaching practice?

KEEP STUDENTS AT THE EDGE OF THEIR MASTERY

LEVELING UP

INSIGHT

A form of Desirable Difficulty, and consistent with principles of video game design, the ability to find the edge and surpass a student's current level of ability engages the brain deeply and builds strong memories.

One of the more important aspects of this insight is that deep learning is highly dependent on motivation and engagement. Engagement is something that video games are quite skilled at architecting. They keep the player in that sweet spot between not-too-hard that the player bails out, and not-too-easy that the player is bored.

But it is not just motivation that makes leveling-up a key aspect of learning. By keeping students at the edge of their ability, we can make learning a little more challenging, which we know engages their brain in a deeper way and strengthens learning.

IN PRACTICE

- Getting students excited about being at the edge of their ability can be a tricky thing. They seem used to it in video games, but not necessarily in the classroom. Creating an environment where failure is fodder (see prior principle) will go far toward supporting students feeling the freedom and safety to fail forward and fast.
- It's often hard to assess the limits of each student's ability, so this is where it is important to enlist your students to be masters of their own advancement. Encouraging students to introspect and self-quiz about where they might be at the edge of their current level of ability will reduce the burden on you as a teacher to personalize your students' learning trajectories.

YOUR TURN

What are some other ways you could use the principle of **Leveling Up** in your teaching practice?

BE TRANSPARENT ABOUT WHY DIFFICULTIES ARE DESIRABLE

INSIGHT

Framing Desirable Difficulties as a way to grow your students' brains can promote 'growth mindset', and foster a healthy 'stress mindset'.

Being explicit with your students about (1) the ways you are including Desirable Difficulties in your teaching practices, and (2) that the challenges are intended to help your students grow their brain, helps frame why the extra effort is important. An important insight from the growth mindset interventions was that they were short-lived without the framing that the brain grows with effort.

Likewise, a healthy 'stress mindset' can reframe stressful challenges as opportunities to mobilize energy, learn and grow, and communicate that everyone experiences stress. Remember the example of the fisheries: the introduction of a natural predator *increased* the health and robustness of the fish!

IN PRACTICE

- Be up-front about some of the frustrations that come with Productive Struggle/Desirable Difficulties, and explain how the struggles are beneficial for learning. Teach students how learning works (encoding, consolidation, and retrieval) so they can understand the many ways that Desirable Difficulties support deep learning, and so they can be empowered to have agency over their learning process.
- A reframe that students tend to appreciate and understand relates to video games. They understand that struggling in video games is necessary to explore the game space and understand the rules and insights of the game. Use this as a lens to view academic challenges: ask students to think about how problem-solving in class and during study is like playing a video game?

YOUR TURN

What are some other ways you could use the principle of **Learning Mindset** in your teaching practice?

DON'T FORGET ABOUT EXERCISE, SLEEP, AND MUSIC!

INSIGHT

Aerobic exercise can increase a neurotrophic factor ('BDNF') that improves the brain's plasticity for at least a short while, and increases hippocampal volume (a key part of the brain that allows us to learn new information). This means that the brain can learn more easily following exercise.

A good night's sleep is not just restful, allowing our students to stay alert in class, but also sleep directly improves memory. Sleep is critical for solidifying learning from the day. Sufficient sleep is one of the biggest factors that supports learning.

Musical training is beneficial for learning in many ways. It has been shown to increase attention abilities, reduce the impact of distraction, and increase verbal and nonverbal skills.

IN PRACTICE

- Exercise: Ensure your students have adequate exercise daily. You can point to the rich scientific literature on the benefits of exercise for learning to make a case to keep PE allocations strong. Some districts are even testing whether putting challenging classes like math and science right after PE can take advantage of the exercise-induced bump in plasticity!
- Sleep: Some schools are putting insights from sleep science to good use by implementing later school start times, recognizing the different circadian rhythms of the adolescent brain. Parents can reduce blue light from digital screens at least an hour before bed, to minimize disrupting sleep architecture from blue light. Students can boost their test performance by putting some sleep between learning and the test!
- Music: A scientific case can also be made to restore budgets to arts programs. Access to dance, music, theater, creative writing, and the visual arts has been shown to support problem-solving, motivation, collaboration, and innovative thinking.

