INTRODUCTION: THE ART AND SCIENCE OF TEACHING

Section 1: Course overview

Welcome to Neuroscience & the Classroom: Making Connections. This is a course for committed educators genuinely eager to engage in new ideas about learning and to use these ideas to invent solutions to problems they and their students encounter. It is a course for experienced teachers, rookie teachers, aspiring teachers, student teachers, administrators—anyone who wants to understand more about how students learn.

The goals for this course are:

- To foster an understanding of the unity of emotion and thinking and learning.
- To help educators connect brain research to classroom practice and school designs.
- To illustrate the benefits of collaboration between researchers and teachers so that research informs what happens in the classroom, and what happens in the classroom informs research.
- To recognize and strengthen two roles of the teacher:
  1. Teacher as designer who creates the context for learning (environment, lessons) and who is able to take the perspective of learners.
  2. Teacher as researcher who treats student responses as data that reveal the effectiveness of lessons and that provide information for the next step in the learning process.

This course provides insight into some of the current research from cognitive science and neuroscience about how the brain learns. The major themes include the deep connection between emotion, thinking, learning, and memory; the huge range of individual cognitive strengths and weaknesses that determine how we perceive and understand the world and solve the problems in it presents us; and the dynamic process of building new skills and knowledge. The course invites you to examine the implications of these insights for schools and all aspects of the learning environments we create for our children—teaching, assessment, homework, student course loads, graduation requirements. It is not a course that offers easy answers or proposes teaching methods that can be universally applied. Rather, it provides new lenses through which to view the teaching and learning challenges you face and invites you to discover your own answers to your own questions. If you want a brief preview of where we hope the course will take you, read the sidebar “Analyzing Classroom Problems through New Lenses.” (Unit 6)
The greatest benefit of this course is that, instead of providing simple answers or "tricks" or teacher-proof lesson plans, it treats you as a professional capable of finding your own answers to the specific teaching challenges you face in your particular circumstances. The course focuses on how learners learn and invites you to consider how teachers teach. As a result, you will become more skilled at inventing teaching strategies to improve the learning of your students.

Along the way, the course offers you an important opportunity to revisit the experience of being a learner. It will remind you of the ways in which your students struggle with new material. In the language we use in this course, you will be "building new neural networks" for understanding and for applying ideas and principles that emerge from the research you study. To get the most from this experience (and from the course), we urge you to become conscious of your own learning—the struggles, the misunderstandings, the moments when ideas gel, the need to revisit a new idea repeatedly, your emotional responses, the conditions under which you do your best learning, the effort required—the whole messy, non-linear process. To this end, you may find it useful to keep a journal of your learning: thoughts, feelings, observations, and insights.
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Section 2: Thinking big, starting small

This course has two main layers:

- It provides new insights into learning based on research.
- It stimulates your thinking about how to connect your teaching and lessons to these insights.

Some of the ideas in the course may challenge your current beliefs about learning and teaching. Some of the ideas may reinforce your beliefs, especially by making you conscious of feelings you have had about learning as a result of your years of experience as both learner and teacher. Either way, you will be filled with ideas, and you may feel a desire to start changing and fixing right away. You may even feel obligated to become agents of change. We can offer only one bit of advice: relax.

Change takes time, and most teachers don't have a lot of that (except in the summer, which is a great time to think deeply about new ideas). The scope of what you can change also depends on how much autonomy, authority or responsibility you have. An experienced division head may be able to implement new ideas more quickly and with wider impact than can a new teacher. You can only do what you can do. What's important is that you start somewhere.

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But even starting can be a challenge. Change is rarely comfortable, even when conditions support it. Some of you will come to this course from schools where you enjoy relative freedom, schools perhaps with small classes and a culture of innovation, but others will come from overcrowded classrooms in rigid systems that discourage change. And, just about all of us are products of over a century of tenacious assumptions about how children learn. Because we tend to internalize these assumptions and teach as we were taught and because the education-testing complex relies on these assumptions, new ideas can feel threatening. What we hope you will find here is a connection to a community of learners who understand both the need and the difficulty of change and who support your efforts no matter how limited or far-reaching. There are no small changes.
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Section 3: Why am I here?

Gary managed to sit in his chair by resting on the lower vertebrae of his long spine, legs thrust well under the seat in front of him. His head rested on the top rung, and he glared at Jim, his teacher. Gary didn't seem to like Jim's sophomore English class despite months of Jim's trying to cajole Gary into participating. It was now winter, and Jim asked Gary to stay after class to discuss yet another dreadful essay. Though, as a young teacher in his fourth year, Jim had pretty much used up his limited strategies.

"Come on, Gary, you could be a terrific writer if you'd just do some work. What's the matter?"

"Nothing," he mumbled.

And on it went, frustration mounting in both of them until finally Gary looked at Jim and screamed, "I don't work because I hate your guts."

"Good," Jim shouted back. "Good, now we are getting somewhere." Whatever that meant.

But they did get somewhere. Jim had no idea how or why, but from that day on Gary became one of his best students. Years later, as Jim learned more about the connection between emotion and learning, he gained more insight into this incident. It appeared that Gary needed some sort of emotional catharsis to tell Jim how he felt in order to move on. Although Jim hadn't known it at the time, he and Gary had managed to align their emotional goals so that Gary could begin to learn how to write.

Most teachers know that emotion is important to learning. Math teachers certainly know how past classroom traumas paralyze students. Science teachers know that explosions, rockets, and snakes can crack the walls of student resistance. Many history, English, and foreign language teachers have become virtual stand-up comics attempting to make their classroom a funhouse of positive experiences. And arts teachers have long encouraged students to rummage about in their emotions seeking inspiration for their paintings, dances, and plays.

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So, what is the point of more research into emotion and learning? What can neuroscience teach teachers that they don't already know? Fun and positive emotions enhance learning; fear and negative emotions prevent learning. What's new?

Well, a lot is new, and you'll discover some of that here. While these are reasonable questions, they also may miss the point as they suggest that the relationship between teacher and neuroscientist is similar to that between supplicant and oracle. Many of the conferences on learning and the brain feel like visits to Delphi—omniscient scientists lecturing a host of teachers looking for answers.

But the truth is that teachers don't need answers to questions about how to teach or how to bring the insights from research into their classrooms. And
neuroscientists don't have these answers anyway. Teachers and neuroscientists are members of a professional community of educators who seek to help young people learn. They are part of the village needed to raise a child. Both groups, though looking at learning from different perspectives, want to understand what works, why it works, and what might work better. Each group has its own job, and each group needs the other.

It Has to Make Sense

Abigail Baird, assistant professor at Vassar College, talks about neuroscience and suggests a simple way for teachers to distinguish between good and bad ideas from...

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INTRODUCTION: THE ART AND SCIENCE OF TEACHING

Section 4:
Teachers and neuroscientists at the same table

Teachers bring with them years of training and real experiences with real students in real settings—classrooms, hallways, cafeterias, recital halls, soccer fields, and basketball courts. No one cares more deeply about the success of students than teachers. They constantly observe students and draw conclusions in order to work on new strategies. They wake up at 4:00 a.m. agonizing about George, who seems to hate reading, or Mary, who still can't write, or Seth, who still can't solve a quadratic equation. They spend years confronting a wide range of learning problems. Not only do they develop deep insight into those problems, but they are also endlessly imaginative in addressing them. They are experts on student behavior, and are artists in the classroom.

Neuroscientists bring new insights into the brain itself. They devote themselves to exploring how the brain learns, how we recruit our different mental capacities to solve problems, how we compensate for our weaknesses, and how we capitalize on our strengths. Neuroscientists wake up at 4:00 a.m. wondering how to design an experiment to understand how a boy who has had his right hemisphere removed manages to do things he couldn't be expected to do—paint pictures, understand tonal nuances of speech, and succeed intellectually and socially in school. One series of experiments to test a single hypothesis can take years to carry out, sort out, and write up. Neuroscientists are experts in the mind and brain, bringing science into the classroom.

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New Metaphors for Teaching and Learning

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Prior to the 1970s, when people tried to explain the process of teaching and learning, they often talked about delivery. Students' minds were often described as if they were "empty vessels" to be filled with new knowledge.

Though such metaphors seemed to have some
element of truth—that the teacher was responsible for delivering content—it didn't take long before educators became disheartened. They discovered that while their students could pass exams, they could not transfer their learning outside of the context in which it was learned. The same skills required to complete an assignment in class would remain untapped in real-world settings like the workplace, or when deciding which savings account is preferable (understanding the concept of compound interest).

Beginning in the 1970s, in reaction to many such observations, educators began to reevaluate the metaphors they used to describe the process of teaching and learning. This prompted a major shift in how people thought about teaching and learning that was detailed in a number of Annenberg programs developed in the 1990s. These include *A Private Universe*, the *Private Universe Project in Science*, and the *Private Universe Project in Math*. These programs are famous for scenes showing that even graduates of Harvard and MIT often fail to explain seemingly simple concepts, such as why seasons occur, even after years of the best education in the sciences. If learning could be explained as filling up empty containers, then how could such drastic failures of learning be explained? In fact, the old metaphor of passive, teacher-directed learning could not compete with more encompassing explanations. New metaphors were introduced that recognized that learning is dynamic; that students themselves must build knowledge to own it; and that the teacher's role is to interact with the ideas that the students are forming and then scaffold the learning experience.

**Learning as a Process That Constructs Understanding**

Once the metaphor for teaching and learning was changed, teaching suddenly became more complicated. Not only were teachers now responsible for understanding the content to be delivered, but they also had to understand what their students were thinking about these concepts. Teachers needed to become diagnosticians, like psychologists, to probe their students’ ideas and understand their thinking. The model of teaching and learning that emerged at that time was often referred to as "conceptual change" or "constructivism," words chosen to suggest that learners build understanding for themselves, starting with their own ideas and modifying their understanding as they learn more about how the world works. In order to understand the seasons, for example, students must face the shortcomings of the common assumption that they result from the distance between the Earth and the Sun. (If you are curious or confused, remember that the seasons are, in fact, the result of the tilt of the Earth on its axis.)

Though the constructivist approach was helpful in promoting meaningful understanding, some educators found that even this didn't adequately describe the teaching and learning process. Educators rightfully observed that not all students learn in the same way, so they looked for some other model to help describe the learning process. Among the more popular ideas was a notion called **Multiple Intelligences**. Here, the idea was that the mind could be thought of as having capabilities in different areas, such as linguistic, interpersonal, or kinesthetic, and that teaching at its best would encourage learning that matched the strengths of individual students. This new metaphor was a refinement on the delivery and constructivist metaphors and honored individual differences among...
students. However, educators began to realize that even this metaphor fell short. The notion that intelligence could be broken apart into separate capabilities, though perhaps a useful idea, was difficult to prove with research and often misinterpreted in practice.

Building a New Metaphor for Teaching and Learning

It may never be practical, desirable, or even ethical to genetically categorize every student or put all children through scanners to observe their brains as they learn. Yet, insights from neuroscience can be helpful in thinking about how teaching interacts with learning. And these insights will lead to new metaphors that teachers can use to sharpen and think about their work. Still, the metaphors for teaching and learning that are useful for teaching are not likely to come from the neuroscience community, at least not without some help. Teachers, who have an intimate understanding of what transpires in classrooms, will need to closely examine the ideas neuroscience has to offer in order to construct teacher-developed metaphors that are useful to the profession.

One goal of this course is to encourage teachers to work hand in hand with neuroscience researchers to develop new metaphors for teaching and learning that build on, sharpen, and refine those ideas previously developed. As you work through this course, either on your own or with your colleagues, think about how the ideas you see coming from neuroscience may refine or change the learning models you already have. Through this process, you will evolve a new set of powerful and useful metaphors for teaching and learning that are grounded in neuroscience. We hope that you will share these concepts with your colleagues and the neuroscience researcher community so that, together, teaching and learning can be made even more effective.

Mind, Brain, and Education

Paul B. Yellin, associate professor at New York University School of Medicine and director of the Yellin Center for Mind, Brain, and Education, talks about the need for an equal partnership among...

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Although they may not realize it, young people need teachers and neuroscientists to work together on their behalf. The collaboration between Jason Ablin, teacher and head of Milken Community High School in Los Angeles, CA, and Mary Helen Immordino-Yang, neuroscientist at the University of Southern California, illustrates the benefits of merging the two perspectives.

Immordino-Yang's research into the social and academic success of Nico and Brooke, two boys who had half of their brains removed to treat persistent seizures, led her to conclude that perhaps the way we perceive and solve problems is influenced by our particular cognitive strengths. We see the world and deal with it in personal ways that make sense in terms of prior experiences and a particular set of skills and abilities. It's not just that men are from Mars and women are from Venus. We all experience different realities in our minds.

In his book *Successful Intelligence*, Robert Sternberg illustrated this theory. As a child, he performed poorly on IQ tests and had very low spatial ability:

> By the time I was in high school, though, a strange thing had happened. My scores on tests of spatial ability improved radically. ...Or so it seemed. Had my spatial ability improved? Not really. It was no better than it had been years before. But I had come to realize that many spatial-ability problems on these tests can be solved verbally rather than visually. In other words, instead of trying to visualize what, say, a set of forms would look like in another spatial position, I tried to talk the problems through to myself. I would describe the figures verbally and then try to match that description with the answer options.

Sternberg had transformed a spatial problem into a verbal problem, a process similar to what Immordino-Yang observed in Nico and Brooke—a process that suits the problem to neural strengths and compensates for neural weaknesses.

Immordino-Yang's research and conclusions resonated with Jason Ablin's experiences in the classroom. Like most teachers, he knew that students often fail to understand homework and test problems as the teacher intended them to be understood. As a result, he saw that students might perform better in a classroom that actively engaged students in designing problems instead of wrestling with problems as
teachers conceived them. This sort of insight emerges when intuition built through practical experience—such as Ablin's experiences with students in the classroom—is reinforced by research into how the brain learns.

It's an exciting, creative moment when theory and practical observation come together and seem to reinforce each other. Of course, to complete the partnership, the teacher must then design the lesson and assess the validity of the new insight in practice. The teacher will likely discover new issues that challenge aspects of the theory and that suggest further research.

This dynamic partnership between teachers and researchers is the source of the goals for this online course.

**Dr. Tami Katzir**

"I think researchers tend to simplify things. Educators in the classroom see much more of the complexity. We need more of a discussion between educators and researchers, so we can form questions..." – Dr. Tami Katzir

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Section 6: Beyond candy and smiley faces

People can be rather schizophrenic about emotion. While they may increasingly, though grudgingly, accept its importance to learning, it can be difficult to figure out how to integrate it into lessons and course goals. As a result, many continue to treat it as a nuisance that must be banished to the edge of the settlement. Rational thought—reason—remains dominant. When asked to discuss the connection between emotion and learning, most teachers mention a few popular notions:

- Negative emotions such as fear make learning impossible.
- Positive experiences enhance learning.
- Therefore, we need to create classrooms that are warm, welcoming, and supportive by smiling, shaking hands with students as they enter, getting to know them personally, making learning fun, and giving out rewards.

These ideas about positive and negative emotions are valid and important, but neuroscience is revealing a much deeper connection among emotion, thinking, and learning. For example, by studying patients who have sustained damage to the ventromedial prefrontal cortex, researchers are becoming increasingly convinced of the inseparable bond between emotion and thinking. Good thinking and good decision-making—"rational" thought—depend on emotional processes. In the words of Dr. Antonio Damasio, "Emotion is the rudder for thinking." We think in the service of emotional goals.

In addition, emotion is essential to good problem-solving. People constantly rely on intuition as they work on problems or seek answers to questions. We "feel" we are on the right or wrong track. We experience a sort of emotional jolt, often just prior to consciously recognizing a solution, whether to the problem of where we left our keys or to the problem of making sense of strings of numbers or pages of data. Intuition and what we call "rational thinking" may be different sides to the same coin called "emotional thought"—one side is more nonconscious and the other is more conscious, but both are minted in emotion.

It is these deeper aspects of emotion and learning that this course will cover. In fact, this deeper understanding will provide greater insight into the truths that teachers already understand about emotion—the reasons that learning is undermined by fear, and enhanced by fun and a balance of challenge and support.
ventromedial prefrontal cortex
An anatomical location in the brain. This region is in the lower half (ventro), deep between hemispheres (medial), in the front portion (prefrontal) of the brain.
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Section 7:
Making meaning vs. getting answers

A learner is a learner is a learner. Regardless of whether learners are students in school or teachers engaged in professional development, the essence of learning is building new skills and new conceptual understanding. Learning is a process of internalizing new ideas so that they become personally meaningful (emotionally relevant) and useful. To solve problems, like how to help Sally learn to write an essay, means wrestling with ideas about learning, understanding Sally, and setting a path toward a solution.

Unfortunately, many educators continue to equate learning with "having" answers, as though knowledge is an object like an apple or a pencil, something that can be grasped or stuffed in a box, usually in one of the memory boxes—short-term memory, long-term memory, or working memory. However, accustomed as they are to an educational system built on correct answers, most teachers come to professional development seeking answers. This desire for answers is understandable, even inevitable, given the huge demands on teachers' time. They want a quick fix. "Don't bore me with a lot of theory or abstraction; give me the answers. How do I apply this stuff? What do I do on Monday morning?"

Although a quick fix would be nice, conditions and challenges vary too much from school to school and classroom to classroom and learner to learner. A solution that works in one classroom for one student might simply make matters worse in another classroom for a different student. Meaningful answers to the multitude of specific questions that teachers face tend to rely on the creativity, flexibility, and skills of the person asking the question. As a result, this online course takes a different approach. Rather than pretending we have answers that no one else has, our objective is to help you develop an understanding of new principles—new lenses for examining the teaching and learning problems you face. That way, you can create and test your own solutions. This course is designed to foster a discussion among a community of professionals interested in education.

As a young theater teacher, Sam recalls the panic of Monday morning. What could he do with 18 acting students? Oh, Viola Spolin has the answer. He grabbed her classic book, "Improvisation for the Theater," and led his students through mirror exercises, tug-of-war, and who-started-the-motion. They had a lot of fun, but Sam's laughter barely hid his growing dismay over how little the students were learning, and how meager their development was as actors. He had no clue how to assess the value of these exercises because, beyond some vague notions about spontaneity and reacting in the moment, Sam had not internalized the concepts on which this method of training was built. They were just exercises that occupied the students—diversions that kept order and created an illusion of purposefulness. They were Spolin's answer, not Sam's.

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So, he spent some time thinking more deeply about acting, about the principles embedded in his own education, and about his experiences with different acting teachers and theater directors. Slowly, Sam built an understanding of acting that was meaningful to him, one that felt true. Acting is living in public as though you are in private. Acting is believing. Based on these ideas, Sam built and borrowed new exercises that made sense, that emerged coherently from these principles, and that seemed appropriate for his 18 students. For example, instead of asking his students to play pantomime games that focused their attention outward on an audience, he had them engage in small tasks on stage—like threading a needle and sewing a button on a shirt. That way, they could begin to build a feeling of private concentration even as others watched.

These exercises, in turn, gave students experiences that led them to develop their own understanding of acting and invent their own ways to approach a scene or build a character. Eventually, Sam even found his way back to Spolin, whose approach now seemed, through the lens of the meaning he had constructed, more suitable for advanced rather than for beginner students. Finally, he was able to create his own solutions to the problem of transforming theory into practice, of understanding and inventing what to do on Monday morning.
Glossary

**short-term memory**
A term used to describe the neurocognitive system that retains a finite amount of information for a short period of time.

**long-term memory**
A term used to describe the neurocognitive system that retains information, most typically described in two forms. Declarative memory includes subdivisions of episodic and semantic memory, referring to specific episodes or facts, respectively. Procedural memory includes knowledge about how to complete tasks or procedures.

**working memory**
A term used to describe the neurocognitive system that simultaneously stores and manipulates information for a short duration. Multiple models and definitions of working memory are actively being explored in research.
Building an understanding of concepts and then creating solutions and answers to problems are essential steps to successful learning and teaching. To paraphrase Kurt Fischer, director of the Mind, Brain, and Education Program at Harvard University, Graduate School of Education, Sam (Introduction, Section 7) needed to develop a new neural network for acting. That way, he could invent classroom exercises that emerged from his understanding—and that, in turn, helped his students build their own neural network for acting. Being given the answers short-circuits the process of understanding because people often fail to create the necessary connections between theory and practice. People fail to create a rich neural network. For Sam, using Viola Spolin's answers divorced from the principles that give them meaning was like a child using a screwdriver as a hammer. The more opportunities people have to work with concepts and to make them our own, the richer, more stable, and more complex the neural connections will be.

Teachers who rely on answers from someone else deny themselves the more engaging challenge and fun of creating their own exercises based on their own understanding of the research. And if teachers can't create their own exercises, they remain dependent on others to tell them what to do. They don't develop their skills as creative teachers, just as students who parrot the answers their teachers give them rarely become creative learners.

It really doesn't matter whether we are teachers or students. The slow process of making knowledge our own is ultimately more powerful, meaningful, and effective in producing learning.

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Yet, many teachers continue to seek answers, and there are plenty of hucksters ready to sell them the brain-based elixir of the day.

Like prospectors following a gold rush, snake-oil salespeople are cashing in on neuroscience, peddling "brain-based" teaching methods that will strengthen memory and stimulate comprehension. For only $29.99, you can buy a book of nifty classroom gimmicks guaranteed to work and backed by scientific studies, complete with standard deviations.

In the absence of sufficient counterclaims, many teachers are buying (see article, "Understanding..."
"Teachers need to know about neuroscience because there are myths out there. And these myths help us stereotype students into different kinds of learners. Consider this idea: There is a right..." – Siri Fiske

The Role of Neuroscience in Brain Based Products: A Guide for Educators and Consumers"). The bottom drawers of teacher desks and filing cabinets, as well as gigabytes of CDs, are filled with free handouts and expensive books stuffed with answers for Monday morning. Most are rarely used, and many are used ineffectively as empty worksheets or busywork. They are as useless to the teacher as memorized formulas or abstract definitions are to students.

Successful professional development brings together a community of learners willing to take the risk of thinking together about insights into the connections among the mind, the brain, and learning, as well as their implications for schools. The major goal of this course is for you to share the experience of a colleague who said, "I expected more 'answers' and am glad I didn't get them. Too much professional development works to give answers and overlooks that the teacher is the skilled professional, acting in a nonduplicable context. This course helped me to THINK better."
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Section 9:
New lenses, eternal questions

Over the six units of this course, you will be encouraged to formulate and understand principles or hypotheses from research and use these to explore classroom and institutional issues. The course asks you to imagine implications of the research for how we teach and then to create lessons and design schools. While exploring the relationship between emotion and cognition, the course examines some specific biology and functions of the brain:

- How the brain recruits its many parts to accomplish different tasks (right-brain/left-brain facts and fiction)
- Developmental differences and individual profiles of cognitive strengths and weaknesses
- The interplay of emotion with the mind and body
- Mirror neurons, empathy, and the self
- The biology of social emotions like compassion and admiration
- The relationship between performance and context in learning
- Skill development via the construction of webs and neural networks
- The critical role of regression in learning

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All of which have significant implications for education:

- Motivation, attention, engagement, and memory
- How different students perceive and solve problems
- Learning differences and disabilities
- Policy and practice issues involving all aspects of school—such as homework, grading, course loads, and graduation requirements

Eric Baylin
"It's important for teachers to know about the research because it can support great intuitive teaching. It can also help us to understand how we can align our teaching to the ways in which..."  – Eric Baylin

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Section 10:
Resources


UNIT 1: DIFFERENT BRAINS

Section 1:
A brief historical note

Q: How does the brain work?

Standard neuropsychological practice often involves comparing atypical to typical brain function in order to gain insight into how parts of the brain normally work. That is, scientists study atypical functioning not simply for its own sake, but also for what it can reveal about the ways in which all people learn and develop. The basic logic, simplified, runs like this: A person can do some task, such as make good decisions. The person sustains damage to a specific region in the brain, perhaps a part of the prefrontal cortex, and now has a deficit in ability to do the task—he or she can no longer make good decisions. Scientists then draw inferences about the role of the damaged area of the brain in typical ("normal") brains, based on analyses of the deficits in the patient.

One of the earliest and best-known studies has been the subject of speculation and debate since September 1848, when Phineas Gage, the 25-year-old foreman of a crew of railroad workers in Vermont, accidentally sparked an explosion that drove a tamping iron up through his left cheek bone and out the top of his skull. The tamping iron was over three feet long and passed through his skull with such force and speed that it landed one hundred yards behind him. Shortly after the accident, Gage was conscious and able to walk, and was driven by cart to Dr. John Harlow. Gage survived, and Harlow wrote an account of the case which was met with great disbelief, as no one could believe that Gage could survive such an accident. Two years later, a second report was published by Henry J. Bigelow, professor of surgery at Harvard, who wrote that Gage was "quite recovered in faculties of body and mind."

Although his ability to reason seemed intact, his wife and friends noticed significant changes in his personality. The likable, capable, and proper young man became angry, rude, and irrational, shouting obscenities at anyone who seemed to stand in the way of his desires. In 1868, Harlow published his second account of the case, detailing all the symptoms and concluding that Gage's "mind was radically changed, so decidedly that his friends and acquaintances said he was 'no longer Gage.'"

The damage to his frontal cortex seemed to have erased many social inhibitions, and the case has
provided rich fodder for over 150 years of speculation and debate

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about the specific disruptions to Gage's neural pathways. In 1994, Hannah Damasio and her colleagues at the University of Iowa used neuroimaging techniques to reconstruct Gage's skull in order to shed new light on the mystery. More recently, the research on the role of emotion in learning is informed by this case. Trauma to the prefrontal cortex, an area central to the integration of emotion and cognition, can impair the abilities to think logically, plan, and make good judgments. This discovery provided a basis for understanding that emotion and thinking are fully intertwined—an understanding with considerable implications for education. Emotion makes a fundamental contribution to thinking logically.

Although the case of Phineas Gage is extraordinary, it is not unique: Accidents and strokes have provided neuroscientists with patients suffering from all sorts of damage to different parts of the brain. Progress in understanding brain function would be less insightful and much slower without such patients. But studying atypical brain function may also result in some misunderstandings and myths about the brain. It is not difficult to imagine that associating loss of specific abilities with damage to particular parts of the brain might produce a theory of the brain as an organ composed of modules—the brain as a super-LEGO® structure—each brick responsible for a separate brain function. Jane can't speak, and she had a left-hemisphere stroke; therefore, the left hemisphere is responsible for speech; it's the speech module. In reality, brain function is the result of activity in networks that connect many regions—webs of electrical connections—not the result of isolated modules for speech or vision or some other specific activity.

**Tools of Neuroscience: MRI/fMRI**

Dr. John Gabrieli of the McGovern Institute for Brain Research at MIT explains the uses of MRI (magnetic resonance imaging), which reveals the structure and function of the brain, and of the fMRI...

[View video](#)

**Tools of Neuroscience: EEG**

The noninvasive technologies of neuroscience include MRI (magnetic resonance imaging), fMRI (functional magnetic resonance imaging), MEG (magnetoencephalography), and EEG (electroencephalography)....

[View video](#)

**Glossary**

**prefrontal cortex**

An anatomical location in the brain referring to the anterior (front) area of the frontal lobe. Cognitive and psychological constructs typically associated with the prefrontal cortex include executive...
capacities, personality characteristics.

**frontal cortex**
An anatomical location in the brain referring to one of four lobes (frontal, parietal, occipital, temporal) that is located behind the forehead.

**neuroimaging techniques**
Neuroimaging techniques are neuroscience tools used to investigate brain structure or activity directly or indirectly. Common tools include magnetic resonance imaging (MRI), magnetoencephalography (MEG), and electroencephalography (EEG).
Q: What's wrong with the old metaphors about brain function?

In 1983, Howard Gardner, also studying patients with damage to different parts of the brain, published *Frames of Mind: The Theory of Multiple Intelligences* and changed the way many people thought about intelligence, teaching, and learning.

To appreciate the multiple intelligences (MI) framework as proposed by Howard Gardner is to embrace the notion that individuals possess a constellation of strengths and weaknesses across the different "types" of smart. To date, Gardner's intelligences include: linguistic, logical-mathematical, spatial, musical, naturalist, bodily-kinesthetic, interpersonal, and intrapersonal. (These intelligences are described in the table below.) We have all felt enabled and adept at some tasks, whether they involved music, language, or math. But we have each felt the sting of being in situations where what was expected of us was challenging, difficult, and all the more frustrating when we were required to do it someone else's "way" rather than our own.

A key point here is that multiple intelligences describe different ways of perceiving and processing information; these are not characteristics that are inherent in a given task per se, but rather in the learner. Many tasks could be completed by drawing on different intelligences, just as many lessons can be communicated using multiple frameworks based on MI. How the mind interacts with the environment and the demands of the task at hand is relevant to every learning situation. So, rather than being concerned with how "smart" someone may be based on an IQ test, educators can better serve their students by working to figure out how they are smart.

Relating the theory of MI to the brain is more complicated. An exciting idea that may attract us to MI is that each intelligence maps onto a distinct part of the brain: The linguistic intelligence has a corresponding part in the brain, for example. However, neuroimaging research on higher-order
cognitive skills and abilities, including intelligence, so far has suggested a reliance on a system of brain regions, rather than a single spot. In order to address this topic specifically in regard to MI, a series of neuroimaging studies, which have yet to be conducted, is required. It should be noted that the intelligences identified have met the criteria related to the consequences of brain damage, but identifying the underlying systems supporting each requires further evidence about brain functioning when there is no damage. A promising hypothesis is that each intelligence relies on a distinct network of coordinated brain regions.

Until there is a deeper understanding of the relationship between how the brain is structured and how it functions in relation to intelligence and cognitive potential, MI remains a powerful idea for shaping educational thought, but not yet one about brain-behavior relationships. However, MI provides a framework for considering essential points about learners:

- A given task can be completed in more than one way, even if there is one right answer. This distinction is referred to as "process versus outcome."

- A consideration of the interaction between a person's profile of intelligences and the demands of the task yields the most helpful educational picture of his or her performance.

- The brain is not constructed into discrete modules; to think about MI in terms of "spots in the brain" would be oversimplifying the theory and the brain's functionality.

<table>
<thead>
<tr>
<th>Intelligence</th>
<th>Description</th>
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<tbody>
<tr>
<td>Linguistic</td>
<td>An ability to analyze information and create products involving oral and written language, such as speeches, books, and memos.</td>
</tr>
<tr>
<td>Logical-Mathematical</td>
<td>An ability to develop equations and proofs, make calculations, and solve abstract problems.</td>
</tr>
<tr>
<td>Spatial</td>
<td>An ability to recognize and manipulate large-scale and fine-grained spatial images.</td>
</tr>
<tr>
<td>Musical</td>
<td>An ability to produce, remember, and make meaning of different patterns of sound.</td>
</tr>
<tr>
<td>Naturalist</td>
<td>An ability to identify and distinguish among different types of plants, animals, and weather formations that are found in the natural world.</td>
</tr>
<tr>
<td>Bodily-Kinesthetic</td>
<td>An ability to use one's own body to create products or solve problems.</td>
</tr>
<tr>
<td>Interpersonal</td>
<td>An ability to recognize and understand other people's moods, desires, motivations, and intentions.</td>
</tr>
<tr>
<td>Intrapersonal</td>
<td>An ability to recognize and understand one's own moods, desires, motivations, and intentions.</td>
</tr>
</tbody>
</table>

(Table from Davis, Christodoulou, Seider & Gardner, 2011)
Gardner succeeded in challenging and expanding the notion of intelligence and revealed the role of cultural and social bias in how different abilities are valued and developed in children. His ideas resonated with the experiences of parents and teachers, who witnessed daily the rich variety of "talent" or "intelligence" in budding poets, mathematicians, athletes, musicians, and painters. IQ tests seemed to view people through a peephole darkly. So when Gardner offered a larger vision of human potential that jibed with observation and experience, teachers and parents rushed to embrace it.

Despite the continuing importance and validity of his richer view of human skill and of the role that culture and social forces play in learning, many educators have reduced Gardner's insights to the modular model of brain functioning that influenced his theory but proved to be too simple to fully explain the richness of the different intelligences. Many persist in believing that our brains have a music module, a language module, and a math module. They do not. The result has been years of misleading talk about designing lessons for visual learners and kinesthetic learners, left-hemisphere learners and right-hemisphere learners. "Right-brainers will rule the future," declares Daniel Pink, former White House speechwriter and author of the popular book, *A Whole New Mind: Why Right-Brainers Will Rule the Future*.

Although such statements are likely meant as metaphors to suggest that those who can think creatively and emphatically will become increasingly important to businesses, they lock us into ways of thinking about brain function that reduce our understanding of the brain and, therefore, limit our ability to develop more effective models of education. This is the nature of powerful metaphors. At first, they capture our imagination and stimulate new ways of thinking about old problems; but eventually they capture us and inhibit newer insights. The left-brain/right-brain metaphor puts us into the very box out of which we encourage creative people to think.

More recent studies reveal that both hemispheres are involved in almost all cognitive tasks. Thanks to functional magnetic resonance imaging (fMRI)

*(End of the first column online)*
MEG), we can now marvel at the cascade of neural activity that is associated with the reading of one simple word. Anders Dale and Eric Halgren have created a movie exploring the interplay of activity from different areas across the entire globe of the human brain during reading.

The more we recognize and understand the complexity of the brain, the greater will be our understanding of learning—and of the inevitability of differences in how people learn and how we might teach them.

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**Tools of Neuroscience: MEG**

Dr. John Gabrieli of the McGovern Institute for Brain Research at MIT describes the benefits of the MEG (magnetoencephalography), which gives us a precise measure of both the timing and location of...

View video

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**Reading a Word**

New imaging tools allow us to observe the rich array of connections between many parts of the brain involved in doing anything. Reading a word, for example, is the result not of activating a...

View video

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Watching the Reading Brain in Action

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University; Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Imagine that you are shown one word on a computer screen, and that the activity in your brain is recorded over the course of a second. What might you expect to see in your brain? Would you expect just the reading part of the brain to show activation; if so, where would that be? Would you think that different parts of the brain coordinate to read the word? What sequence might different parts of the brain activate? These questions are intended to get you thinking not just about what parts of the brain are relied upon to read a word, but to consider the thinking processes that are integral as well.
When cognitive neuroscience researchers put these sorts of questions together, they are able to use cutting-edge neuroimaging technologies to answer them. Using a novel approach to record brain activations (Dale et al., 2000), the "Reading A Word" video was created by Anders Dale and Eric Halgren. The video relies on the combination of two neuroimaging technologies: MRI and MEG. MRI is an excellent tool for determining where in the brain activation occurs. In the same way, MEG is a tool best used to determine when in the brain activation occurs. Taken together, we are able to view the intricacies of the reading brain in action both in terms of time and place, by viewing the results of these technologies combined.

Take a look at the video a few times. Once you have taken in the majestic ebb and flow of brain activations in the video, consider how it compared to your ideas of what it takes to read one word as an adult. In a split second, swaths of brain regions are awash in a red and orange hue. (Of course, the brain doesn't actually light up colorfully, but scientists apply statistical analyses to brain data to create graphical depictions representing the areas with changes in brain activity, which you can't see otherwise.) As you can see, the sequence is not random: Activations begin in the back of the brain, where the visual system is largely situated, and move forward to the front of the brain where systems for articulation of a word and activating its meaning are based. In the video, we see a carefully crafted choreography of brain activations for reading even a single word. We are not born with the functional wiring to be readers; this process requires years of reading practice that goes along with the rewiring and recycling of the brain's systems for other purposes, such as vision, audition, translating between symbol systems (sounds and letters), attention, and memory. In the flash of activations seen in the video, we can easily see how involved such a seemingly simple task becomes when we peek behind the curtain that is masking the workings of the brain.

The "Reading A Word" video reveals the dynamic and distributed reading systems required to read a single word. Rather than a unidirectional, static, single stream of activation, the brain regions recruited for a single word tell a story of the brain's interactive approach to reading.

**Glossary**

**functional magnetic resonance imaging (fMRI)**
A neuroimaging technique using radio and magnetic waves to indirectly index brain activity relative to specific task comparisons.

**magnetoencephalography (MEG)**
A neuroimaging technique that detects the magnetic properties of electrical impulses resulting from neuronal communication to produce maps of brain activity relative to a task. MEG is used most typically for research purposes to investigate cognitive and psychological processes. The main strength of MEG is the high temporal resolution; the main limitation is the relatively limited spatial resolution. Based on these characteristics, MEG is most effective for investigating questions of timing in brain activity rather than where in the brain activity originates.
Q: Can you give me an example of how brain function is integrated across regions?

People generally believe that language is a left-brain function separate from music, which happens over on the right hemisphere. The persistence of this belief is not surprising. Research during the 1960s and into the 1990s found that patients with damage to certain areas of the left hemisphere suffered from "aphasia," the inability to speak; while those with damage to certain areas of the right hemisphere developed "amusia", the inability to process musical pitch. Although it might initially make sense to conclude that language must be a left-brain function, a closer look reveals that language recruits areas and abilities from both hemispheres, as does music. All major categories of human behavior, especially the skills that schools strive to develop in students, use multiple parts of the brain, not merely the left or right side.

Broca's area and Wernicke's area, two parts of the left hemisphere (in most people), had been thought to be exclusively responsible for the production and perception of language.

However, using functional magnetic resonance imaging (fMRI), scientists discovered activation in two overlapping areas when music was being processed: The inferior frontal gyrus and nearby premotor cortex (overlapping Broca's area) were recruited for sight-reading, while reading and listening to a score activated the supramarginal gyrus (overlapping Wernicke's area).

It seems that language areas are not "language," and music areas are not "music." Instead, the left and right hemispheres may have broader functions that are recruited across domains like language and music to support abilities in each. Both hemispheres contribute to the production and understanding of language and music. The left hemisphere seems to specialize in tasks involving hierarchical sequencing (like grammar, syntax, and meaning), and the right hemisphere seems to deal more with contour-based patterns (like melodic contour and large repeating patterns, especially with emotional significance). The contributions of the left hemisphere are less emotional—such as grammar and definitions of words. The contributions of the right are more emotional—such as the
aphasia
An acquired disorder, most commonly the result of a stroke, which impairs a person's ability to use and or understand language in service of communication. Difficulties can extend into reading and writing skills in addition to oral language.

amusia
A general term referring to a collection of possible difficulties, acquired or congenital, related to music-related processing in relation to features such as rhythm, pitch, or tone.

Broca's area
The region of the brain functionally associated with spoken language production discovered by Paul Broca in the late 19th century. Disorders arising from damage to the left inferior frontal cortex, as classically defined, most typically involve difficulty in using language (i.e., expressive) with the preserved ability to understand (i.e., receptive) language.

Wernicke's area
A region of the brain functionally associated with spoken language comprehension discovered by Carl Wernicke in the late 19th century. Disorders arising from damage to left posterior temporal gyrus, as classically defined, most typically involve difficulty in language comprehension (i.e., receptive) and meaningful use of language with preserved ability in other language features such as melody and contour that produce the affective music of language (intonations that express our intention, like sarcasm or sincerity). Broadly speaking, the left hemisphere works with the denotation of our language; the right plays with the connotation. In most people, both are essential for fully expressive communication and understanding.

Take a simple example: Two sentences have the same words, syntax, and grammar but communicate very different meanings, depending on how they are said:

"You love me."

"You love me?"

Beyond the rising inflection that distinguishes the question from the statement, speak these words with different melodies, stresses, and pitches, and each result will yield a different meaning. The emotional prosody of language, its rhythms and intonations, is neurologically related to music processing.

But there is another layer to prosody: Some languages, like Mandarin, rely on prosody for grammatical and lexical meanings; the syllable "ma," for example, has four different meanings depending on the melody with which it is pronounced (only one of which is "mother"). Because grammar and definitions tend to be left-hemisphere functions, it may be that the purpose to which prosody is put determines which hemisphere will be more heavily recruited. In most Mandarin speakers, the right hemisphere is recruited for tones communicating emotional meaning, and the left is recruited for tones communicating "denotative" meaning, such as the specific meaning of "ma."

Glossary

aphasia
An acquired disorder, most commonly the result of a stroke, which impairs a person's ability to use and or understand language in service of communication. Difficulties can extend into reading and writing skills in addition to oral language.

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form and rate (i.e., expressive).

**inferior frontal gyrus**
An anatomical location in the brain referring to one of three main gyri in the frontal lobe (inferior, middle, superior).

**premotor cortex**
An anatomical location in the brain referring to a strip of cortex in the posterior (back) region of the frontal lobe that is critical for motor function.

**supramarginal gyrus**
An anatomical location in the brain's parietal lobe that, with the angular gyrus, makes up the inferior parietal lobule. This region has been shown to be critical for skills including reading.

**prosody**
Prosody refers to features of language including—including tone, stress, and pitch—which is used to communicate emotion, express sarcasm, denote types of utterances (question versus statement).
UNIT 1: DIFFERENT BRAINS

Section 4: Succeeding with half a brain

Q: If the two hemispheres are heavily involved in virtually everything we do, what happens when one hemisphere is removed?

Two young men, Nico, an Argentine, and Brooke, an American, provide some insight into this question. Nico's right hemisphere was surgically removed when he was three to control severe epilepsy; he has become an engaging young man who enjoys fencing, art, and singing, and who has been academically and socially successful in school in Spain, where he moved with his family. Brooke's left hemisphere was removed when he was 11, also to control persistent seizures. He, too, is a charming young man who attended high school and college and works at a recycling center. What is striking about these young men is that both are able to do things that they "shouldn't" be able to do according to conventional views of the brain—such as use their remaining neural hardware to produce and understand language and its emotional meanings.

(Opened ScienceTalk sidebar)

Self in Relationships

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University: Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Our lives are defined in large part by the relationships we have and our respective roles in each. The Self-in-Relationships Interview (SRI) is a tool to explore the dynamics of those relationships by ranking their level of importance and by assigning a positive or negative valence to each. Through the SRI, originally created by Susan Harter and Ann Monsour (1992) and revised by Kurt Fischer and Bruce Kennedy (1997), the organization of relationships in a person's life is evident from the resulting diagram of concentric circles, with most important relationships in the center circle and those of least importance in the outermost circle. Adjectives are linked to how a person feels in each relationship, such as serious, considerate, honest, or self-conscious. For example, people who perceive their relationship with their mother to be positive and most important would list this information in the inner circle. The dynamic with a souring romantic partner may be categorized as uncomfortable and least important. Relationships with parental figures, siblings, and those in daily living and school...
environments are also categorized. As the interviewees' depiction of relationships become personalized, they capture the most salient and relevant characteristics of a person's role in these social dynamics. The SRI provides a platform for mapping out the different sides of ourselves across relationships. It can reveal the truth behind the cliché about "being different things to different people."

Image: SIR diagram showing a set of lines drawn by the participant between self-descriptions and/or categories that "relate to self." Source: Laura Hsu (from her PhD dissertation).

In addition to providing a visual representation of an interviewee's web of individual relationships, the SRI also explores how an individual sees the connections among these relationships and how he or she describes them. Participants are asked to indicate which relationships and descriptors go together and to categorize them. These self-generated categories can include social life, ideals, or identity. (See the circled items in the SRI figure.) Next, participants mark with solid lines those categories that seem to go together and mark with dotted lines those categories in apparent conflict. Participants mark conflicting or contradictory self-descriptions with an "X" (for example, "I can be kind in this dynamic and..."
Along with Ekman’s test of facial recognition and the Self-In-Relationships Interview (see sidebar above), Mary Helen Immordino-Yang designed two tests for her study of these young men’s ability to understand and produce the prosody of language. One test determined how Nico’s and Brooke’s prosodic discrimination and comprehension compared to their peers, and one test compared the intonation patterns in their speech to that of their peers. Although the boys certainly revealed weaknesses, they generally compared favorably to their peers. How can these findings be interpreted in terms of the young men’s emotional profiles? What can the results teach us about brain plasticity and development, especially in social contexts, and their relation to compensation and learning?