YOUR TURN

What are some other ways you could use the principle of **Non-Cognitive Support for Learning** in your teaching practice?

INEFFECTIVE LEARNING TECHNIQUES

HIGHLIGHTING AND RE-READING

INSIGHT

While highlighting and re-reading are the most popular study techniques, they are very ineffective in that they lead to short-term learning instead of durable mastery. These techniques are so often used because they foster feelings of fluency, which students misinterpret as signs of mastery. In other words, students get trapped in a **myth of fluency**, which leads to a **delusion of mastery:** they cover the material in a superficial way that leads them to feel fluent with the material, but this 'mastery' of the material is superficial and transient. For true mastery in the long-term, these techniques are not the best use of time.

Because these techniques lead to retention in the short-term, students who use them immediately before the test often demonstrate fine performance. However, if not combined with deeper learning strategies, the learned information will fade quickly. Research suggests that approximately only half of what students learn in school is remembered three months later, and much less than that can be remembered years later. That is not a great return on our investment in these students' futures.

IN PRACTICE

- A particular challenge is to motivate students to replace these popular study techniques, because they are easy for the students to do, they give the students the rewarding (albeit deluded) feeling of mastery, and they seem to help on short-term tests.
- It is our responsibility as educators to introduce more effective teaching and learning strategies that can replace highlighting and re-reading. In this course, we have covered many techniques that learning science and neuroscience shows to be effective. We'd love to hear your success stories about how you motivate your students to use these techniques!

YOUR TURN

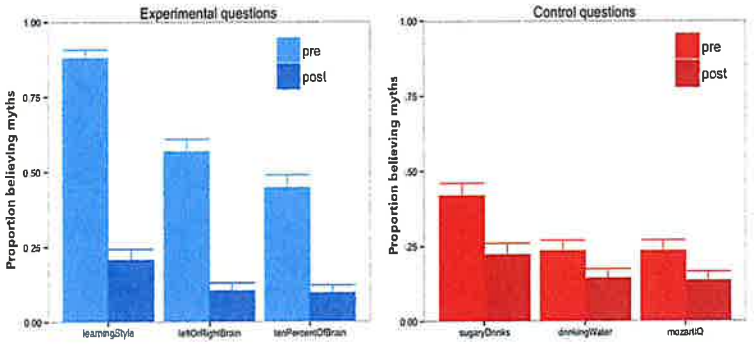
What are some other ways you could encourage students to replace highlighting and re-reading in their study habits?

MY THOUGHTS, INSIGHTS, DOODLES

OUR IMPACT

We have taught our science of learning teacher training to hundreds of teachers, superintendents, and principals throughout the U.S, who serve close to 50,000 K-12 and adult ed students. As shown below, these interventions have dramatically reduced teacher misconceptions about learning:

Principals and teachers serving 46,000 students:



Intervention effect:
p=0.000000018
$X^2 = 40.68$
EXP_{mean} reduction= 50%
CTL_{mean} reduction = 13%

Uncapher et al. *(in prep)*

Figure 1. *The Science of Learning teacher training intervention significantly reduces teacher misconceptions for topics discussed in the intervention (blue, left graph) relative to misconceptions not discussed in the intervention (red, right graph)*

OUR FACULTY AND ADVISORY FACULTY

Our programs are taught by practicing researchers at Stanford and UC San Francisco, and include learning scientists, neuroscientists, and developmental scientists. The curriculum was designed by the Institute's co-founder, Dr. Melina Uncapher, a neuroscientist with 15 years experience studying how the brain learns and pays attention. Our faculty contribute to **a living curriculum** that is based in foundational knowledge, and yet evolves as new science of learning discovery is reported.

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To learn more about how we may support your school's teaching and learning efforts, please reach out

Our research team will craft a personalized program for your school

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