The SRI has proved to be useful across research, education, and in clinical settings. The cases of Nico and Brooke, two young men each missing half of a brain, are described in this unit (Unit 1, Section 4) and exemplify how closely the brains we have to work with affect, define, and constrain our behavior. For Nico, the SRI helped researchers understand the connection between his avoidance of discussing emotions and his obligatory reliance on the left hemisphere. With no access to the right hemisphere, Nico could not draw on regions where much of language processing related to emotional information typically occurs. On the other hand, Brooke indulged in the descriptions he offered, showcasing his access to the right hemisphere; but, lacking a left hemisphere, he could not reign in his elaborated discussion.

REFERENCES:


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Nico's Story
The right hemisphere of the brain is generally considered to be dominant for many functions,

Brooke's Story
At the age of 11, Brooke Smith had the left side of his brain removed. The left hemisphere
Glossary

**Ekman's test of facial recognition**
An assessment tool developed by Paul Ekman and Wallace Friesen in the 1970s to measure recognition of emotions based on facial expressions.

**brain plasticity**
The potential for, or ability of, neurons or brain systems to modify functionality based on experiences. The degree to which brain function can be modified is a question of high interest, particularly for addressing topics including recovery from brain damage, responsiveness to intervention, learning, and skill acquisition.
Q: How does our brain determine how we see and interact with the world?

In most people, the two hemispheres of the brain exhibit different strengths and weaknesses, and people tend to see the world through the lens of their strengths. They interpret and solve problems using these strengths to compensate for their weaknesses. Despite their significant differences, Nico and Brooke are no exception. Essentially, it seems that these boys rely on the strengths of their remaining hemisphere to meet the challenges the world presents them, such as the challenge of successfully interacting socially with their peers, especially by understanding and using the nuances of language.

Overall, Nico's and Brooke's ability to distinguish between sincere and sarcastic tones was good, and both could use these tones appropriately in their everyday conversations with others. However, neurologically, their approaches were quite different—from each other and from their more typical peers. You could hear the difference from their peers in the exaggerated and somewhat unregulated tones the boys produced, but insight into their methods of compensation was most evident in how they talked about emotions. Nico, lacking the emotional processors of the right hemisphere, tended to avoid talking with any depth about emotion, while Brooke, who retained the strengths of the right hemisphere and lacked the mediation of the left hemisphere, tended to talk excessively about emotions.

In one exercise, Nico quickly identified the speaker's tone but seemed unable to analyze the source of his judgment. When asked how he knew the speaker was joking, he responded, "How did I know that? Because I just heard it." End of discussion. Brooke, on the other hand, went to the opposite extreme, analyzing the situation thoroughly, speculating on the psychology of the speaker, and using his own experiences as sources for insight: "She was probably joking around. But I think she was serious at the same time. It's like two things at once...joking around is like, 'You don't have no homework.' [Said in a joking tone.] That's joking around. Serious is like, 'You have homework? That's a drag.' [Said in an exaggeratedly serious tone.] That's serious. So it's like a little mix."

This difference in discussing emotion was also evident in the Self-in-Relationships interview. Nico evinced little ability or willingness to talk about his emotions, though reports from his family indicate that he certainly shows them. In marked contrast, Brooke not only is willing to discuss his emotions, but also expends considerable energy dealing with them, particularly controlling negative emotions: "I put those questions away in the back of my head... . I really don't want to [pull them out]... . It's like a locked door... . All those things you are saying that I don't want to do, 'cause I try to hide those things. I don't open it up. That's my theory. That's why I'm always happy."

Given Nico's avoidance of emotion, it isn't surprising that in the facial recognition test this difference would again show up. Although both boys were moderately accurate at identifying emotional states from facial expressions, Nico's errors tended to follow more of a predictable pattern than did Brooke's. Nico generally
saw emotive faces as neutral, expressing no emotion.

The results of these tests suggest that the problems presented (identifying emotions in tone of voice and facial expressions and analyzing one's own emotional state) are not the same for the two boys. The strength of Nico's left hemisphere is hierarchical sequencing or categorizing; it's good at things like grammar, syntax, and word definitions. In the absence of his right hemisphere, he is weak at processing emotional information. So, perhaps Nico approaches these tonal qualities that express emotion as “pseudogrammatical” memorized categories. That is, relying on the strength of his remaining left hemisphere, Nico is handling affective prosody like a Mandarin language speaker, effectively memorizing tones and their meanings. For him, emotion becomes, essentially, a nonemotional grammatical problem; he interprets emotional tones of voice as categorical information rather than emotional information. "How do I know she is joking? Because I just heard it." That sound equals joking, just as the word "dog" equals this animal I am patting. And he is able to call up and use the required tone when his social situation suggests joking is appropriate.

Brooke, on the other hand, uses the strengths of his remaining right hemisphere: recognizing patterns and processing and analyzing emotion. So, in solving problems, he becomes deeply immersed in the connections between emotion and tone of voice, even when the problem doesn't call for such analysis. For example, during the facial recognition test when all he had to do was label the emotion expressed in the face, Brooke adopted an exaggerated angry voice when naming the emotion on an angry face or a deeply depressed voice to label sadness. This same overreliance on his emotional processing strengths resulted in his making errors on tasks when emotional interpretation was not relevant. He was unable to move beyond looking at and looking for the emotional content in any situation. As we have seen, this hypersensitivity to emotion resulted in his needing to pay constant attention to dealing with and trying to control his own negative emotions.

Both boys, then, appear to be reinterpreting and solving problems by using their neuropsychological strengths, including emotional strengths, associated with their remaining hemisphere, rather than by adapting their remaining hemisphere to act as the missing hemisphere would have. That is, Nico and Brooke are recruiting basic processing mechanisms common to all of us, but they are using them in a new way, to solve problems that would normally be handled by different mechanisms that they lost when half their brain was removed. They are adapting the problems to suit their processing strengths. Rather than trying hard to learn to do what their brains have trouble doing, the boys appear instead to have changed how they think to suit the brains they have.

The boys do not consciously seem to know that they are making these adjustments to their thinking. The way in which their brains are organized and function is a result of their biology, experiences, and
emotional goals (their desire to interact with their peers and to successfully pursue their interests). These, in turn, determine their way of perceiving and making sense of the world and the problems it presents them. Nico and Brooke are simply more dramatic versions of all of us. We all bring certain strengths and weaknesses to our interactions with the world. Using our strengths in whatever way we can manage, we do what we need to do, mostly not knowing exactly how we are doing things.
Q: How does this research apply to teachers in the classroom?

For educators, certain principles arise from the study of Nico and Brooke, principles that provide useful lenses through which to consider many fundamental, time-honored school assumptions, designs, and practices:

- All brains are different.
- One teaching style, one approach, one design will not succeed with all learners.
- What a teacher imagines will be easy can be very difficult.
- A child's brain is remarkably plastic (malleable) but inefficient; an adult's is less plastic and more efficient.

**All brains are different.** They develop, adapt to, perceive, and interpret the world differently. So, it's hardly surprising that learners learn in different ways. Although the recent interest in ideas like differentiated instruction reflects this truth, many people continue to cling to a view of the brain as modular (for example, kinesthetic, visual, spatial learners) and draw a distinction between "normal" and "learning-disabled" brains. This creates an impression that most people have the same brain, except for the group of students getting special services and untimed testing—this despite the insight from neuropsychology that everyone is learning-disabled to some degree.

Research suggests that our experiences, our emotional goals, social context, and particular profile of cognitive strengths and weaknesses shape our brain and determine how we perceive the world and how we approach problems. Viewed from this perspective, it seems inevitable that students frequently will not understand problems put to them by teachers in the same way in which the teachers understand them. As a result, teachers and students are often not looking at the same problem, though they may assume it is the same. So, their ways of working toward solutions will also be different—rather like the old idea that an engineer and a philosopher standing in the same engine room on a ship will not see it or think about it in the same way.

As Mary Helen Immordino-Yang writes, "This implies a need for careful attention to learners' perceptions of the educational problems put to them, as well as a need to design learning environments that support such differences. Students from different cultural and social backgrounds may well interpret the same classroom exercises in very different ways. For example, in a second-grade math class, a student was confused over the correct answer to a problem about whether a six-foot-wide car could park in a seven-foot-wide garage. No, it could not, she explained, because the driver would not be able to open the car door. Clearly, although this student's initial response was labeled incorrect, she had indeed solved the math problem correctly but had gone beyond to consider the personal perspective of the driver. While a
simple example and one that was quickly resolved, it nonetheless illustrates that this student was considering not simply numbers but practical, personal concerns in solving her math problems." (A Tale of Two Cases: Lessons for Education From the Study of Two Boys Living With Half Their Brains).

Students' comments and answers come from their perspectives, which need to be understood and respected. Taking the time and developing the skills to see problems from the point of view of learners may be teaching's greatest challenge.

Here are several important implications:

**One teaching style, one approach, one design will not succeed with all learners.** Given the almost unique nature of Nico's and Brooke's challenges, their teachers were forced to meet the young men where they were and to take their lead from the young men. In this extreme situation, the teachers had no way of predicting how Nico and Brooke would function. So, the teachers needed to study the young men without preconceptions and see what the young men could or could not do, and invent various ways of supporting and helping them to learn and develop. They could not meet Nico and Brooke with a predetermined curriculum based on some standard of "normal" functioning but, instead, had to give the young men the freedom to engage in their own learning. The teachers were not limited to a fixed curriculum with its expectations that everyone can proceed in lockstep toward standards that are based on age groupings and expectations that have been "normed" across populations scattered over an amazingly complex landscape. This freedom to match tools for learning to each young men's strengths may be a major factor in the success of these two boys.

Perhaps this research suggests a need for administrators to rethink our current school models that, like Procrustes' Inn, provide a one-size-better-fit-all bed and then stretch or chop the students to fit it. Graduation requirements, grade point average (GPA), grouping by age, course loads, expectations based on identical standards for all, narrow concepts of excellence and rigor, homework, assessment, learning disabilities—these all look very different in the light of the implications of new research. Teachers can, as they have done for decades, continue to meet the challenges of changing their methods and lessons, but their efforts must be supported by the structures and practices of the schools themselves.

As educators, school leaders belong to this community of professionals who share a responsibility to study the research and consider its implications.

Another implication arose from this research:

**What a teacher imagines will be easy can be very difficult.** Teachers often isolate low-level skills assuming that the skills will be more accessible and easier to learn. At some point, most teachers use drills—grammar, math, science, and music drills—that are intended to isolate skills for intensive, decontextualized practice. One of Immordino-Yang's tests involved pitch contour matching, which asked Nico and Brooke simply to listen to two short phrases with the same number of syllables but different intonation (primarily rising and falling pitches). Using nonsense syllables ("na na"), the boys were asked to match the original pattern. "How are you?" "Na na na?"

Immordino-Yang expected that Brooke, with his intact right hemisphere, would perform well and that Nico would struggle a bit. Instead, Brooke performed significantly worse than his peers, while Nico performed significantly better than his peers. Given these results on a "simple" test, it seemed unlikely that Brooke
would perform well on the subsequent, more "difficult" task of recognizing sarcasm in various real-life stories. Yet, he performed extremely well, leading the researchers to recognize the importance of context for interpretation.

In this case, the social and emotional context of the real-life events producing sarcasm (the stories in the subsequent tests) played to Brooke's strengths, while the decontextualized matching of tones using nonsense sounds offered no meaningful clues to feed his mind. On the other hand, Nico's more emotionless "grammatical" approach jibed nicely with the emotionless task of the "simple" (na na) test. So, for Nico and the "teacher," the nonsense task was simpler; for Brooke, it was more difficult. In a classroom situation, it is likely that the boys' grades would reflect the teacher's preconceptions and expectations: a good grade for Nico, a poor one for Brooke.

This example suggests that teachers need to be very careful when separating skills from the contexts in which we typically use them and equally careful to search individual performance for clues as to how the student perceives and approaches the problem. Simple may not always be simple, even if that's the intention. Some students may be more able to perform a skill in a complex context than to perform it in a stripped-down context. Brooke needed the emotional context to make sense of similarity between vocal tones.

The example also suggests one reason for teachers to consider student responses to problems as data rather than simply reflections of correct or incorrect answers. Data are sources of insight that can be inferred through careful thought and analysis. Correct and incorrect answers tend to be treated as results that can be judged and assigned a grade that accurately captures understanding or ability. Had the researchers simply "graded" Nico and Brooke's responses to the contour-matching task (above the norm and below the norm), they would not have developed their insights into how each boy's brain was processing information. Grading often misses the point about a student's strengths and weaknesses. Teachers and learners need insight, not a GPA.

Here is another implication:

**A child's brain is remarkably plastic (malleable) but inefficient; an adult's brain is less plastic and more efficient.** It was this plasticity that enabled Nico's and Brooke's brains to adapt to trauma; adults suffering dramatic brain damage are less fortunate. A child working through a math problem might run up and down a maze of neural pathways playing with solutions, deciding what information might be relevant, while an adult has developed clear avenues that zip toward a solution past old pathways that have been closed off and forgotten.

Perhaps this difference offers some insight into the difficulty many teachers have imagining what is happening inside a child's mind and into the impatience many teachers feel as they watch children struggle to find the well-worn path that seems so obvious to teachers. If so, it suggests that teachers could benefit from focusing less on answers, less on the what, and more on how and why different students grapple with problems as they do. There are many paths up the mountain. Each student has to grow a new neural network that builds on a good way for him or her to climb the mountain. The more of these possible pathways teachers know, the less likely that students will become lost.

**Glossary**

Procrustes' Inn
In Greek mythology, Procrustes was a the son of Poseidon, who physically attacked people by tying them to an iron bed and stretching them or hacking off their legs to make them fit. When something is "Procrustean," different lengths or sizes or properties are fitted to an arbitrary standard.
UNIT 1: DIFFERENT BRAINS

Section 7: Resources


Q: What is emotion, and why do we have it?

The streets were quiet and dark when rehearsal ended at 2:00 a.m. and Dan started walking to his car. The School of Communications and Theatre had been built on the edge of campus, a relatively new incursion into an inner city of mostly abandoned buildings and smoldering resentment. Normally if people left the building after dark, they called security, which would send a few officers to create an illusion of activity and safety. But tonight, Dan was alone.

As he reached the top of the street where he had parked his car, he saw, down at the other end of the block, two figures pass beneath one of the few dim street lights that still worked. A slight glint reflected from a piece of metal in the hand of the second figure. They wore sweatshirts with hoods, and they turned up the street toward Dan. "Oh, hell," he thought, "this isn't good." He had started toward them at just about the same time they turned toward him. Dan glanced at a walkway that went off to his right toward another university building, dark and empty but perhaps with an unlocked door. A moment of decision. He didn't turn, and he and the figures kept walking toward each other into deepening darkness. Dan's heart raced, and he began to sweat a bit.

Just before he reached his car, the two young men stopped him.

"Got a quarter?" the one in front of Dan asked. The other stood behind him, and carried a large crescent wrench in his left hand. "Sure," Dan said and thrust his hands into his jean pockets with the sudden realization that he was a moron, standing there, both hands trapped, while some guy with a wrench stood behind him. He fumbled with the change he felt in one pocket, quickly producing a coin. "Oh, that's just a nickel." Babbling now, he desperately felt around for a quarter, found one, gave it to the guy in front of him, and stepped out from between them toward his car, as they moved to continue up the street, laughing at Dan, mocking him. He felt that a game had ended—a game that he was doomed to lose. In one outcome

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he lived, and in the other he died. Dan sat in his car feeling sick, shaking, simultaneously filled with fear and elation, and wondering what had happened. Why had he walked toward them? How had he survived? All he could come up with then was that he had been lucky, which was part of it but not all of it.

Today, thanks to insights from neuroscience, we can understand that Dan's emotions saved him. In fact, that's the purpose of our emotions: to keep us alive. This idea that emotions are essential to our survival may be startling; most of us tend to think of emotions as simple (though often powerful) feelings, like joy, sadness, anger, and fear. However, from a neurobiological and evolutionary perspective, emotions are
behaviors and thoughts that are automatically triggered in certain contexts, either real or simulated. Emotions are physical manifestations of our reactions to what is happening around us—the increased heart rate, sweating, gestures, facial expressions, and vocal noises. And emotions produce thoughts about what we will do, thoughts, in a general sense, of moving toward or moving away from the thing that has triggered our emotion. If the trigger offers pleasure (social connection, hope, reward), we usually approach; if the trigger threatens, we typically move away or try to make the threat move away.

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**Measuring Emotional Response to Physics**

Guilherme Brockington, a doctoral student at the University of São Paulo, explores emotional links to physics. He measures relative changes in skin conductivity when experts and novices view...

[View video](http://www.learner.org)
Q: What is "street smarts"?

Take the lowly ant, a simple, nonconscious organism whose behavior and "thinking" are automatic, innate, reflexive responses to stimuli. Each day, it ventures out, genetically programmed to search for crumbs of food to carry to its nest. As it returns along a sidewalk gripping its scrap, it senses the shadow of a large foot, and immediately it scurries into a crack to avoid being stepped on. Once the danger has passed, it continues on its way back to its nest. Clearly, the "decisions" (in the ant's case nonconscious and automatic) to carry the food, to hide to avoid being crushed, and then to continue in the direction of its nest are primitive instances of cognition. Each decision is composed of complex packages of innate responses that enable the ant to react advantageously to particular kinds of situations (moving toward sustenance, fleeing threats). What is essential to understand is that these primitive examples of cognition, the ant's "decisions" and behavior, act together in the service of an emotional goal: to maintain and promote stability and fitness (survival).

Humans, of course, are more complex. In threatening situations like the one in which Dan found himself on that dark city street, we can either decide to flee it to save ourselves or to confront it to save ourselves. However, Dan's decision to move forward was not the result of some sort of rational deliberation during which he consciously weighed his options. He didn't have time.

Sitting in his car immediately after the confrontation and thinking about it later, he realized that emotion had guided his responses, and subsequent reflection has allowed him to make some sense of the emotional decisions he had made that resulted in his survival. His body had become more awake and alert; and though he was really scared, he walked with a confidence that struck him in retrospect as odd but essential. He couldn't appear frightened. That was the reason he didn't take the path to the right toward that other building. It would have signaled that he was running and invited them to chase him.

When they asked for a quarter, he was able to control his voice so that it seemed casual and tired; he knew that both fear and any disrespect would be disastrous, though he made these decisions so quickly that it's difficult now to call them decisions.

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Also informing Dan's behavior was the knowledge that, a few months prior to this moment, a classmate had been killed in a subway station when he refused a request for a cigarette. He had been shot, and subsequent investigations suggested that he had been the victim of a game in which the assailant asked for a cigarette and if the victim gave him one, the victim lived; if he didn't, he died. Dan felt that story
flicker through his consciousness as soon as he was asked for a quarter.

So he was very lucky to have had a quarter (he doesn't smoke), but his behavior and his thoughts during those few seconds were the result of his emotional goal: to survive. Emotion is a form of decision-making. While the decisions of ants are little more than genetic responses to triggers in the environment (finding crumbs of food, avoiding being squashed), people learn from experiences and develop a repertoire of actions that allow them to respond appropriately to different situations. As our world becomes more complex, particularly our social world, so do the situations with which we must deal. If we have good mentors, whether they are parents, older peers or caring teachers, our responses become increasingly sophisticated and nuanced, and we develop the "street smarts" we need to function effectively.

The Amygdala

"The amygdala is basically your brain's burglar alarm. It keeps you alive and lets you know whether you need to fight or..."
– Dr. Abigail Baird

View larger image
UNIT 2: THE UNITY OF EMOTION, THINKING, AND LEARNING

Section 3: Emotion and thinking in the sociocultural jungle

Q: Why do we experience threats to our identity so powerfully?

Although the modern jungle poses more threats from drunk drivers, gang-bangers, and grifters than from the occasional grizzly bear, our emotions continue to work to protect us not just from contemporary predators, but also from the new dangers of the more complex social and cultural jungle we have created. In essence, we have reinterpreted survival, adding a new layer of social well-being to our continuing need for physical well-being. Today, threats to our social identity are experienced every bit as keenly as our primitive ancestors experienced physical threats; both use the same neural and chemical mechanisms.

"My parents are going to kill me if I fail this course." "I'll die if I don't get into Stanford, if he doesn't ask me out, if I don't make the team, if I'm not invited to her party." On one level, these are metaphorical rather than literal expressions, but on another level they bespeak real fears of social "death." We all know stories of young people who killed themselves rather than face social humiliation.

We also know stories of inspiration and great compassion—stories of young people whose emotions have moved them to help others. Consider Pam, for example, a student from an urban neighborhood who grabbed the chance to leave the poverty and violence of her home, where, in her words—"opportunity and advancement were stifled by underfunded schools and withered dreams"—and attend a better school. There she found an adult whose belief in her taught her to "believe in someone else's story and invest in that person's life," a lesson she now applies to young people with whom she works in other cities. Pam's emotional response to the world, based on powerful experiences that have shaped her values, compels her to choose an identity that gives her a sense of well-being and health by helping others.

Human societies have become amazingly complex social and cultural worlds that expand our definition of survival. Most of the decisions we make today determine whether we will flourish or perish in this socially and culturally constructed reality. Lev Vygotsky got it right. There is a culture that shapes our ends. Why does a high school student solve a physics problem, for example? The reasons range from the intrinsic reward of having found the solution to getting a good grade, to avoiding punishment, to helping tutor a friend, to getting into a good college, to pleasing parents or the teacher. All of our private reasons for succeeding at physics have a powerful emotional component and are connected both to pleasurable sensations and to survival within our culture—to living happily in a social world to being loved and respected. Our emotions make us social animals.

Although what we mean by surviving and flourishing is interpreted in a cultural and social framework, our
brains still work to achieve their original purpose: to adapt and manage our bodies and minds in the service of living. These emotional goals continue to operate using our primitive neural machinery (albeit with cortical upgrades) which connects our emotions to our thinking and behavior. We think in the service of emotional goals; the goals that matter to most of us—those that keep us alive both physically and socially—are what motivate us to thought and action.

Dr. Mary Helen Immordino-Yang

"I don't like to think of emotion and cognition as separate things. There's thinking. And thinking has an emotional aspect, and it has a cognitive aspect. You can analyze one aspect or..."  — Dr. Mary Helen Immordino-Yang

View larger image
Q: Doesn't emotion just get in the way of rational thinking?

Phineas Gage (the man whose brain was damaged by a tamping iron driven through his skull, described in Unit 1) may well have provided an early example of the connection between emotion and cognition. However, for over a hundred and fifty years since his accident, conventional wisdom has doggedly insisted that reasoning plays the critical role in governing behavior and that emotions are a largely female distraction that need to be banished to the edge of the settlement to ensure that order is maintained. Then, in the 1980s, Dr. Antonio Damasio, current director of University of Southern California's Brain and Creativity Institute, and others began looking at patients who had sustained damage to emotion-related brain areas and discovered that they could not explain the resulting irrational behavior through cognitive deficits alone.

Like Gage, these patients became oblivious to the consequences of their actions. Although their apparent understanding of social conventions and rules remained intact, their behavior nevertheless violated these norms and reflected no sensitivity to the feelings of others; they also lost the ability to learn from their mistakes. For example, although a formerly able business executive still understood and could explain the risks of an impending deal, he made one disastrous decision after another and eventually destroyed his company. At home, this once affectionate husband no longer offered sympathy to his wife, who had always been able to rely on his support, and his marriage fell apart. Eventually, researchers' attention focused on one particular group of patients whose ventromedial prefrontal cortex had been compromised.

These patients seemed to retain their ability to reason and to recall social rules, even to explain the sort of conventional behavior that might be expected in various social situations. Their knowledge base was intact. They could speak intelligently about future planning or business decisions. However, their ability to make good decisions or to apply the rules of conventional behavior was clearly impaired. It soon became apparent that they could no longer use emotional understanding from past experiences to guide their decisions and behavior in the present.

As we live our lives, we make decisions

and act, and the results teach us about the wisdom or folly of our actions. In effect, we "tag" the consequences of our behavior and store them as emotional knowledge to guide us when we find ourselves in similar situations, faced with the need to make decisions about what we will do this time. Knowing that drinking and driving are not a good combination is one thing; slamming a car into a house at 40 mph after a night of beer and shots adds an emotional dimension to the rule and makes it more likely that our next decision about drinking and driving will be more "reasonable." This is not to say that
experience is the only teacher, for we also learn from emotions that result from imagining the consequences of our behavior.

Patients with ventromedial damage lose the ability to behave rationally because they have lost their emotional rudder. It turns out that reason without emotion is every bit as terrifying and useless as we have always claimed that emotion without reason is. Not only are these patients unable to use emotional tags from past experiences to make good decisions, they are unable to learn from and tag new experiences, so they continue to make one bad decision after another. They have lost the essential connection between emotion and cognition that results in meaningful rationality. When emotions are disconnected from rational thinking, the abilities to think, make decisions, and learn are impaired. It seems that for the village to function, emotions and thinking must live together in the same hut and work together to make sense of the world and to function intelligently in it.

Good Idea?

Prof. Abigail Baird of Vassar College discusses how fMRI studies reveal differences between teen and adult brains when considering dangerous behavior. Evidence suggests that emotion plays a critical...

View video
UNIT 2: THE UNITY OF EMOTION, THINKING, AND LEARNING

Section 5:
Emotional Thinking

Q: How does emotion help me solve problems?

The relationship between emotion and thinking is captured nicely in the unified idea of emotional thinking, a process that can be conscious or nonconscious and that is often both at the same time—as it was the night Dan was asked for a quarter. Emotion guides cognitive learning, as is demonstrated in the Iowa Gambling Task, described below by Mary Helen Immordino-Yang and Matthias Faeth in "Building Smart Students: A Neuroscience Perspective on the Role of Emotion and Skilled Intuition in Learning."

A participant in a study sits at a table with four decks of cards before her. Her task is to choose cards from these decks. With each card she draws, she has the chance to win some amount of money. Unbeknownst to her, certain decks contain cards with larger wins than other decks, but these same decks also result in occasional enormous losses that make them a bad choice in the long run. The participant must learn to play this game by deducing the "cognitive" rules for calculating and weighing the relative long-term outcomes of the different decks. An examination of the player's performance reveals that the process of learning how to play the game involves both emotional and cognitive processing and begins with the development of (generally) non-conscious emotional "intuitions" that eventually become conscious rules that she can describe in words or formulas. The development and feeling of these intuitions are critical for successful, usable knowledge to be constructed.

As she begins the game, she at first randomly selects cards from one deck or another, noting wins and losses as they come. But soon, before she is even consciously aware that the decks are stacked, she begins to show an anticipatory emotional response in the moment before choosing a card from a high-risk deck: her palms begin to sweat in microscopic amounts, measured as "galvanic skin response." Unconsciously, she is accumulating emotional information about the relative riskiness of some decks. As she proceeds, this emotional information steers her toward the 'safe' decks and away from those with high gains but the possibility of large losses. After playing for a while longer, she accumulates enough information about the decks that she is able to describe the rule governing which decks to play and which to avoid, at which point we would say that she has "learned."

The Iowa Gambling Task and other experiments have taught neuroscientists about the importance of emotion in the learning process, an importance that probably applies not just here but to math learning, social learning, and learning in various other arenas in which people must accumulate information from their experiences and use this information to act advantageously in future situations. Emotion guides the learning of our participant much as a rudder
guides a ship. Though this guidance may not be visible, it provides a force that stabilizes the direction of a learner's decisions and behaviors over time, helping the learner to recognize and call up relevant knowledge—for example, knowledge about which deck to pick from or which math formula to apply.

Students struggling with a math problem—or writing, social, or other problem in which they are engaged—draw upon memories of past experiences with similar math problems, searching for strategies that might apply to this new problem. Is it like a distance-rate problem? Can I express it in a quadratic equation? As we approach a solution, we experience a series of small emotional "jolts" of recognition that lead us to feel we are on the right path; we are getting warmer.

Essentially, we feel our way to solutions to problems that matter to us, and that are emotionally relevant to us because we experience them as essential to our physical or social well-being. How do I learn organic chemistry so that I can become a doctor? How do I handle all this homework so that I can maintain a GPA that will make my parents happy? How do I find a new metaphor around which to build this poem to express my feelings and share my experiences with others? If the problem doesn't matter to us, we quickly lose interest. Our attention wanders; we disengage, and we learn only that organic chemistry is boring—though if the grade matters, we will most likely learn strategies for getting the grade without meaningfully learning chemistry.

Depth of Field
Photography teacher Eric Baylin struggled with teaching the technical concept of depth of field. After attending a workshop presenting neuroscience research that reveals the neural connection between...

View video
UNIT 2: THE UNITY OF EMOTION, THINKING, AND LEARNING

Section 6: Implications for education

Q: What is the connection between emotion and motivation?

So, there they sat in Karen's office—one disaffected eighth-grader (Molly), her mother and father, her five teachers, her advisor, and the assistant head of school (Karen). Nine adults, nine talking heads all making suggestions, cajoling, pleading, and painting different pictures of the child's future. For an hour, they invented strategies for Molly, offering deals and rewards for behavior that would result in her succeeding in classes that meant nothing to her.

You could tell by looking at Molly that she was bored, annoyed, and defeated, impatient to be elsewhere. She slouched into the sofa, glaring through a veil of blonde hair at the floor. "God," Karen thought, "all these earnest adults doing all this work for this child." And that, of course, was the problem. The adults had the plans and the strategies. What did Molly have? What was her investment in all this? "Molly," Karen said abruptly, "what do you want to do? What do you think the problem is?" Molly looked up, startled, stunned even. She was accustomed to adults talking at her, making plans for her. "Huh?" she grunted, mouth agape, a suggestion of a sneer of incredulity etched into her lips.

School for so many kids is like a tsunami—something that just happens to them.

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They become passive victims of its power. Teachers droning, bells ringing, chairs scraping, humanity swirling through halls and buffeted from room to room, weighted down with backpacks and expectations, drowning. Too few students experience education as something over which they exercise any meaningful control or that has anything to do with their interests or needs. School is boring or even worse. Yet, if we listen carefully to their voices, we can hear echoes of the lessons that neuroscience teaches us. Like Ian's voice. He, too, hated high school, and saw it as "the state-imposed mandatory four-year sentence. I was waiting for school to end so I could start the real learning and work I wanted to do in my life."

Then he made a life-changing choice. He enrolled in an alternative program that freed him from the usual...
high school requirements and let him study and make films. He spent part of his day away from school at a nearby studio, where he enrolled in film and video classes with adults. For the first time, he felt the excitement of being in a classroom "where everyone was there because they wanted to be."

Ian experienced school as Molly never did, despite all the effort adults made on her behalf. "My program," said Ian, "put 'the system' much more in the student's control. If you failed, you had no one to blame but yourself. All of a sudden, there weren't just dreams or ideas or theories; there were real projects, real deadlines, and real consequences that meant much more to me than getting a low grade on a test."

Teachers know these things about learning. They know that Molly and Ian represent the extremes of a spectrum of meaningful engagement, and they struggle heroically to shepherd their students toward Ian's experience. Neuroscience can help. Perhaps guided by new ways of understanding learning, we can design more learner-friendly schools and experiences for more of our students. Perhaps we can help our students engage in school by encouraging them to take control of their own learning.
UNIT 2: THE UNITY OF EMOTION, THINKING, AND LEARNING

Section 7:
Principles to consider

- Emotion is the rudder for thinking, learning, and decision-making.
- Motivation is rooted in emotional relevance.
- Meaningful learning requires three ingredients: factual knowledge, skilled emotional intuition (emotional tags), and practical understanding of the rules or principles governing the specific area of study.
- The purpose of education is to develop students' abilities to recognize the emotional implications of situations and to help them create increasingly nuanced and sophisticated strategies for acting and responding.
- Social and cultural factors are just as significant inside as they are outside the classroom.

Emotion is the rudder for thinking, learning, and decision-making. The inability of patients with ventromedial brain damage to function, rudderless, in the world emphasizes the critical role of emotion in transferring previously acquired knowledge to real-world decision-making and problem-solving. Without these emotional processes, we cannot move the skills and knowledge acquired in school to novel situations and to life beyond school. That is, emotion seems to play an essential role in helping children to decide how and when to apply what they have learned in school to the rest of their lives.

Of course, emotion is needed to acquire this knowledge in the first place in any sort of meaningful sense. Students who can only parrot what teachers tell them haven't really learned anything useful. They may have learned the skills of memorization and regurgitation, but meaningful learning—internalizing concepts and skills and connecting them to emotional goals—results from emotional thinking. It is significant that children who suffer ventromedial damage never learn the social rules that should govern accepted ethical behavior. Adults who learned the difference between right and wrong prior to their injury still know these social rules after the injury. They can discuss them; they cannot put them into practice. But without the emotional connection, children with this brain damage never even learn them. Emotion is essential not just to applying knowledge, but also to learning it.

Motivation is rooted in emotional relevance. Many teachers understand this truth because the emotional relevance of their own studies attracted them to teaching. The courses they now teach allow them to continue to study the Civil War, speak French, solve problems, or look for evidence that local farms are polluting a nearby stream. Teachers love these things: these things matter, they're important. What's important to the students, on the other hand, rarely finds its way into the classroom. Yet, like Ian, those few who do find emotional relevance in their schooling offer convincing arguments for rethinking
schools.

Consider Ted: "The only thing I felt truly connected to was my poetry writing and English classes. I did poorly in all of the other classes and was on academic probation off and on during my sophomore and junior years. I remember feeling like I wanted to give up if I had to follow the standard coursework that awaited me. I was not engaged, and I desperately needed the freedom that came with a course of study that was created out of my own interests."

Or Andrea: "My motivation changed once I was accepted into this independent program because my interest and involvement with the studies became more personal. I immediately began to think differently about school and what I could do. I felt a brand-new set of doors was opening. I pushed myself because I was motivated to learn more because it was information I was interested in and felt it was important to know."

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**A Student Voice**

(A letter from a high school student to a researcher)

Dear Professor:

I am currently in the eleventh grade. I have been researching your School of Education for the past few weeks, and your field of study in neuroscience and education psychology intrigued me the most. My school and community are extremely focused on academics, including SATs, GPAs, and extracurricular activities intended to create good résumés for colleges. This almost overbearing focus on academia has pushed me to try to understand the reasons for this emphasis and to delve further into the "why" and "how" questions of public education. In studying my school, I began to ask questions about conformity and intelligence. The stereotypes that teachers have of our Asian community made me eager to prove them wrong—to show them our creativity and our abilities beyond memorization and test-taking. I realized the education we were given prepared us purely for middle management in some businesses.

I understand that elementary school and middle school are primarily meant to teach us the basics and provide a foundation, but I could not come to terms with the fact that in high school we continue the same routine: one that suppresses our curiosity and individuality. This year, in my U.S. History class, I was reading about the creation of higher education, which inspired me to research the origins and purpose of education. The system was established to create good citizens, unify society, and teach religion. Also, in order to give voting rights to all citizens, it was necessary that they be educated. I often feel as if we have lost that purpose, and, more importantly, we have lost the enthusiasm for knowledge. The mundane routines of teaching and the strict classroom curriculums and a near obsession, in communities such as mine, with college admissions have replaced a love of learning.

I recently read your piece on the implications of neuroscience for education and the necessity of considering the role of emotional thought processes as a means of attaining our intellectual goals in school. I feel as if this is what my school lacks: an overarching goal, or even smaller goals from topic to topic—an objective that ties together and helps us to understand what we study.

Because of these multiple factors, I have developed an interest in education as an area of study,
Or Cynthia, who described herself as "the type of person who prefers to learn about something that, to me, has relevance. It was clear that those subjects that did have relevance were more interesting; and if I was interested, then the motivation to work and study and learn was there. Basically, once I got going with my program, which entailed working with children with severe special needs at a local nursing home up the road, I felt like my school had meaning, like there was a purpose."

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**Affective Neuroscience**

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*Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University; Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.*

Even a glance at a person's face or a snippet of conversation can reveal vast amounts of emotional data about how the person feels about a topic. However, masked behind furrowed brows or gleaming smiles is a vastly intricate network of neurons that builds the brain systems responsible for emotion and feeling. The field of affective neuroscience has blossomed to reveal some of those intricacies.

Recall a recent exchange, with a coworker or new acquaintance perhaps, during which time you heard about an experience that was foreign to you. As you hear the story, you wonder... Why would she act that way? Why would he say that? That doesn't make any sense to me. Now, compare your desire to relate that fell short to other experiences, often with close friends and confidants, when you felt that you were "on the same page," ready to complete each other's thoughts, and comforted with the sense that you mutually "get" each other. A major difference between these two types of experiences is our ability to relate, in a socio-emotional context, because we can intuit or virtually experience, or not, the mindset and experience of another. Affective neuroscience studies are beginning to parse out the distinction in these experiences and relate them to the ways in which emotion is experienced and processed in the brain.

The emotional brain, in a sense, relies on the very basic neural structures and systems that allow us to maintain our basic sense of well-being. One distinction to draw is between the physical-emotional (exteroceptive) and the socio-emotional (interoceptive) ways in which we can relate to others. The
Meaningful learning requires three ingredients: factual knowledge, skilled emotional intuition (emotional tags), and practical understanding of the rules or principles governing the specific areas of study. Motivation, purpose, engagement—these are the qualities most teachers long to see in their students, the same qualities that prevent adults from burning out in their jobs, and the same qualities that neuroscience connects to emotional relevance and the central role that emotion plays in learning. Teaching for understanding, cooperative learning, portfolio assessments, differentiated instruction, project and service learning, and online courses are just some of the latest creative solutions many teachers have developed to make their classrooms positive experiences for students. And for some students, these innovations have helped. For others, simply having teachers who care about them as individuals worthy of all this invention has helped.

Yet, the system does not seem to be succeeding. Too many students continue to drop out—if not actually, then effectively; too many learn too little; and too many teachers become frustrated, anxious, and cynical. Our expanded understanding of the brain and how and why it learns suggests that the system may be flawed. At a time when it is fashionable to blame teachers, the critics may be ignoring a deeper problem. If the system is flawed, and if the assumptions and basic structures of schools are at odds with how the

RESOURCES:

brain learns, then all the innovation in the classrooms seems little more than well-intended jerry-rigging.

The purpose of education is to develop students' abilities to recognize the emotional implications of situations and to help them create increasingly nuanced and sophisticated strategies for acting and responding. Emotional relevance can have many sources: innate curiosity or ability, the discovery of a new idea through exposure to the rich variety of human endeavor, or the enthusiasm of a parent or teacher. It will always be important for adults to expose young people to the possibilities the world has to offer, and it is useful for teachers to help students connect their studies to their lives. But we must also consider that schools might be so much more successful if they were truly conceived and structured to nurture students' curiosity and encourage them to pursue their interests, changeable though they are—from kindergarten (where children's interests already tend to influence curriculum)

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right through college (where choosing a major again allows students to pursue a deep interest).

In addition to an emotional goal, meaningful learning requires three ingredients: factual knowledge, skilled emotional intuition (emotional tags), and practical understanding of the rules or principles governing the specific area of study. Factual knowledge alone is useless without a guiding emotional intuition, and intuition grounded in insufficient relevant experience will be equally useless.

Social and cultural factors are just as significant inside as they are outside the classroom. From the perspective of affective and social neuroscience, the purpose of education is to develop students' abilities to recognize the emotional implications of situations and to help them create increasingly nuanced and sophisticated strategies for acting and responding. In the area of disciplines like math or history, for example, this means, in essence, helping students begin to think like mathematicians and historians—building a base of knowledge and successful experiences solving problems so that they can become inventive as they feel their way to solutions to increasingly complex problems. Of course, this level of engagement depends upon caring about math or history.

In the world outside the classroom, the goal is essentially the same: to help young people develop increasingly nuanced and sophisticated strategies for acting and responding to whatever life throws their way. While too many young people find little emotional relevance in their studies, they are frequently overwhelmed by their emotions as they navigate the cliques and shifting friendships in the sociocultural jungle of the hallways, cafeterias, and locker rooms, or as they struggle to make decisions about their plans for the future. (It is important to note that these realities of everyday life can make good starting points for engaging students in math or history.)

We all have automatic emotional responses to events and situations, whether real, imagined, or remembered. A fight with a friend, a sad movie, or the memory of recalling a family vacation can trigger an emotion that signals its presence through various physiological changes. Our heart rate changes; we sweat; we feel nauseous or incredibly good; we close our eyes or reach out or hit. These physical changes are accompanied by all sorts of thoughts: I'm no good; I hate her; I am the greatest; how can I get out of here with the least amount of embarrassment? Although these emotional responses are automatic, they are not simple. They are complex responses shaped by our knowledge and experience. Thus, as we mature and have more experiences, our emotions become increasingly complex.

Young people generally are still developing sophisticated ways of understanding or dealing with their feelings and emotions. Often, they misread their or others' emotions—or even trigger an emotion that is
not appropriate to the situation—and miss what is really going on. For example, they can easily misread a comment or facial expression as a threat, especially to their sense of who they are, and can be quickly swept away by negative emotions and accompanying thoughts of worthlessness. These feelings, in turn, can feed off each other and spiral out of control. (How many times have teachers marveled at a student's angry response to what the teacher thought was an innocuous, even supportive comment?) On the other hand, sudden, unwarranted enthusiasm can also lead them quickly astray—into dangerous relationships and behavior.

As we mature and gain more experience, we learn to rethink and reinterpret these reactions in order to build more advantageous ones. The process of maturing involves feeling and understanding our emotions and learning how to change our thinking so that we can induce, regulate, and use our emotions in productive ways. Shakespeare was right: "There is nothing either good or bad but thinking makes it so." Survival in the sociocultural jungle means feeling good about ourselves in relation to others. If one of the goals of schooling is to socialize young people, then helping them develop strategies for invoking advantageous and appropriate emotions and for feeling, understanding, and regulating their automatic, complex emotional responses is essential.

(Opened ScienceTalk sidebar)

**The Work of Marc Brackett**

**Insulted**
- You're ugly
- I know
- I have been told this
- You're silly
- I know
- I have realized this
- You look like an alien
- I know this has been pointed out to me
- You have big eyes
- I know I have looked in the mirror
- You can't be a pilot
- You're not smart enough
- It is possible, I have considered this
- With every insult you invent, it's strange but it's true
- You point out my many failings and help me to improve
- As you highlight my many weaknesses you also highlight my strengths
- My openness leads to my kind personality
- My silliness brings laughter to the world
- My resemblance to movie aliens only highlights my intelligence
- My big eyes portray my feelings and widen my view
- I may not make it as a pilot, but I could be
- You see, every insult you invent gives me a view into your mind
- And although I have many problems, I feel sorry for you
- Why oh why do I feel sorry for you?
Because your mind cannot break free
The wall of insults you build limits your mind and feelings
So soon if you don't stop, you'll turn inhuman
And have the biggest problem of all
Loneliness
Think about it

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University; Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Navigating the socio-emotional landscape of childhood and adolescence for many students trumps the most difficult of academic challenges. One challenge, however, is that schools focus on training academic skills and problem-solving strategies, whereas the how-to's for dealing with socio-emotional challenges remain often implicit and unexamined. A child may leave his third-grade classroom knowing how to attack a multiplication problem but have no approach to dealing with the playground bully or his anxiety about his performance on a standardized test. A skilled social butterfly may feel the trauma of failing a social studies test because she fears the repercussions, real or perceived, from her parents and not talk about them. In both cases, the students lack appropriate strategies for navigating how they feel and deciding what they will do with those emotions.

Marc Brackett, a scientist based at Yale University, has dedicated his career to researching, developing, and implementing explicit knowledge and strategies around feelings, emotions, and relationships. The work of Brackett and his team focuses on using and understanding the terms and terrain of the socio-emotional landscape. Impressively, following participation in classrooms that use Brackett's RULER Approach, students and school staff not only add an enhanced vocabulary for verbalizing emotions and feelings, but also learn to judge their own feelings, empathize based on the emotional state of another, and understand intentionality and how emotion and behavior are linked. RULER is an acronym for five key emotion skills: recognizing, understanding, labeling, expressing, and regulating emotion. The benefits of this program have been shown to extend from the socio-emotional realm to academics, classroom climate, and student behavior.

Bringing about change in social and emotional learning (SEL) is not a simple process. To effect such changes requires more than adequate funding or a few teachers with high levels of compassion. To promote a healthier socio-emotional environment for staff and students in a school, Nicole Elbertson, Marc Brackett, and Roger Weissberg (2010) identify some key elements:

- Support of school leadership and active involvement of staff
- Appropriate training of staff members in principles, theories, and practice elements
- Well-coordinated efforts for implementation with adequate treatment fidelity
- Matching school culture and program goals and strategies
We have to take the time to feel our emotions, to feel what our automatic responses to situations actually mean, and to make sense of them. The impact of an emotion on our body and mind alerts us to the meaningfulness of a situation and invites us to make sense of it. For example, Amy participated in an experiment to study reactions to stories meant to induce admiration for virtue. While listening to a true story about a young blind German woman who learns the Tibetan language by ear, invents a Tibetan Braille system, and travels to Tibet to start a school for the blind, Amy's emotional response is visible in her body: widened eyes, erect posture, slow and deep breathing, and open mouth.

At the conclusion of the story, the interviewer asks Amy what she feels, and she responds, "Extremely impressed because she went above and beyond. I think I also just respect her for not only helping herself out of her own situation and making the best of it, but for trying to help other people's situations as well, especially those who are less fortunate. [long pause] I found the story very motivational, too. It kind of makes me reflect upon my own life and realize that considering that I haven't had as extreme, like, uncontrollable circumstances as a lot of these people [whose stories are featured in the experiment]... . It makes me realize, well if they can do that despite, like, whatever hardships they have, then I definitely should be making more of my resources in my life." Clearly, Amy is guided through a process of transforming her emotional response into feelings and meaning and discovering her motivation to seize the opportunities in her own life.

Teachers constantly work with young people to help them understand their reflexive emotional responses. People have emotional triggers, and both teachers and students must be conscious of the potential for firing these. Whether with a more reflective adolescent like Amy or a 7-year-old bully, caring teachers take the time to develop their students' insight into their own feelings so that they can improve their ability to manage emotion and interact productively with the world. If emotion is our rudder, it makes sense to help young people learn to steer their own course and perhaps share William Ernest Henley's claim: "I am the master of my fate: I am the captain of my soul."

It's also important to recognize that social and cultural factors are just as significant inside the classroom as they are outside it. Wherever learning happens, it is not a rational or disembodied process; neither is it a lonely one. Learning is all tied up in our social relationships and our cultural context. We learn with our teachers and our classmates and our parents. This is true even if we are by ourselves. We always function—make choices, interpret meaning, derive motivation—within a cultural framework. At the very least, mom and dad and their expectations are forever within us, whether we are striving for them or reacting against them. We can't check our culture or our emotions or our bodies at the door to clear the way for rational thinking. Schools need to be rethought not as ivory towers of rationality, but as community
centers of emotional thinking.
UNIT 2: THE UNITY OF EMOTION, THINKING, AND LEARNING

Section 8:
Resources


UNIT 3: SEEING OTHERS FROM THE SELF

Section 1: Monkey see

In the mythology of *Star Trek*, Vulcans like Spock repress all emotions in an attempt to live a life of pure reason. In order to share experiences, thoughts, memory, and knowledge with other individuals, they resort to the Vulcan mind meld, which requires physical contact—placing the hands on the head and face of someone else to establish a conduit between brains. Humans, on the other hand, use emotion to link minds. We intuit the thoughts and motives of others by observing physical behavior and facial and bodily expressions, listening to vocal clues, and trying these out on our own neural networks. We notice the flushed face, the slight tremor of the lip, and the shift in vocal pitch and internalize these by imagining ourselves in some ways as if we were experiencing these changes. We experience these changes vicariously in the appropriate parts of our brain, and we sense the emotional state of the other person and imagine his or her thoughts. This simulation of the emotional cues of others allows us to infer their thoughts and goals, using networks of interconnected brain areas that, together, are responsible for all our various skills, behaviors, and sensations. In essence, we understand others through our understanding of ourselves.

Q: How do mirror neurons work?

A few years ago, a macaque monkey watched an Italian researcher walk into a lab eating an ice cream cone. Giacomo Rizzolatti and his team had taken a break from studying the neurobiology of delayed gratification but had left the monkey wired to the single-cell recording apparatus. So, they noticed the surge in activity in a certain part of the monkey’s frontal cortex each time it saw the researcher lift the cone to his mouth to take a lick. What these researchers discovered was that the same parts of the motor cortex used for planning actions were activated when the monkey did no more than watch someone perform an action that it found both familiar and interesting. The monkey had tasted ice cream cones before, so it knew what the researcher was doing; presumably, the monkey needed its previous experiences in order to understand the researcher’s actions. And so began the discovery of a basic biological mechanism that enables us to understand the goals and to imagine the feelings of other people, a mechanism with the...
slightly misleading name of "mirror neurons"—an important mechanism for empathy and learning.

New evidence suggests that this neural activity of "mirroring" occurs in areas where perception and action converge. In these areas, information from our senses might tell us that it's snowing, the road is icy, and the car approaching us is going much too fast. So, we step back quickly onto the curb. These are areas of high-level sensory association and motor planning.

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Development and learning have long been understood to involve increasingly complex cycles of perception and action. We internalize our interactions, our sensory experiences, with the world and construct ever-improving skills for acting in it. But our experiences don't have to be real; they can be simulated or imagined and experienced as if they were real. Hook up a tennis player to an fMRI (functional magnetic resonance imaging scanner) and ask her to imagine playing, and neural activity will occur much as though she were running about on the court, though, not surprisingly, to a lesser degree.

Significantly, when the monkey observed the researcher pick up a pencil and use the same motion to bring it to his mouth as though he were going to eat it, there was no corresponding spike in neural activity in the monkey. This lack of activation indicates that the monkey's experiences with ice cream cones, its memory of eating and enjoying food, were critical to its empathic response. It appears that the monkey understood the goal of the researcher's action with the cone but not with the pencil; the cone-goal relationship meant something to the monkey and elicited the mental simulation of the action. So, it seems that mirror activation requires a shared understanding of the goal implicit in the actions being observed.

As a high school teacher who had once wrestled on a team in middle school, Bill always tried to attend wrestling matches at the schools where he taught. He found them exhausting. For as he watched, his body constantly tensed and contorted as he simulated the various positions and struggled in his imagination along with the wrestlers, trying to pin an opponent or escape a hold. At the end of each three-minute period, he consciously relaxed his muscles, easing himself back to a position that more closely resembled sitting. Colleagues with whom he sat at matches and who had never wrestled told Bill they tended not to have this physical reaction. It seems that understanding the goal of a certain move, like grabbing an opponent's wrist to shift his weight in order to set him up to dive at his legs and take him down, was critical to internalizing what he was watching. On the other hand, watching field hockey, which Bill never played, quickly bored him—no internal identification or understanding, no simulating the experience, and no interest.

A mirror, then, is a slightly misleading metaphor, for a mirror suggests passive reflection as opposed to a shared understanding of and active participation in goal-directed actions. Mirrors reflect whatever passes in front of them; the mirror areas of the brain are more selective. To the monkey, the researcher's action of moving a pencil toward his mouth is meaningless. The monkey has never done that, or if it has, the experience wasn't particularly memorable. So, mirror activation does not occur. By contrast, when the monkey observes the licking of an ice cream cone, which it has tasted and enjoyed, the goal is apparent, interest is engaged, and the mirror neurons fire.

It may be, then, that this "mirror" property forms the most basic biological mechanism by which we internalize and learn from another person's thoughts and actions. Although mirror neuron systems don't tell the whole story of how we process social interactions, they do provide an explanation for our ability to internalize and "read" the goals of others as a starting point to feel and understand their actions and
emotions.

**Glossary**

<table>
<thead>
<tr>
<th><strong>motor cortex</strong></th>
<th>An anatomical location in the brain in the posterior (back) region of the frontal lobe responsible for motor planning, control, and execution.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>mirror neurons</strong></td>
<td>Term describes an important neuroscience discovery at the turn of the 21st century regarding brain systems that show similar patterns of activation when engaged in, and observing others engaged in, familiar experiences.</td>
</tr>
</tbody>
</table>
How does empathy work?

Like a candle within a jack-o-lantern, emotions are the physiological light within us, shining outward through our eyes, body postures, and behaviors. And, of course, we are not single, independent agents. We are part of a society of jack-o-lanterns glowing in the darkness, inferring information about the candles illuminating those around us. As social beings intent on thriving in a culture, we care about what others think and feel, especially about us. We look for signs of displeasure or affection in our partners, bosses, children, and friends.

If you take some time to dwell on the picture above, you might notice changes in your physiology—perhaps your respiration slowing or a relaxation of muscles you were unconsciously holding tight. The picture might elicit a sigh of contentment. These physiological changes are a natural response to the emotions manifested in these people and even in the dog: their proximity to each other, the touching and embracing, the hints of smiles, the physical relaxation, and the vulnerable and open position of the dog. The picture becomes a trigger for our emotions, stimulating physiological changes and thoughts and feelings.

Emotions are social in the sense that the behaviors that comprise them can be visible and public, but they also lead to the private experience of feelings. We can see the bodily manifestation of the emotions in this family, but not the private and subjective experience of their feelings. Empathy allows us to infer their feelings and their thoughts because we imagine ourselves as if we are they in these physical postures and relationships. We imagine that we know a lot about what they are thinking.

Notice here that the emotions that each of these people and the dog are experiencing—the physiological state of their bodies—are quite similar. However, the feeling of this emotional state is different for each, based on the developmental level and sociocultural knowledge that each brings to the moment. That is, the father experiences or feels his emotion in the context of his role in the family, as the man who is responsible for these children and who has certain memories of and hopes for them. He feels his emotion
in a "fatherly" way. At the same time, the dog probably simply experiences the emotion that results from being bonded to these people, without any meaningful or socioculturally attuned reflection.

The people in the picture and our reaction to them provide a sense of the relationship between our biology and our experience: Our emotions are automatic biological reactions—packages of physical changes, behaviors, and thoughts. These reactions are shaped in part by our experiences, our culture, our socialization, and our learning. Although we do not purposely control the physiological package of behaviors that accompanies them, we can learn about what triggers our emotions, and we can learn to interpret them in more and more complex ways. The experiences of those in the picture give meaning to their emotions. They share the same physiological manifestations of their emotions—the rosy cheeks, the calmness, and the slow breathing.

However, the father may experience his physiological well-being as happiness because his children are thriving and as pride in his ability to provide a certain kind of life for his family. The younger boy may simply feel happy to be able to spend some time with a father who is often away at work. Although those of us looking at the picture cannot know for certain what any of them are feeling, our relaxed physiological response, our similar experiences, and our shared cultural understanding allow us to infer meaning that we assume is very close to the meaning felt by those in the picture. We look at them empathically, assuming that their feelings reflect experiences that we also have had. Our emotions, feelings, and thoughts seem aligned.

However, this alignment is more fragile than we often imagine, for it depends on shared experiences within a shared culture. This picture would likely elicit a very different reaction if shown in Korea, where people don't normally snuggle with dogs. Or try this experiment: Look back at the picture and pay attention to the changes in your body and mind as you interpret the interaction of these people in a new context—such as imagining that the man is recently divorced. Suddenly, the emotional context changes, and we might find ourselves feeling sad and thinking very different thoughts as we simultaneously empathize with and pity the different people in the picture. We are able to simulate or imagine this new situation in the sense of inferring a new goal for the man based on a new understanding of the context. We might imagine him enjoying a weekend visitation after two weeks of separation from his children. We might notice, too, a different interpretation of the look on the older boy's face, a hint of ambiguity that, in our original response to the picture, we overlooked.

The point is that context matters. The context in this picture and the experiences of these people determine the meaning each finds in this moment together. Context determines how we react to the picture. And context, both the classroom and the experiences students bring to it, affects the emotions of our students. (Note: This exercise is intended to demonstrate a point. This man is not divorced; he is the happily married friend of one of the authors.)

Like all emotions, empathy rides on the neurological platform of the body and the "self"—that sense of a "real me" (my needs, my desires, my beliefs) that is formed from our experiences.
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Philosophers and theologians have speculated about the relation between mind and brain for millennia. More recently, psychologists and neuroscientists have taken up many of the same questions. A wide variety of views about the nature of the mind and brain have been offered over the years, so philosophers have come up with broad labels to categorize the different views.

Materialism comes in many varieties and is the most popular position in contemporary science. The central idea for materialists is that the mind is nothing but the brain. This basically means that all statements about the mind can be translated into statements about the brain, without remainder. There is only the brain and the physical world. What we consider to be the mind is merely epiphenomenal, inessential, and, to some, illusory.

The various proponents of idealism espouse the opposite, maintaining that the brain is better thought of as a by-product of the mind. The broad idea here is that mental phenomena are causally prior brain processes. For example, some idealists will argue that the mind’s grasp of universal truths, such as those of mathematics and logic, suggests we have access to a realm of ideas that is fundamentally irreducible to, and somehow constitutive of, the physical world. These kinds of “mind-only” views are less popular than they used to be, but still find strong support in some philosophies and religions, such as Buddhism.

Interactionism is a group of views in which the mind and brain are seen as distinct yet intimately interrelated, with causality running in both directions. According to these views, the brain and mind co-create one another in an evolutionary dynamic, a kind of psycho-biological boot-strapping, with the brain giving rise to the mind that then, in turn, reshapes the brain. Many contemporary psychologists and philosophers are interactionists, although experiments aimed at proving these views have been inconclusive.

Finally, monism refers to views in which there is a category of existence more comprehensive than both mind and brain. Monists argue that there is only one basic ontological reality. It has many dimensions that can be differentiated for heuristic and practical purposes, but ultimately questions about the relationships between mind and brain are misguided from the start, entailing a category error. These views are uncommon and found mostly among philosophers. The aim is to transcend but include the distinction between mind and brain, seeing them both as partial aspects of a more fundamental reality.

Questions about the relation between mind and brain are important in education, especially for those who want to use neuroscience to inform policy and practice. For example, the current popularity of materialism lends credibility to the idea that problematic students simply have problematic brains — “their brain made them do it.” Taken to an extreme, these trends could replace personhood with brainhood and change the very nature of education. If the personality or self is removed as the locus of agency and replaced by a semi-deterministic biological process, education could become primarily about methods for building better brains, as some proponents of psychopharmacology and
We see ourselves in others, and we understand others by simulating their actions and circumstances on the same neurological structures that keep us alive or maintain our sense of social well-being. Critical to this process is our ability to recognize the goals inherent in the actions we observe, which means that actions that appear random—actions seemingly unconnected to any goal—either go unnoticed or are misunderstood because we assign an incorrect goal to them. And randomness tends to be in the eye of the beholder. The behavior of most people, even of delusional paranoid schizophrenics, is goal directed; there is an internal logic (I stabbed her because she is an agent of the CIA, which is after me) even though it may appear random to others. Too often, what happens in classrooms can seem random because students and teachers fail to understand each other's goals.

Glossary

Gordian knot
It is often used as a metaphor for an intractable problem solved by a bold stroke (“cutting the Gordian knot”). In Greek legend, the Gordian knot was the name given to an intricate knot used by the peasant Gordius, who became King of Phrygia, to secure his oxcart. Oracles foretold that, not only would Gordius become King, but he who untied the knot would rule all of Asia. Alexander the Great severed the knot with a powerful stroke of his sword.
Q: Why is empathy important to learning and teaching?

Learning in social contexts, like schools, depends on recognizing, understanding, and sharing goals. If people do not recognize that another's actions are goal directed, simulations will not be activated, and the intended learning may not occur. Learners must understand teachers' goals, and teachers will be more effective if they understand their students' goals. Of course, as we have seen, in addition to understanding goals, teachers and learners must share a sense of the emotional relevance of the goals. It's possible to understand others' actions and goals but not to care about them. To foster meaningful learning, the goals must both be understood and matter to teacher and student. Most of us have been in classrooms in which the goals seem either misunderstood or misaligned—or both.

For example, Mr. Davis stands in front of his ninth-graders and begins a lesson that asks students to identify direct and indirect objects. He writes two sentences: "Sally kicks the ball to Sam," and "Sally kicks Sam the ball." The students, with Mr. Davis's help, will circle the subject, underline the verb, box the direct object, and star the indirect object. The goal is crystal clear to Mr. Davis, and he has explained it to his students. They have studied sentences, sentence parts, and parts of speech several times before. Mr. Davis begins: he asks questions, discusses the suggestions he gets and marks the words.

Sarah looks out the window at the soccer field, where she notices her coach getting ready for the afternoon game. Jamie stares at the white board, sees the first group of words and the marks: circle, underline, box, but no star. So he follows that pattern when marking the second sentence, making "Sam" the direct object. When Mr. Davis points out that the second sentence should have a star over "Sam" and a box around "ball," Jamie is quick to pick up the new pattern. "Ball" in both sentences is in a box, so why not a star over each "Sam"? Bob, who sits in the back row next to Sarah, a pretty girl whom he likes to make laugh, cracks a joke about Jamie. Clearly, the goals in this class are not shared. Sarah has more important things on her mind. To Jamie, the teacher's actions appear random, though he tries to figure them out, and it may be that Jamie's actions appear equally random to Mr. Davis. But everyone understands Bob's behavior.

Hallie Cohen, a music teacher at a public school in Ohio, had a class like this one. She teaches classes of as many as 45 middle school students, many of whom have no musical background. "I struggle with communicating and being able to pave a clear path between my knowledge and what I want to impart to students. The most effective way that I have found is through demonstration. But demonstrating has its limits. My toughest class to instruct was a group of seventh graders, a violin class. I had a small group within that class that had a different agenda from mine. They were hellbent on making my life and others' lives difficult. So my struggle was to get them on the same page.
as the rest of the class without compromising instruction. The biggest lesson that I had to teach this class was how to work as a team: they had to be able to be part of a violin section in their school orchestra. Teaching teamwork to kids who are struggling with their identity and who have an inherent lack of respect for people in authority is challenging."

Although Hallie's goal and her students' goals seemed to conflict, she realized that they shared a common thread: the desire to communicate. The students wanted to gab with each other about social stuff, and Hallie wanted them to work with others to communicate through music.

Re-examining her class using the idea of aligning the teacher's goals with those of the students, she developed the plan of having them use the violin as an instrument for social communication. She began by having them work in small groups to develop skits about any social topic, whatever was going on in their life, but they were not allowed to use words to communicate with each other. Instead, they had to use the violin to create sounds that would express what they wanted to say to each other in the skit, and the audience would then guess what the skit was about.

At first, the students acted silly, but then the challenge of the game engaged them. As they became more involved, they began to understand that the purpose of the violin, of any musical instrument, is to express feelings and thoughts to someone else in a musical medium. The students connected with the violin as a way to connect with each other. Hallie's intervention succeeded because they used the violin in a way they could understand by connecting it to their goals.
she and her students had overlapping...
Q: Why don't people do what they know they should do?

This process of simulating the actions of others within ourselves, on the neural machinery that regulates and senses our own internal body states, enables us to do even more than infer the mental states and goals of others. Our mirror systems and our ability to empathize also may be the basis for our most complex moral and ethical decisions. When we see someone in pain, either physical or emotional, we vicariously feel some aspects of that pain, a response that often induces compassion. And when we watch extraordinary feats of skill or virtuous behavior, our ability to simulate the experience internally and to understand and interpret it based on our world knowledge lays the basis for admiration. And both of these emotions, compassion and admiration, can motivate us—to emulate Mother Theresa or help the victims of Hurricane Katrina or develop the skill of LeBron James.

Mary Helen Immordino-Yang and her colleagues recently conducted an experiment to study the neurobiology of admiration for virtuous behavior and compassion for social or psychological pain (see "The Study," in the next section). Their discoveries may provide deeper insight into the relationship between the mind and the body driving emotion, particularly as these interact to produce intrinsic motivation. The data revealed that even the most complex, abstract emotions—those that require maturity, reflection, and world knowledge to appreciate—do involve the highest sorts of brain networks, but they still get their "punch," their motivational push, from activating basic biological control structures in the lowest (most primitive) parts of the brain. Motivation, it appears, comes not simply from understanding the cognitive aspects of a situation, but also from the ensuing recruitment of the same biological drives that literally regulate the body's survival, including breathing, beating the heart, controlling blood pressure, and adjusting hormones.

And so, although research is still in progress, studies on emotion may provide a key to understanding one of the most persistent frustrations teachers confront: the great gap between students' good intentions and...
their actual behavior. Almost like patients with ventromedial damage (see Unit 2), students often know exactly what to say; they know that the social norms and expectations—they know that success depends on their practicing better study habits, planning their time better, and resisting more attractive temptations. They know that they should be kinder to each other, more respectful of their parents, and more willing to help others. Yet, they walk away from motivational talks with their teachers leaving a trail of promises floating like empty candy wrappers as they hurry back to their friends and parties.

"Why didn't you study last night as you promised? Why didn't you keep your promise to meet Paul at the senior center on Saturday to help? Why didn't you come by for extra tutoring?"

"Oh," they say, "I guess I just didn't feel like it." And that, it seems, may well be exactly the reason, as neuroscience is discovering. People have tended to think of motivation as a conscious, cognitive function under our control. "Decide what you want to do, pull yourself together, and do it"—the old willpower-and-bootstrap theory of success. Neuroscience is revealing that the relationship between the body and the brain likely plays a critical role in motivating our thinking, learning, and behavior, both on conscious and nonconscious levels.

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We have a brain whose original purpose was to ensure our survival. It regulates functions such as our breathing, heart rate, blood flow, and hormone levels. It allows us to feel the state of our body, to feel its harmonious functioning, or to alert us to malfunctions like disease or stubbed toes. It guides us to food and friends or away from predators. The brain links our body and mind and supports complex processes responsible for emotion, thinking, feeling, and behavior, both nonconscious and conscious. As we developed into more complex social beings, this same mind-body system, the same primitive brain parts, enabled us to experience feelings of well-being or threat in the social world—and to feel these with the same intensity and loaded with the same significance as they came to our ancestors in the red-in-tooth-and-claw physical world.

(Opened ScienceTalk Sidebar)

Motivation from the inside and out: What motivates learners to action?

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Incentivizing behaviors, on scales large and small, is a pervasive goal in educational settings. Research dedicated to discovering what it takes to motivate a learner to action has revealed insights that clarify just how much—and how—externally driven versus internally driven motivation and incentives work. Here, we focus on one of several researchers who have explored questions in this domain: Kou Murayama and his team have used both behavioral and neuroimaging techniques to study motivation, emotion, and cognition.

Personal Goals in Context
The majority of studies on motivation have focused on what Murayama calls "personal achievement goals." For example, one type of personal achievement goal is how a particular student is performing relative to personal or peer expectations (Murayama and Elliot, 2009). Murayama and his colleagues make the case for an additional dimension focusing on classroom goal structures. Examples of classroom goal structures are those that emphasize performance and ability (termed "performance-approach goals"), such as the achievement expectations and academic standards subscribed to by the instructor and students. Murayama also is interested in the potential for interaction between personal and classroom goals. Consider that the prevailing approach for measuring motivation occurs either at the individual student level or as an aggregate of classroom performance indexed by averaging across students. Both approaches obscure information at the intersection of the individual and the classroom.

This work has expanded the focus of the types of questions that can and should be investigated by contextualizing personal goals in classroom settings so that student motivation profiles can be understood as they interact with classroom practices that are meant to motivate students. In practical terms, this work highlights an important concern of many educators: creating a classroom environment that communicates to learners that the teacher's expectations for performance are as important as the motivations the learners bring with them.

**Neural Correlates of Motivation**

Early studies investigating the impact of extrinsic motivation have focused often on monetary reward, a straightforward tool used in research to determine whether and how payment motivates a person to want to achieve a specific outcome. Murayama and colleagues (K. Murayama, M. Matsumoto, K. Izuma, and K. Matsumoto, 2010) used brain-imaging methods (functional magnetic resonance imaging, fMRI) to study what the neural correlates of motivation are and how these correlates are affected by monetary reward. Their behavioral and neural findings revealed the following patterns:

- **Behavioral Findings:** When a monetary reward was offered for completing a task, participants were less likely to be intrinsically motivated to engage in the task independently when the reward was later eliminated (in comparison to a group that was never offered the monetary reward to begin with). In essence, participants didn't pursue a task when they were accustomed to getting an external reward, while those who never got the reward were more likely to be intrinsically moved to do so.

- **Neural Findings:** Neural correlates reflected a boost in activation for systems supporting intrinsic motivation associated with monetary reward, followed by a sharp decline in activity in brain systems linked to reward and valuation when the monetary reward was no longer available.

**Motivation and Education**

Taken together, these findings provide evidence that extrinsic rewards can boost motivation, but only as long as the reward is available. In addition, external rewards actually undermine internal motivation. When the reward is removed, the motivation to engage in the task and the associated neural correlates are less than they are if a reward is never offered. This effect suggests the need to rethink how both learners and teachers value rewards and emphasizes the need to ensure that goals and rewards are aligned. If educators aim to harness and foster internally driven motivation, the use of temporary extrinsic rewards may undermine that goal, especially in the long term. This research provides an opportunity to consider how to improve educational practices so that they are as effective as possible in motivating learners for the appropriate reasons.

**REFERENCES:**
What does this mean for our social lives, particularly for our moral behavior? Our ability to empathize, to experience emotions based on our inferences about the minds and feelings of others, plays out on this same mind-body system. We discover that even our most exalted moral feelings and behavior (that which we claim make us most human) also may rely on this same primitive system, though the system is activated differently in the social world than it is for basic biological needs.

While our reactions to physical threats are instinctual and automatic, high level moral motivations, though grounded in the same basic system, result from complex, nuanced knowledge and critical reflection. Admiration for Mother Teresa, for example, relies on values (altruism, a belief in a responsibility to alleviate the suffering of others, a sense of a greater good) that are culturally transmitted and results from thinking about the suffering we see around us. Our experiences living in the world also contribute to our developing the values through which we view Mother Teresa’s behavior. We need to have suffered a bit ourselves in order to intuitively recognize the suffering of others and to appreciate the efforts of someone like Mother Teresa to alleviate suffering despite difficult obstacles.

However, although this sort of knowledge and cognition is essential in the moral realm, the motivation to do anything—to do, for example, what we know we ought to do—also may depend on this primitive system. In other words, the research suggests that those who want to flourish in the social world by pursuing meaningful goals may derive their motivation to act from the same system whose original purpose is to support basic survival through maintenance of the body. In essence, they feel like doing the right thing (often expressed as a "gut" feeling); but without that feeling, they may not do anything, no matter how good their intentions.

Using Emotional Content in the History Classroom

At Boston Latin High School, Judi Freeman teaches a course on genocide and the Holocaust. She has incorporated video
testimonies of the Holocaust collected by the USC Shoah Foundation Institute for...

View video
Q: How do we develop empathy? Why do we need time to direct our attention inward?

As you may recall from Unit 2, basic emotions comprise our reactions to situations—we notice certain constellations of provocative circumstances, and our body and mind cohere around a strategy for responding. Our muscles contract or relax; we approach or ready our muscles and minds for flight. But what about complex, abstract situations that pose no immediate threat or offer no immediate help? Might even our reactions to these situations continue to honor their evolutionary history, calling into action basic readiness, even though our fight is for a moral cause, rather than for physical safety or comfort?

To find out, Immordino-Yang asked participants to listen to true stories about real people, stories meant to evoke admiration or compassion. The experiment involved videotaped interviews, fMRI scanning, and collecting psychophysiological data (such as heart and respiration rates). One story was about a young boy who grew up in a small city in China during an economic depression that often left him and his family hungry. John, a participant in the experiment, was shown a video clip in which the boy's mother describes how, one winter afternoon, she found a coin and used it to buy warm cakes for her son, who had been in school all day with nothing to eat. Despite the boy's hunger, he offered his mother the last cake, which she refused by lying and telling her son she had already eaten.

After the video, the experimenter asked John how this story made him feel, and John responded, "[Of the stories featured so far in the experiment], this is the one that's hit me the most, I suppose. And I'm not very good at verbalizing emotions. But ... um ... I can almost feel the physical sensations. It's like there's a balloon or something just under my sternum, inflating and moving up and out, which, I don't know, is my sign of something really touching ... . And, so, the selflessness of the mother ... and then also of the little boy. You know, having these wonderful cakes that he never gets to have, and he still offers them to her ... and then her turning them down, is ... uh ... [long pause]. It makes me think about my parents, because they provide me with so much, and I don't thank them enough, I don't think ... . I know I don't. So, I should do that."

John's response offers a clear picture of the interplay between physical sensations in the body (the signals of his emotional response) and the feelings and thoughts that these lead him to discover and articulate. He responds to the story using his own physical and psychological self, his memories, his feelings, his thoughts—all in the service of making sense of the story and of his emotional response to it, and he arrives at a discovery about a change he needs to make in his
behavior to his own parents. John comes to a motivated state that, despite its complex cognitive influences, certainly doesn't present itself as a purely rational manifestation that engages only his consciousness.

(End of first column online)

It also is deeply rooted in the nonconscious systems that keep us alive, that make us act, that organizes and regulates the functioning of our body.

As the fMRI revealed, activation extended all the way into the brain stem, far below the level of awareness, into the systems that keep our bodies alive, our most primitive depths. So, it seems, conscious thinking about the story combines with nonconscious gut reactions to produce the necessary motivation to stimulate meaningful action. Both processes, the cognitive and the emotional, work together and are necessary.

(Opened ScienceTalk sidebar)

**What happens when we are at rest? Why the brain’s default system is anything but resting**

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Imagine the scene: A teacher wraps up a lesson and calls on a student, Alex, to answer a question, but he is obviously not paying attention to the lesson because he is day dreaming. Not surprisingly, the teacher is frustrated—how can Alex learn if he is always disengaged with her lessons and in his own head? Well, neuroscience may shed light on this, and the answer may surprise you!

When a person spends time reflecting, without the distraction of external stimuli but rather being absorbed by personal thoughts, the default mode (DM) of the brain is activated. The DM relies on a distributed network of regions near the midline of the brain, tucked deep within each hemisphere. This system is considered to be a complementary attentional system to that recruited when a person is asked to attend to externally driven information, as would happen in a classroom when a teacher is instructing. One of the most exciting advances in neuroscience research since 2000 has been the identification of the DM. The relevance of this brain system was not immediately apparent but has since become an active area of research, including understanding how the DM relates to education and to the development of the learner.

What Alex's teacher and, indeed, nearly all of the educational contexts we encounter demand is attention to externally driven processing of information, such as a lesson or demonstration. Attention can toggle between information generated by others that is externally directed to an internally driven focus on topics of personal relevance. We regularly ramp up the externally driven attentional system
and necessarily ramp down the internally driven system, and vice versa. In Alex's case, he was focusing attention inward while his teacher was expecting him to focus outward. Could there have been any benefit to Alex's daydreaming?

The recent history of understanding the activation pattern of the brain when not engaged in a specific task set the groundwork for understanding Alex's behavior. The most important lessons to date are several. First, the live brain is never idle or at rest; however, when individuals are not directing attention outward to a task at hand but inward to personal thoughts, a unique brain activation pattern begins. Second, the default mode of the brain has been associated with self-awareness and reflection, recalling personal memories, imagining the future, feeling emotions about the psychological impact of social situations on other people, constructing moral judgments, and other psychosocial mental processing. Furthermore, activity in this brain system has been linked with performance on measures of both intelligence and reading ability.

The lessons for education based on the default mode of the brain will emerge slowly. But so far, it appears that when we are internally reflecting, we may be developing systems that are critical for socio-emotional health and understanding. This discovery suggests that we need some sort of balance between external and internal focus in order to reach our potential and that both attentional systems are skills that require practice to develop. In some contexts, such as in violent communities, students may be trained to overly employ the outward attention system to the detriment of developing skills associated with the inward attention system. Working together, educators and neuroscientists have an exciting new framework to consider the next time a student, like Alex, gets lost in daydreams. He may or may not be internalizing and integrating information from the lesson at hand. Perhaps he is processing a fight he had with his mother or creating the lyrics for a song that expresses his feelings about some aspect of his life. But chances are good that he is doing something. And what he is doing may well be what is most emotionally relevant to him.

Taken a step further, perhaps it is possible to create classrooms that invite students to internalize the day's lessons by choreographing a productive fluctuation between external and internal focus and helping students develop the skill of toggling between these attentional states in order to make sense of the lessons. For example, if Alex's internally focused attention could be harnessed to process how his learning relates to his sense of self or his understanding of others, then his time indeed would be productively spent. Among educators, the most common concern is how much attention a student is paying to the task at hand. Now research is making progress in understanding what happens when attention is not being outwardly directed. The next wave of research might benefit from focusing on what is happening when students are asked to focus not outwardly but inwardly. If current research continues to develop in the direction it has taken so far, we may be able to understand how internally focused attention is crucial for an individual's development of sense of self, relation to others, and understanding of others.

REFERENCES:

At one point, John's recounting of his feelings about the story echoes Amy's response (Unit 2, Section 7) to the story of the blind woman who opened a school for the blind in Tibet. (Amy reported that she "found the story very motivational.") Both had a similar long pause before moving from their feelings about the story to talking about how the story has made them look more deeply at their own circumstances and feel motivated to take action toward others. In turning inward, they reflected upon the stories as a means to experience the internal, psychological self, or the "real me," and to access their memories and to feel what these meant to them in relation to the stories. This process of inward reflection leading to meaningful analysis and a feeling of motivation requires more time than processing, which is externally directed. John and Amy both paused as they looked more deeply into the significance of their reactions to the stories they heard.

The area of the brain that becomes active when this internal reflection occurs also becomes active when we daydream, but it is suppressed when we turn our attention outward to the external world. Perhaps this slower internal focus on the self is essential for finding meaning. Perhaps neuroscience offers a biological basis for Wordsworth's observation that: "The world is too much with us; late and soon, Getting and spending, we lay waste our powers: Little we see in Nature that is ours."

To see a classroom implementing these findings watch "Music and Emotion." View Video

**Empathy**

Research participants listen and react to stories designed to evoke social emotions such as admiration and compassion. The neural activity deep within the brain, including nonconscious systems that...

View video
UNIT 3: SEEING OTHERS FROM THE SELF

Section 6: Implications for schools

Q: What does it mean to build schools for learners rather than for teachers?

Principles to consider:

- Schools must make room for the self of the students.
- Learning depends in part on mirror neurons and our ability to simulate.
- The goals of teachers and students must be aligned.
- Motivation to take moral action may derive from engaging in meaningful reflection about others' situations in relation to one's own.

"I just need a place where I can be myself." This was Jill's assessment of what was missing from her life in school, her feeling that school had nothing to do with her interests or goals. She spent hours in classes and doing homework that felt alien to the "real her." Experience suggests that she speaks for hundreds of thousands, maybe millions of students. School is not typically a place for the self, at least not the self of the student.

For example, during a department meeting, William, an English teacher, sneers at the fuzzy notion of the self, smelling the suspicious odor of low standards and "nonsense" like self-expression and self-esteem ("self-of-steam," as one former student humorously heard it). "What on earth is this self?" he asks as though holding it by two fingers at arm's length.

"Well," responds a colleague, "it's rather like your affection for Hemingway. You tell me he speaks to you, he touches some core of truth within you, and you love to read and teach his books. It's like that wonderful scene in The History Boys when Hector (I think that's his name), the old English teacher, is explaining the moment when you read a truth that you thought you were the only one to feel. Hector says something like, 'At that moment, the book reaches out and takes you by the hand, and you know you are not alone.' The book speaks to your self, speaks to that jumble of emotions and beliefs and memories and understandings that you experience as you. The book matters to you, and you feel it in your body and mind. When what you study and who you are come together, your education starts to matter to you."

Neuroscience seems to suggest a powerful case for making room for the self of students in school. The self is the platform on which we construct an understanding of the world and of others. We internalize our interactions with the world—whether with people or concepts—and give these meanings based on our experiences and our sense of how to thrive in this world. Our mirror systems—our innate ability to simulate and imagine, our sensitivity to the emotional responses of our body and our ability to make sense of these emotions by feeling them and reflecting on them—are critical tools for survival. Schools that take seriously their responsibility to help young people become skillful at using these tools
might look very different from our current institutions. They also might feel very different to students. One difference could be that students’ studies come to matter to them so that learning becomes more important than merely amassing grades for a college résumé; learning becomes emotionally relevant. But the most dramatic difference might be that students become attuned to physical and mental changes that signal the presence of an emotion that needs to be felt and understood. Perhaps the emotion is the result of skilled intuition, a gut feeling that is guiding a student toward a solution to a problem. Perhaps it signals a response to someone else's tone of voice or a look that needs to be reassessed. Schools that take emotions seriously as indispensable to and inseparable from cognition and learning might well achieve their lofty claims to "teach the whole student."

Our brain’s mirror systems and our ability to simulate experiences are powerful allies for learning. "If" is the "open sesame" for the imagination.

More than 100 years ago, the Russian actor Constantin Stanislavski created an entire system of acting based on "the magic if," a system of training actors to improve their skill at imagining themselves in the situations of characters they played. The goal was to induce the proper emotions within themselves and more powerfully move the audience. In an interview, Marlon Brando, a great American actor who was trained in the Stanislavski method, was asked by a skeptic how he could portray a murderer if he had never murdered anyone. He responded that he had killed a fly. His answer suggests that once we have experienced the irritation that results in squashing an insect, we can imaginatively induce the emotion necessary to kill a person and communicate that emotion on stage.

This is the same technique English teachers have used for years to get students to imagine the lives of fictional characters—to "walk a mile in someone else's shoes," as Atticus Finch advises in To Kill a Mockingbird. Some great scientists also have stood on the platform of the self and felt their way to solutions to problems that mattered to them. Jonas Salk, inventor of the polio vaccine, said, "When I worked on the polio vaccine, I had a theory. I guided each [experiment] by imagining myself in the phenomenon in which I was interested. The intuitive realm ... the realm of the imagination guides my thinking." Einstein imagined riding a beam of light and discovered relativity, and Nobel Laureate Richard Feynman imagined himself floating among electrons and discovered new insights into physics. Such imaginative role-playing (imagining you are a character or an object) is likely to trigger mirror systems and help develop empathy and learning.

Too often, schools treat imaginative ability as "nice," perhaps something for the arts department, but as secondary to the real business of rational, rigorous, intellectual work. The evidence suggests that this point of view is not likely to produce large numbers of creative, effective thinkers.

Teachers’ and students’ goals must be aligned for meaningful learning to occur. Although more and more teachers over the past few decades have taken this responsibility seriously by stating their goals or writing them down for students to read, understanding the goals of someone else requires an emotional, not just an intellectual, recognition. Therefore, teachers cannot assume that stating a goal means the students have understood or internalized it. In fact, they may well have internalized an entirely different understanding than the teacher intended. In addition, aligning goals also requires teachers to understand students' goals, for it is the teacher who is ultimately responsible for creating the circumstances that bring
the goals together.

Of course, it is easier to align goals if students and teachers occupy the same classrooms for similar reasons—if the students have come because they want to learn chemistry or film or how to write poetry or how to work with special needs children. At the moment, most schools are not designed with this idea in mind, so teachers must work much harder to lasso the social goals that interest most young people (like figuring out who they are and who will accept them) and pull them into the corral. What if we imagine new ways to design schools based on a new understanding of how people learn—new structures, new practices, and new policies to support the imaginative work that many teachers are doing despite being hobbled by the old ones?

It may be that to develop the sort of morality that motivates us to take socially significant action requires that we reflect on events and people that inspire us. Perhaps schools need to help young people become more skillful at directing their attention inward in order to feel this inspiration—a process that requires more time than schools often allow for deep thinking or reflection. Schools constantly claim that their mission is to produce good citizens, yet so many of the motivators remain external—grades, college readiness, pleasing parents, and the ubiquitous fear factor. And conditions in the classroom tend not to foster meaningful reflection. Perhaps our ends and our means are not aligned. What do we mean by "good citizens"? Is neuroscience offering insight that might be useful to achieving this goal? Could it be giving us a glimpse into the survival and self-related processes underlying social behavior and creativity?

Peer Mentoring

Music teacher Hallie Cohen recognized that early adolescence is a time when making connections to other kids is a very powerful motivator. As a result, she began creating structured time for peer...
UNIT 3: SEEING OTHERS FROM THE SELF

Section 7: Resources


Q: Why are we calling some children "learning disabled"?

Henry Ford's invention of the assembly line at the start of the last century introduced the concept of mass production that revolutionized how consumer products were manufactured. Prior to Ford's invention, each car was built individually by a team of skilled mechanics expert in virtually all aspects of automotive assembly. Ford realized that, by making each car identical to the next, he could eliminate the need for tradesmen skilled in all stages of assembly. Instead, the assembly could be broken down so that each mechanic worked at a station specializing in just a single phase of the process. Cars would be passed down a line from station to station as identical copies of each product were built, reducing costs and improving efficiency.

When Henry Ford was growing up, children who lived in rural parts of the country typically attended school in a one-room schoolhouse. Henry Ford went to such a school for eight years of his life. Ironically, as Henry Ford grew up, not only did our nation inherit the innovations he pioneered for mass-producing consumer-products, but we also moved toward a wholesale adoption of a system of education that in many ways resembled the assembly-line process Ford used to manufacture cars. Though the suggestion that schools treat children as if they are cars on an assembly line is in many ways preposterous, the belief persists that our current school system works best, matriculating students with the greatest efficiency, when children can be treated as if they are identical, one to the next, passed from station to station down a line from kindergarten to graduation.

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**Advances in Genetics and Neuroscience**

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While educators were grappling with the changing metaphors for teaching and learning, the fields of genetics and neuroscience had been undergoing revolutions of their own. Efforts to map the human genome gained momentum in the 1990s and early 2000s, and technologies for genetic analysis became cost-effective and widely accessible. For the first time, it became practical to identify the
genetic makeup of thousands upon thousands of people for a single research study, making it possible to understand how individuals compare in their genetic makeup. The intersection of genetics and education suggested that we might finally understand learning from the very basis of a person's being. However, rather than simplifying the story, the genetics of learning revealed a complex and intertwined narrative complicated by factors such as a person's development, the influence of genes on one another, and the context or environment. To date, no single gene has been discovered to determine the kind of learner a person will be. Even focusing on a specific learning disability such as dyslexia has revealed that multiple genes are potential contributors to that learning profile. Most important, scientists showed that the labels commonly used in education, like dyslexia, are not reflective of how genes are organized.

One advance in genetics and neuroscience that has reshaped the field comes from the Generalist Genes Hypothesis by Robert Plomin and Yulia Kovas, geneticists who argued that learning abilities and disabilities stem from the same genes. Have damaged genes for math? Damaged genes for reading? Not quite: This hypothesis offers a scientific basis for why academic difficulties do not come down to a "gene for X." In fact, genes underlying difficulties in one area—like reading—are often implicated in another—like math.

At the same time the field of genetics was undergoing a revolution, neuroscience was experiencing its own advances. Sophisticated brain imaging techniques became more common research tools by the end of the last century, allowing scientists to "look" into the brains of living, awake individuals, noninvasively, to investigate activity in the brain. Rather than relying on individuals with a brain injury to determine how the brain processes information, scientists could answer questions about how brain areas work together to achieve the feat of learning, whether that referred to juggling, reading, or musical talent. So much remains to be discovered about the workings of the brain as they relate to learning. To date, however, the brain has become appreciated as a dynamic, interactive, plastic, and complex organ that continues to reveal itself slowly through neuroimaging experiments about typical and atypical development. Even our understanding of the visual cortex, housed in the back of the head, has evolved: blind individuals recruit the visual cortex.

**Glossary**

**visual cortex**
An alternate term for the occipital lobe, located in the back of the brain, that is primarily responsible for processing of visual information.

Obviously, children are not identically produced cars, and schools are not assembly lines. And yet, one of the greatest challenges facing teachers in the classroom is how to address the tremendous diversity present in each and every class, and cope with the range of learning differences a classroom can present. Students can differ in the way they learn for any number of reasons. These reasons can be socioeconomic: perhaps the student needs to take on an afterschool job to help out with the family and doesn't have time to study. Or, the reasons can be socio-cultural: perhaps the student is frequently up all night texting or playing video games and isn't getting the sleep she or he needs to learn effectively. Other reasons may be related to how students process information, such as whether they have difficulty
sounding out words from their spellings, or whether they are easily distracted.

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While the range of factors that determines the diversity of learning in a given classroom can be exceedingly broad and complex, certain aspects of this diversity can be understood in terms of neuroscience. In this unit, we will examine some neurological factors that influence learning diversity, and will begin to think about the strategies that teachers can adopt to begin to address the needs a typical classroom presents.

Richard Konicek-Moran liked to tell the following story based on his research. He taught in New England where the weather is cold. All his students knew that when it's cold outside, you put on a down jacket to stay warm. Konicek-Moran was curious why his students thought the coat kept them warm. So, he gave his students thermometers and asked them to predict what would happen if their thermometer was wrapped up in a cocoon of down. Virtually all of his students predicted the temperature would go up. But, when they tried the experiment, they were surprised to see that wrapping a thermometer in down didn't make the temperature reading increase. Many blamed their equipment. They insisted that their thermometer had to be broken. So, they tried thermometer after thermometer only to discover that all of the thermometers in the classroom had to be broken! Very few arrived at the expected scientific explanation: that the jacket is just an insulator, incapable of generating its own heat.

In this example, the cause of the students' learning difficulties was clear. The children grew up in New England where it's cold, and their experience with down jackets led them to believe that down generates heat. But, in many cases, we can't so easily understand why some children appear to have difficulty learning. All too often, if we don't get the results we expect, when we don't understand, just like Koniceck-Moran's middle school students, we tend to blame the equipment: The child isn't learning because the child is "broken." Sometimes, we even go so far as to label children as "learning disabled": unteachable and incapable of learning.

As we'll discover in the following sections, neuroscience tells us that it's not that the child is "broken," but rather that our teaching approach may be inappropriate, given the needs of the child.

Neuroscience can provide clues as to why certain forms of learning can be difficult for some people but easy for others. Armed with this knowledge, there are many things teachers can do to help students learn more effectively, and these are some of the ideas we will explore in this unit.
Q: Can "disabled" be "normal"?

Nestled in the shadows of the nation's capital is a remarkable institution known as Gallaudet University. As signed into law by Abraham Lincoln in 1864, Gallaudet was originally known as the "Columbia Institution for the Instruction of the Deaf and Dumb and the Blind." Because today virtually all of its students, faculty, and staff are deaf, most classes are conducted in silence, using sign language. At Gallaudet, it's not normal to speak, and one's voice is essentially useless there. The hearing visitor, unschooled in American Sign Language (ASL), cannot even so much as beg for a sip of water without asking for help from a translator.

Turning Tables at Gallaudet University: What is "Normal"?

Hearing is not the norm at Gallaudet University. It is a university for deaf and hard-of-hearing students. The campus is fully adapted for life without sound. Where possible, structures avoid right angles, so people who cannot hear someone approaching can see who is nearby. Halls are built extra-wide to accommodate students who gesture while walking side-by-side. Every room is equipped with a button outside the door to flash the lights inside, which substitutes for a knock.

As at any college, the dining halls are alive with students excitedly chatting and gossiping, but hardly a sound is made.

Instead, students communicate efficiently using hand gestures that are punctuated by animated movements of the face and body. Students talk on the phone using videophones located throughout the campus. People who are able to hear and are unschooled in ASL, who outside Gallaudet may think of themselves as "normal," are likely to feel very much inferior and out of place in this society where people speak so eloquently with their hands. In effect, those who are "normal" outside become "disabled" inside, turning our definitions of "normality" and "disability" on their heads. Unless people can master ASL, those who are "normal" outside the walls of Gallaudet will be unable to learn, or even use their voice to perform basic important life functions, once inside. On the other hand, those who are deaf, who work and reside within Gallaudet, do not perceive their life in silence as a hindrance or a loss.

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As at any college, the dining halls are alive with students excitedly chatting and gossiping, but hardly a sound is made.

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In the context of Gallaudet, the person who is "normal" is the person who is handicapped outside Gallaudet. This important fact serves to remind us of something we all know that is all too often forgotten: "Normal" is a relative term, and "normal" or "typical" are not synonyms for "better." As educators, though few of us regularly deal with students who are deaf, all of us are faced on a daily basis with students who exhibit a broad range of differences in ability. Though one student may perform more poorly than others at doing some task in some specific context, it is important to recognize that if this context is changed, or if the task is modified in even a small way, this same student who performs poorly may outperform his or her classmates. Our job as educators is to recognize the degree to which we can influence how well any given student may learn, by simply restructuring the environment or by changing the context for learning so that a difference that was once a disadvantage can be turned into an advantage. Let us look at some of the ways the neuroscience of teaching and learning can help us to do this.
Teachers often despair that students don't pay attention in class. Easily distracted, all too often students chat with friends, listen to iPods®, and text on their phones during times when we expect them to be paying attention to the lesson and whatever else is going on in class. When we encounter this kind of behavior, often our first reaction is to assume the thermometer is broken, that it's the child who has a "behavior problem" and that it's the child's fault that he or she isn't paying attention in class. But just as people vary in how well they are able to see and hear, abilities for attention are tied to neurology, and it is perfectly natural for such abilities to vary among children. Therefore, it is the teacher's job to provide students with a variety of options to help them attend to the material, regardless of how their brains may be wired.

Any classroom will have a few students who have exceptional abilities for attention, as well as a few who are challenged in this area. As professional educators, we don't want to choose which of our students will or will not learn from us. We want all of our students to learn. So it's our commitment as professionals to understand how differences in attention interact with our teaching, and then adjust our approach so that we reach all of our students, not just a few.

We may assume that students who are best at paying attention are the ones who will learn best. However, it may be surprising to discover that, in some circumstances, the students who are least able to pay attention may be the ones who are able to learn best. Let's begin to look at how understanding the neurology of attention can help us to be more effective teachers, who are able to reach and affect an entire class.

Success Story: Dr. Stephen Shore

Educators supporting students with autism face many challenges in providing them with a meaningful education. Dr. Stephen Shore, Professor of Special Education, who was diagnosed with autism at 18... View video
how many times the ball is passed.

(Opened ScienceTalk sidebar)

Anyone Can Be Disabled

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Dr. Matthew H. Schneps is the George E. Burch Fellow in Theoretic Medicine and Affiliated Sciences at the Smithsonian Institution, director of the Laboratory for Visual Learning at Harvard-Smithsonian Center for Astrophysics (CIA), and executive director of the Science Media Group at CIA.

At the end of a long, hard day's work, perhaps there's nothing you'd rather do than sit down in a comfortable chair, put your feet up, and curl up with an interesting book. But then, just as you're getting deep into the story, an inconsiderate neighbor fires up a leaf-blower, creating a racket that makes it impossible for you to concentrate on your interesting book. Libraries have "Quiet, please" signs for a good reason. If you're trying to concentrate on reading an especially difficult passage, the last thing you want is your attention competing with a distraction that interferes with your ability to learn.

Reading invokes a complex network of attention that serves to reduce our sensitivity to distractions. But, in situations where our senses are overloaded (say, by someone talking loudly in a library), these irrelevant sensory inputs can overwhelm the brain's ability to focus attention, and learning can become difficult. When your attention becomes divided among many different things at the same time, your ability to concentrate on any one of them is diminished, and learning is impaired.

From time to time, every one of us, without exception, has experienced attention overload caused by sensory distraction. Perhaps the source
of the distraction is an auditory input (say, a person gossiping in the library). Or, maybe what's causing you to divide your attention is something visual (a flashing neon sign outside the window). Or, perhaps the distraction is tactile (a particularly scratchy tag in your shirt). Sometimes, the source of distraction is internal: pain from a sprained ankle, hunger pangs from a skipped meal, or even a persistent nagging thought (remember to buy milk). While we can control how we allocate our attention to a certain extent, more often than not our neurological attention networks are responding involuntarily to sensory inputs from our environment, and there is very little we can do to control this.

When we experience attention overload, we become "learning disabled," at least as long as conditions of cognitive overload persist. You are probably familiar with the consequences: You may find it difficult to follow a complicated train of thought, your reaction times may become slowed, and you may find it difficult to perform precise controlled movements (like threading a needle). When we experience attention overload, all sorts of negative stress-related emotions automatically kick in. We feel frustrated, incompetent, and out-of-control. It happens to all of us.
UNIT 4: DIFFERENT LEARNERS, DIFFERENT MINDS

Section 4:
Learning

Q: What does it mean to learn?

Nothing is quite as frustrating as when you are standing in front of a class giving a lecture, and the students look bored and don't pay attention to you. It feels disrespectful, and eats away at your feelings of competence as a teacher. And yet, even though students are more likely to sit quietly and "pay attention" to a teacher who is entertaining and who is able to "command attention" in class, research shows that such qualities in a teacher don't necessarily correlate with student achievement.

That is not to say that attention doesn't play a role in learning. On the contrary, research in neuroscience shows that attention is a pivotal part of the learning process for many types of learning important in school. However, the word "attention" means different things to different people. For example, if your spouse says, "You never pay attention to me," then you know you're in trouble. In this context, the word "attention" is used to connotate a lack of respect, consideration, courtesy, or politeness. But, when neuroscientists use this term in the context of learning, usually they are talking about something very different from the everyday sense of the word.

Attention, in the neurological sense of the word, is not necessarily something a person is able to control, so it has nothing to do with respect or politeness. Instead, neuroscientists use this word to talk about a complex neurological network that helps the brain manage the flow of information coming at it and to filter out information that is irrelevant, while enhancing sensitivity to information important to the task at hand. Attention, in the neurological sense, is a little like the switches and lights in a train yard. The brain is being bombarded by information (sights, sounds, smells, tastes, and sensations) coming at it from the senses, and attention networks act like the track switches and signals to control this flow so that the result isn't just a pileup and chaos.

Attention acts in two ways. It serves to reduce (inhibit) our sensitivity to distractions and enhance (facilitate) our sensitivity to things that are important. For example, when we focus intently on some task (as you are doing now reading this text), inhibitory attention networks are automatically being called into play, and these diminish your sensitivity to sounds and peripheral visual distractions that may detract from the task. At the same time, the attention networks help you become extremely sensitive to the smallest details in the text. You can more easily distinguish subtleties, differentiate one letter from the...
next, see the patterns making up words, and quickly make sense of their meaning.

If the brain had unlimited capacity, attention networks wouldn't be necessary. We could simultaneously pay attention to all the sensory information bombarding our nervous system and process this information accordingly. However, we cannot pay attention to everything at once. Our neuronal resources are limited, and we need to be selective in how our brain allocates the limited resources that are available. This is where attention comes into play.

**Attention Varies**

People vary widely in how well their attention networks serve to control the information bombarding the brain. First, people differ in how sensitive they are to sensory information. Some people can hear high-pitched sounds others cannot, some can see differences in colors others cannot, and some may be very sensitive to touch. So, the amount of information that the brain has to deal with, which comes in on any given sensory channel, differs from person to person. Furthermore, people differ in how well their attention networks filter out the information that comes in. Some people can concentrate intently, focusing on a book while the TV is blaring, while even the slightest sounds would distract another person. Therefore, abilities for attention vary from person to person, sense to sense, and task to task. Some people may be very good at concentrating on something that is interesting to look at, filtering out even the sounds of someone calling their name, but may nevertheless be easily distracted by the scratchy sensation of a tag in their shirt.

Ordinarily, we think of learning as something students do when they master the material presented in class, so that they do well on assessments. But, from the standpoint of neurology, this process is extremely complicated and difficult to describe. We can instead think of learning more simplistically. Learning might be thought of as a process that takes information coming into our minds through our senses, so that we can build

*(End of first column online)*

mental representations of these inputs that remain in our minds even after the sensory inputs have ceased. We call these mental representations "memories." When seen in this way, learning is what we do when we build new memories from information we perceive through our senses. Learning is powerful because we can access, recall, and mentally manipulate these representations, long after the original sensory input has ceased. Attention networks play a role in learning because these networks determine which streams of sensory information we can access to use in building new memories.

Memory is not well understood by neuroscience, but there are a few properties of memory that have been well studied. For example, it is known that there are different forms of memory, and that these are distinguished by how fragile the memory is and by the quantity of information the memory can hold. Short-term memory sometimes lasts for only a fraction of a second and can barely hold a handful of elements. For example, if a number string is flashed on the screen, you might only be able to recall a few of the numbers, and even then not remember them for more than a few seconds after the event. However, other forms of memory are capable of holding information for a long time. This form of long-term memory is durable and seemingly expandable without limit. For example, maybe you learned a poem or
lines from a play in elementary school and committed it to memory: "What's in a name? That which we call a rose by any other name would smell as sweet." And perhaps those are not the only lines that you've memorized and committed to memory. Yet, such memories sometimes remain accessible for a lifetime.

One theory of memory that applies especially to words is that the volatile short-term memories are converted into longer-term memories that are stable through a process of repetition, sometimes referred to as "rehearsal." For example, if somebody tells you his or her phone number, in order to remember it for more than a few seconds, you might silently repeat the number to yourself, saying the number over and over, rehearsing it until your memory of this number feels stable.

(Opened ScienceTalk sidebar)

Labels Hurt

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People differ in their abilities for attention, and people who are diagnosed with neurological conditions such as attention deficit hyperactivity disorder (ADHD), dyslexia, and autism spectrum disorders often struggle with challenges pertaining to attention and short-term memory that are persistent and outside their control. People with dyslexia and ADHD can be very sensitive to distracting influences in their environment. And people with autism spectrum disorders (and some with dyslexia) can have an opposing difficulty disengaging their attention, so as to shift their awareness and notice something unexpected in the environment.

Though the cause of the attention issues may be neurological, their impact on learning is the same: These students experience the same attention overload any of us feel when our attention is pulled uncontrollably in directions we don't intend. Learning suffers and negative stress-related emotions automatically kick in. These students end up feeling exactly the same way we all do when we're overloaded: frustrated, incompetent, and out-of-control. And the negative consequence of this emotional response is to compound whatever difficulties these students are already experiencing. The net result is that these students find it difficult to learn, and performance suffers. As teachers, we often find ourselves feeling powerless to help.

Image Source: © National Institute of Environmental Health Sciences.

When our classroom includes students with specific neurological diagnoses, it can be very difficult as a teacher to avoid the temptation to label these students "learning disabled" and walk away. They're broken thermometers. We are tempted to think: Of course, they can't learn. But, as we discussed earlier, such reactions are just our human response to things we don't fully understand. When something
Attention interacts with learning in a number of ways. First, attention alters the quality of the sensory input. Have you ever tried to listen to a conversation at a noisy party? Even though it's difficult to follow the thread of the conversation, if the discussion is interesting, you're able to hear and make sense of the conversation despite all the noise and distraction. Attention is what allows you to follow the conversation by directing neurological resources toward sensory events of interest, inhibiting information that distracts. Thus, attention promotes learning by improving the quality of the information perceived by the brain, to ensure that the brain is receiving information coming primarily from the informational event we want to learn.

Have you ever tried to remember a phone number while a friend tries to distract you by saying some random numbers? Attention helps build memories by keeping such distractions at bay, and this allows...
rehearsal to take place unimpeded, enabling the information in short-term memory to make its way into stable long-term memory. If your abilities for attention are poor, or if your attention is otherwise overloaded, you are more likely to be distracted during rehearsal, and this distraction, in turn, could interrupt the process required for building stable memories.

(Opened TeacherTalk sidebar)

**Neuroscience-based practical tips for directing student attention**

*Julia Volkman is a Montessori mentor who works with the Springfield, Massachusetts Public Schools. Here are some techniques about guiding student attention that she shares with fellow teachers.*

First, teachers can help by physically putting their attention on the stimulus of interest. That means you need to have a stimulus of interest and not just be a talking head. This is particularly important in some cultures (as in many Latino cultures) where it is impolite for a child to look an elder directly in the eye. They are taught to look away or down in order to show respect. If teachers say, as we often do, "All eyes should be on me," they can actually be causing stress and conflict in a child from such a culture. Instead, they need a visual aid: a map, a globe, a graph on the chalkboard, an image in a slide...someplace where children are able to focus their vision.

Also, it's best if the visual aid is not text but requires some interpretation. While reading text is automatic (Raz and Buhl, 2006), associating a photo with a concept is not. It requires encoding and association and that improves retention (Medina, 2008). Thus, photo-based slides draw interest and attention to key concepts, invite storytelling to explain those concepts, and create a more elaborate encoding mechanism thereby improving memory (Medina, 2008).

Next, teachers can incorporate movement in the presentation. For example, rather than hand out materials, have children come up and get them. Poll the students after 10 minutes by asking everyone to stand up and then ask them to sit down if they respond a certain way to a question you ask. The question should not put the children on the spot for a right answer but instead ask for a qualitative response like their opinion on the topic. This gets oxygen flowing to improve attention and engages the students in emotion...their opinion.

In the PreK–K classroom, when we present a lesson, we have memorized specific points of interest in the materials. During the lesson, we draw attention to these points of interest, much like a magician. For example, when pouring water, we notice the sound of the water landing in the glass. We hold the pitcher above the glass and wait for the last drop to fall out (it usually hangs on for a moment or two so this is a truly intentional pause). We notice any drops of water on the tray, on the glass, on the pitcher, and take a small sponge and dab the drips away. So, we are constantly training the powers of attention by noticing everything of relevance in the child's perceptual field. We also talk sparingly to reduce distractions and allow the visual sense to focus on the mechanics of the procedure. We then let the child do it immediately. We keep the presentation short and make sure the child can step in at the earliest possible moment.

Of course, we know that attention follows interest. So, when presenting a new topic, teachers must find
a way to link the topic with the child's life. They must help the child understand why he cares about it, why it is relevant to his life. You can do this in many creative ways. You may ask one student in advance to share a story about herself with the class that brings the topic to life. You might tell a short story about the history of the concept...to create a sense of magic, awe, and mystery. For example, share a very brief history of the written alphabet (think of the power it gave the Phoenicians or how it has preserved the Cherokee language) as a prelude to introducing cursive handwriting.

When doing division, one of the PreK and Kindergarten teachers at the Alfred G. Zanetti Montessori Magnet School, Maureen Ryan, likes to give an example relevant to each individual child. "Because I know the children, I can do this. For example, Marcus's mom sings in the choir and he accompanies her to practice. So, when we are studying division, I say that Marcus has so many people in his choir who all need the same number of cookies after they sing. If we start with this many cookies and we have this many people in our choir, how many cookies will each person get?" So, if you know the children well, you can always find lots of connections between the school curriculum and something that is relevant to their lives. This helps the students build an interest in the topic and, in turn, helps their attention.

In the PreK–K classroom, we actually teach the body mechanics of physically putting your attention on something just as magicians put their attention on a missing coin. Students use these techniques when they want to get the teacher’s attention, something that’s specifically taught as "grace and courtesy" lessons. We teach students to wait nearby and in the line of sight of the person whose attention they want, and look at their eyes. When the teacher's eyes are looking at the child we say, "Oh, you can see my eyes looking at you, so you know you have my attention."

Also, when a classroom is rowdy, many teachers use a technique that can be very effective: simply turn off the lights and, thus, change the perceptual setting. It redirects the attention in a gentle way. This is particularly effective in signaling transitions. For example, five minutes before lunch a teacher might turn off the lights or turn on some quiet music. This indicates to the children that it is time to put their work away, tidy up, and move on to the next thing. It gently calls their attention to the time of day.

REFERENCES:


**Glossary**

**neuronal resources**

A term used to describe brain systems recruited for a particular task.
Q: What can we do to help students who struggle?

Attention is required in order to move information in volatile short-term memory to stable memory, and is therefore a critical gateway for learning. So, what can teachers do if they suspect that their students may be having difficulties with attention?

The first thing to keep in mind is that anyone can become "learning disabled" if attention networks are overextended. Therefore, simply telling someone to "pay attention" doesn't help. Imagine you're on the golf course, focusing on lining up a critical putt. Does it help to have your teammates scream, "Concentrate! Don't screw up!"? Probably not. In the same way, telling students to "pay attention, sit straight, and stop fooling around" is likely to do more harm than good. Telling students who are struggling with attention to "pay attention" only adds to their attention load, and increases the chances that they will perform poorly.

As we saw in the previous units, learning can be improved simply by eliminating sources of unnecessary stress. Teachers can accomplish this by simply striving for a more sympathetic tone of voice and approach, and by eliminating unessential stakes in learning (e.g., the "pop quiz") that serve little purpose other than to raise stress levels in students. Urging students to get sufficient rest and sleep can also help, as research has shown that sleep and rest have a beneficial effect on abilities for attention.

(Opened ScienceTalk sidebar)

What Curriculum Developers Can Do

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Another, much more sophisticated way educators can help the learning process is to alter the pedagogical approach so as to minimize demands on attention and memory. To see how this can work, let us illustrate the principles involved through an example in arithmetic, using an attention and memory management tool invented in the 15th century by merchants from Treviso, Italy.

To illustrate these principles, take a piece of paper and try doing the following multiplication problem,
longhand, the way you were trained to do when you were a student in school: 247 x 834. (Really try it!)

For our purposes here, the answer isn't important. Instead, pay attention to the process. As you work the problem, try to notice which parts of the problem place the greatest demands on your short-term memory and attention.

Did you get 205,998? What parts of the problems required you to remember things for short periods of time and hold this information in your head while you did other things? These are the parts of the problem that stressed your abilities for short-term memory and attention.

Chances are that recalling multiplication facts and performing the single-digit products (e.g., 8 x 7 = 56) weren't the most difficult aspects of this problem. If you are like most people, much more of your mental effort (commanding attention and short-term memory resources) was spent tracking the columns of numbers and dealing with the carry digits.

Imagine you had to deal with lots of other distractions while you were trying to keep track of the columns and the carry digits. A small lapse in your abilities for attention or working memory, whether caused by neurological differences or distractions within your environment, could easily cause you to make an error and do the problem incorrectly.

Now, let's try the same problem using the 15th-century Treviso method rediscovered by the mathematician and education researcher Robert Speiser and his colleagues as an alternate approach to multiplication that greatly reduces demands on attention and short-term memory. To start, a matrix of boxes representing the dimensions of the product is drawn (for 247 x 834 the matrix is 3-by-3), and the digits of the problem are written along the top and right-hand sides of this matrix.

Next, diagonals are drawn.

Any pair of numbers (e.g., 7 and 8) is chosen and the product performed and placed into the corresponding box.

Then, other pairs of numbers are chosen (say, 4 and 8) and the product similarly performed and entered in the box, until all the products have been done.
Though it may sound obvious, perhaps the most direct way teachers can reduce demands on attention and short-term memory, and thereby improve student performance, is to simply reduce the memory and attention loads we demand from our students. We can get some hints as to how teachers might be able to help their students do this by taking a look at how major corporations manage...
Corporations recognize that if they required their top executives to answer phones, make appointments, do filing, track budgets, fill out forms, and so forth, the corporate machine would grind to a halt. So corporations protect their scarce "executive resources" by having executives delegate as many attention-demanding tasks to others as is practical. The executives sometimes have a small army of administrative assistants to help deal with the relatively inconsequential tasks, and they make use of electronic devices (e.g., cell phones, computers, PDAs, calendars, and other organizers) to help the executives track their work. As a result, the top executives can devote their full attention to tasks that are most important to the corporation, and leave more routine tasks to others, tasks that may not require the same sort of attention.

Teachers can help students manage their attention by helping them offload the more routine, attention-robbing tasks to others. The students may not have access to an army of "executive assistants" (other than their parents), but teachers can nevertheless look for ways to reduce the tension load, and eliminate as many routine tasks from their list of responsibilities as is practical. Web-based calendars with alarms can be used to help students keep track of their class schedules, as well as due dates for homework or tests. Calculators can be used in situations where learning math facts is not a primary goal, and students can be allowed to use computers for spelling and grammar checking where possible. Other techniques to limit demand on attention include the use of headphones to block extraneous sounds, music to mask distractions, and FM amplification systems to isolate a teacher's voice. At the same time, care must be taken so that these executive assistants don't themselves become a burden and a source of distraction. If such tools are used judiciously, they can help students reduce their attention load, and help protect the scarce neurological resources required for learning.

You can contribute to research

Many of the tasks teachers ask students to perform place unnecessarily high demands on short-term memory and attention. Regardless of whether or not a given student has a learning disability, such extraneous demands compete for scarce resources essential for learning, and make it needlessly difficult for students to learn. Unfortunately, neuroscientists and education researchers have not been able to develop a magic bag of tricks similar to the Treviso algorithm (see sidebar and video on the left) to solve such problems. Therefore, there is a need for professional educators to help advance this research.

The next time you develop a new lesson plan or look at new approaches to teaching, you may want to examine these approaches for potential working memory and attention bottlenecks, and think about whether you can devise alternative approaches that minimize short-term memory and attention demands. You can then use your classroom as a laboratory to test your improvements: Does this new approach lead to improvements in student performance?

Only through the active involvement of professional educators such as yourself can neuroscience help...
bring about new approaches to instruction that will result in advancements that are practical for the classroom.

Interested in doing research? We invite you to share your ideas here!

From the Classroom to Research: A Teacher's Journey

Lysandra Sinclaire-Harding has 10 years of experience teaching primary school in the United Kingdom. Driven by a desire to better support her students with learning and behavioral difficulties, she turned to research in neuroscience with support from the Faculty of Education, University of Cambridge.

My journey to the research desk began with Jack, a seven-year-old in my class full of energy and trouble. Whenever Jack entered the room, he demanded attention. During lesson time, he would frequently interrupt with shrieks or shouts. Jack was resourceful and entertaining, but he had a hard time interacting with others. At times he was volatile, aggressive, and easily angered. In the playground he was a risk to the well-being of his peers who kept their distance, never quite sure when they might be on the receiving end of a kick, bite, or punch. Jack struggled with reading and writing, could hardly sit at the desk long enough to try, and would spend day after day outside the classroom for his disruptions.

His mother told me that her pregnancy had been full of scares for Jack's health and she admitted emotionally detaching herself in case he did not survive. Jack's parents' separated when he was an infant. The youngest of three children, he was left in his father's care. I wondered if Jack's emotional development had been somehow damaged as a result of this remote relationship with his mother.

By chance we discovered Jack's response to enclosed spaces—a cardboard box he could crawl into or the small space beneath my chair. Whilst inside, he would be still and calm, for once allowing me to read or talk with the rest of the class uninterrupted. It seemed that, in these enclosures, he found a certain sense of security and safety.

Concerned and intrigued by these complex and contrasting behaviors, I wanted to better understand how children such as Jack experience and manage their emotions at school. I wondered whether such emotional factors create barriers to learning, and I wanted to know whether these negative emotional responses could be explained scientifically. It was with such questions that I turned to cognitive neuroscience.

Each day at school, we ask students to perform a range of cognitive and social tasks such as: planning group projects, learning new vocabulary, or understanding and interpreting class texts. They are expected to remember which resources are needed for class, choose what to prioritize when studying for a test, and even learn how to fit in with a group of friends. The capacities required to support the daily demands of school-life require judgment,
planning, decision making, and social conduct, and are of enormous interest to neuroscientists who
define them as "**executive functions.**"

In recent years, "**affective neuroscientists**" have produced an abundance of empirical breakthroughs
and new theories on emotion and its impact on executive functions. Brain images show how specific
(prefrontal cortex) regions of the brain are active when a task demands attention and concentration,
and how these areas are anatomically at some distance to the deeper (limbic) regions that would
usually activate with emotion experience. Evidence of connections between these regions is well
established, and they suggest that the emotional reactions of Jack and others like him could help to
explain the deficits in attention, decision making, and social functioning that teachers frequently
observe and manage in their classrooms.

By way of response to the summons for educators to become critical consumers of neuroscience
research, and with support from the Psychology, Neuroscience, and Education Master's program at the
University of Cambridge, I developed research questions generated from laboratory findings that I
investigated from within the classroom. I collected evidence of moment-by-moment emotional
experience, provoked by specific events in English, math, and social studies classes.

In different age groups, brain imaging studies suggest that executive functioning is improved during
positive emotional experience whilst negative emotions such as anxiety, frustration, or boredom have
the opposite effect. From my experience, and conscious of ongoing concern for boys' educational
underachievement, I had a sense that in my investigation, I might find gender differences in emotional
response.

**What does neuroscience tell us? Generating research questions for the classroom.**

<table>
<thead>
<tr>
<th>Scientific finding</th>
<th>Education research question</th>
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<tbody>
<tr>
<td>Positive affect enhances executive function.</td>
<td>Do positive emotions support higher-order thinking skills?</td>
</tr>
<tr>
<td>Negative affect provokes autonomic responses leading to stimulus avoidance.</td>
<td>Do negative emotions result in withdrawal from learning tasks?</td>
</tr>
<tr>
<td>The male brain is more sensitive to negative affect due to earlier development of the orbitofrontal cortex.</td>
<td>Are boys more likely than girls to avoid learning tasks that stimulate negative emotional experience?</td>
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I combined observations, interviews, and questionnaires with a technique called "video-stimulated
recall," where a videotape of the lesson is replayed to the student during the interview. Behaviors,
facial expressions and gestures are captured and students give their interpretations of events, together
with their consequential effect on thought processes and feelings, as far as they are able to recall and
describe. Emotions were expressed in response to the teacher-student relationship, group work,
classroom reading materials, discussion topics, problem solving, and delivery of oral presentations.

Although the methods employed here are a long way from the IMRI laboratory, the findings do support
the scientific hypothesis that students are more likely to engage and perform in class if they are
experiencing positive emotions such as enjoyment, pride, interest, and satisfaction.
In my study, response to negative emotion was less predictable. Students reported disinterest, boredom, frustration, worry, and shame. However, there was a substantial variation between individual responses to a single event, as well as between gender. Whilst the girls were more articulate in describing their emotions, the boys reported more negative emotion and were more likely to avoid or withdraw from the learning activity than the girls. It seemed that when boys experienced a negative emotion, their ability to take positive action and maintain effort in classroom activities was less than that of the girls.

To conclude, this inquiry and subsequent reflection have provided me with a greater sensitivity to the constant undercurrent of emotion experience in my class. As a consequence, in my teaching and planning I seek out opportunities to support my students in attaching positive emotions to specific learning moments. I also try to be vigilant for signs of frustration, boredom, and anger, and I provide vocabulary for my students to help them identify and describe both positive and negative feelings. Previously, such discussions were timetabled as a separate curricular activity; now my class is encouraged to make meaningful interpretations of their feelings as they relate to their frustrations and successes across all curricular subjects.

But most of all, I am aware of the vulnerability of children such as Jack, whose adverse start in life has left him susceptible to being overwhelmed by negative feelings. For him, as with all of us, attention is a limited resource, and frustrations and anger are constant diversions from the learning opportunities he struggles to maximize.

With guidance from neuroscience research, in my next steps I seek to develop an intervention that can strengthen the socio-emotional competencies of students. Just as Jack sought out momentary safety, I hope to support young people to find their secure space from which they can be challenged to explore and learn.

**Glossary**

**executive function**
(also referred to as executive capacities) A term describing cognitive resources available or abilities for planning, organizing, carrying out, and evaluating goal-directed behavior.

**affective neuroscience**
A term used to describe the field of neuroscience investigating questions related to affect, including emotions, goals, etc. Affective neuroscience questions are interrelated with questions in cognitive neuroscience; these fields are considered to overlap significantly.
Q: How do we know when a dog is a dog?

The late education researcher Rosalind Driver, King's College, London, who pioneered studies in how children construct their understanding of ideas in science, felt it was important to distinguish "school science" from the science that scientists actually use in research. While a mastery of school science is often measured by abilities for rote memorization (e.g., how well students can regurgitate boldfaced words in a text), success in science as practiced by scientists is measured by the person's abilities to solve problems and make sense of difficult ideas. While memorization certainly plays an important role, this type of learning represents just one relatively minor aspect of science as practiced by scientists in the real world.

Many of the ideas that are traditionally valued in education, such as memorizing the boldfaced vocabulary words in a science text, are tasks that place strong demands on attention and short-term memory, and that lead to learning through a process of rehearsal and repetition. Even though these forms of learning are relatively easy to test, and are therefore emphasized in schools, these do not represent the only forms of learning important in everyday life.

Take, for example, the remarkable abilities we have for classifying objects. Even a four-year-old child can tell that an object is a "dog," whether it's a St. Bernard or a Chihuahua, despite the fact that there are a seemingly infinite number of possible variations in this object's appearance. Even as an adult, most of us would be hard-pressed to articulate the qualities that define "doggyness." And yet, we can confidently distinguish a dog from a cat, or equate a poodle to a Great Dane, despite the fact that we may not be able to describe in words how we accomplish this amazing feat.

Learning the gist of what makes a dog a dog (learning the concept of doggyness) is a form of learning that is distinctly different from the learning we use to memorize a phone number or a list of state capitals. Rote memorization makes use of attention and short-term memory to promote learning through a conscious process of repetition and rehearsal. Learning the gist of doggyness, on the other hand, is to a large extent unconscious.

When we learn the classification "dog," we unconsciously take note of myriad, unarticulated visual nuances common to each of the things we have been told are dogs. We then build our understanding of the concept of dog over time, without consciously rehearsing the factors used to categorize the gist of a dog.

Though there are clear prescriptions for how to teach through rote memorization (make a list of things to memorize, review it over and over, test the learning, repeat, review), we don't yet have a similar prescription to help students learn gist.
And yet, many of the ideas important in life (the ideas that separate school science from meaningful understanding) are concepts that we learn unconsciously in this way, using a process that is very similar to the one we use in learning the gist of a dog. For example, learning to tell the difference between the sound of an oboe and a clarinet, or knowing which kitchen drawer has the bottle opener, are everyday examples of learning that takes place (for the most part) implicitly through gist.

Implicit Learning

Implicit learning can be measured by how much we improve with repetition—for example, on the speed at which we complete a task, such as finding a target in a visual field. While people with...

Deaf Gain

Dr. M. Diane Clark is a professor of Educational Foundations and Research at Gallaudet University in Washington, DC, where she teaches educational psychology and statistical methods.

What is the impact of learning through the eyes in contrast to learning through the ears? What is the impact of using a visual language rather than an auditory language? The Science of Learning Center on Visual Language and Visual Learning (VL2) was established to gain a greater understanding of what influences the acquisition and use of language, both written and signed, through the visual modality. Research by VL2 investigators Matthew Dye (University of Illinois), Peter Hauser (RIT/NTID), and Daphne Bavelier (University of Rochester [Dye, M.W.G., Hauser, P.C. & Bavelier, D. (2009), Is Visual Selective Attention in Deaf Individuals Enhanced or Deficient? The Case of the Useful Field of View, PLoS One, 4, e5640] found that adolescents and adults who are profoundly deaf from birth have enhanced abilities for visual spatial attention. In other words, these profoundly deaf individuals are better able to notice the occurrence of events that take place away from the current focus of gaze. So for example, if they're concentrating on studying the structure of some interesting symbol here on this page (e.g., 📚), the people who are deaf are more likely to notice something else interesting popping up elsewhere on the page, which a person who is not deaf is likely to miss. This sensitivity in people who are deaf is sometimes referred to as "deaf gain."
Even though neuroscientists have long recognized that learning gist differs fundamentally from other forms of learning that we associate with rote memorization, the neuroscience underlying gist is only just now coming under study. One finding relevant to our discussion on individual differences in learning is that abilities for learning gist don't necessarily correspond to abilities for rote memorization.

Just because a student may have a great deal of difficulty with attention or short-term memory, and consequently have difficulty memorizing names, numbers, or other rote facts, he or she may not show any difficulties learning gist, and in some cases may even outperform those who otherwise memorize well. Let us illustrate this finding with some recent examples drawn from the field of dyslexia, a neurological disorder that impairs abilities for spelling and reading, known to be associated with difficulties in visual attention and short-term memory.

Being deaf results in a redistribution of resources for spatial attention so as to make those who are deaf more sensitive to visual information in the peripheral parts of the visual field. Though deafness is generally perceived as a disability, deafness tends to reorganize the brain so as to enhance certain abilities for vision, and provide people who are deaf with cognitive advantages over people who are able to hear.

**What is the impact of learning through the eyes in contrast to learning through the ears? What is the impact of using a visual language rather than an auditory language?** The Science of Learning Center on Visual Language and Visual Learning (VL2) was established to gain a greater understanding of what influences the acquisition and use of language, both written and signed, through the visual modality. Our discoveries provide insight into the principles of human communication and optimal practices in education.

VL2 has established a Center to support leading researchers from a variety of disciplines to understand basic principles of visual learning and to translate those findings into educational practices. Our research looks at learning at how the brain functions, how visual cognition develops, as well as how one's culture impacts development. The Center's long history of close association with underrepresented people leads to mentoring of deaf and hard of hearing students to become future scientists.
Q: Can not paying attention be good for learning?

If you have been teaching for a number of years, one of the great delights is to see your former students—now grown up—come back to tell you how they’ve turned out. It’s always wonderful to hear from students who succeed, and sometimes students surprise us. A student who may have done very poorly while in your class, once grown up may have gone on to achieve great things.

But how does this happen? Performance in school is supposed to predict and facilitate performance later in life. Why then do some of those who perform so poorly in school nevertheless do well later? The answers to such questions are complex and may have something to do with the difference between "school science" and "real science" that Rosalind Driver talked about earlier. Perhaps aspects of performance important in real life are not being emphasized or measured in school, and some students do well later in life because these different forms of learning are emphasized and valued in their chosen careers.

People with neurological learning impairments can be among those who come back and surprise the teacher. People with autism spectrum disorders, dyslexia, or attention deficit hyperactivity disorder (ADHD) struggle tremendously in school, but sometimes do well later in life. For example, the animal researcher and author, Dr. Temple Grandin, attributes much of her success to her autism, which has given her the ability to imagine the world from the perspective of an animal. She uses these insights to understand animal behavior. John Elder Robison, an expert in audio and electronics who never graduated from high school, links his strong interests in electronics to his Asperger’s syndrome, and this has led him to become successful in his career despite doing poorly in school. Others, such as the education researcher Dr. L. Todd Rose, who struggled with ADHD as a child and only barely completed school, nevertheless earned a PhD from Harvard, and achieved many important accomplishments in the field of education.

Among those with dyslexia, it has long been noted that many people perform well in visually intensive
careers despite the fact that they have considerable difficulty with reading and writing. One study showed that people with dyslexia are overrepresented in art schools, and another showed a similar overrepresentation among business entrepreneurs. Certainly, there are numerous examples of accomplished people with dyslexia who struggled in school and yet achieved recognition later in life. These include artists such as Chuck Close, writers such as John Irving, and Nobel Prize-winning scientists such as Carol W. Greider and Baruj Benacerraf, all of whom achieved success in their careers despite the fact that they struggled in school. Such examples reiterate the need for us to question what we mean by "learning disability." For here we see that the students with "impairments," who perform poorly in school, can be among those who come back as adults having achieved great things in their careers. Their performance in school did little to predict what they achieved later in life. Thinking back to the example of Gallaudet University, where the hearing person becomes the one who is "disabled" in an environment where everyone speaks ASL, the definition of "disabled" can be turned on its end when the context is changed. Therefore, perhaps we need to revisit the context of learning currently valued in school, and broaden our definition of learning to include ideas that are more broadly useful in life outside of school. Opening the door to other contexts for learning, and using these as a measure of success, we can raise the achievement levels of all students in our classrooms, and hopefully do away with ambiguous labels like "learning disability" that do more harm than good.

Let us examine how inabilities for attention, traditionally thought of as impairments to learning, can help us turn the definition of "disability" upside down, so as to help those with attention difficulties turn this challenge into a strength. We will illustrate this idea with examples drawn from research about people with dyslexia.

Sensory attention is important in learning because it helps students focus on a task and prevent the influence of irrelevant distractions that interrupt the rehearsal required by the learning at hand. But these attention networks are actually serving two functions that are distinct: On the one hand, attention increases our sensitivity to information that's important at the moment (facilitation); on the other hand, attention decreases our awareness of stimuli thought to be irrelevant (inhibition). Attention therefore acts like a seesaw. It increases our awareness of some things, but at the same time decreases
our awareness of other things. This seesaw quality of attention can lead to learning advantages in people whose abilities for attention are poor.

**Attention Deficits Also Can Lead to Strengths**

Attention difficulties can lead to advantages because attention networks sometimes make mistakes. The brain is being bombarded by sensory information, and attention networks guess which of these bits of sensory information are important, are deserving of scarce cognitive resources, or can be safely ignored. Attention is therefore acting like the editor of a newspaper. Editors guess which stories are going to be most interesting and important to the paper's readers and set those stories on page one in big boldface type, but they bury other stories deemed to be less important in a tiny column on page 52.

Because editors are guessing, they sometimes make mistakes. Unless they get direct feedback from their readers (say, in the form of letters to the editor), there is no way they can know in advance whether or not any given bit of news will be important to a reader such as you. Maybe what is most important to you is a tiny little personal ad on page 52. But, because the editor put a story about the mayoral race on page one, you spent all your time reading a story that turned out not to be very important to you, and caused you to overlook the personal ad that could have changed your life forever.

*(End of first column online)*

Sensory attention networks are making similar guesses. Unless they get feedback from the brain, they can sometimes hinder learning by directing precious neuronal resources to page-one items that are in hindsight not so important, and bury on page 52 the sensory information that could change your life. This can happen especially if the important information comes as a surprise, so that the brain doesn't have time to provide feedback that consciously redirects the flow of information (say, by telling the eyes to look elsewhere).

Sensory attention networks can also make a mistake that hinders learning when the information is something we learn implicitly, without conscious awareness. For example, learning visual gist is something that happens without conscious awareness, such as when we learn the myriad, subtle visual distinctions that make a dog a dog. Under such circumstances, a person who has superb abilities for sensory attention may learn poorly, while the person whose abilities for attention are poor may be more likely to learn well.

Imagine you are commuting by subway, deeply absorbed in a novel. The process of reading invokes inhibitory attention networks that help you focus on your book. You become oblivious to your surroundings. Perhaps you become so absorbed in your reading that you no longer are aware of the constant clicking of the tracks, or the sounds of the people coming and going from the train car. You lose track of time, lose awareness of your surroundings, and perhaps don't even notice you missed your stop! Though your excellent abilities for attention served you well for the task of reading, they also caused you to fail to notice important information that would have helped you realize that you had arrived at your stop. In this case, when the important task was to notice you had reached your stop, strong abilities for attention were a detriment that caused you to do something you didn't intend.

Whether or not excellent abilities for attention can be regarded as a talent or a deficit therefore depends entirely on the context. Attention is a talent if the context of learning requires focus and diminished sensitivity to distraction, but the same abilities for attention can be a deficit if the learning context requires awareness of a broader, holistic set of factors that are difficult to explicitly define. Simply by changing the
task we require of our students, we can turn a student who is performing poorly into a student who performs at high levels.

This observation points to two important lessons for educators:

First, it suggests that we can improve achievement for all students, regardless of their neurological predisposition, simply by addressing both ends of the seesaw of attention when we teach and evaluate our students. All too often, instructional strategies tend to overemphasize one end of the seesaw. We tend to emphasize teaching approaches that place high demands on abilities for focused attention by relying on the use of words, text, and/or numbers. Instruction at the opposite end of the seesaw, which builds knowledge through images, stories, models, experiences, and metaphor, tends to be deemphasized in the classroom once students learn to read. And yet, the implicit learning that is possible through mechanisms of distributed attention is no less valid than the learning that takes place through focused attention. To make better use of the capabilities that all students bring to learning, presentations grounded in words, text, and numbers should be balanced by other forms of instruction that build intuition through implicit learning, and that make use of neurological abilities people are capable of at the opposite end of the seesaw. For example, consider the words we use to help students categorize a dog: "a dog is a carnivorous mammal that is a domesticated variant of the gray wolf, characterized by a long snout and acute sense of smell." These words should be balanced with instruction that provides students with rich experiences—visits to pet shops, movies, storybooks, pictures, and physical interactions with pets—to help students grasp the gist of a dog by making use of attentional mechanisms on the opposite end of the seesaw.

Moreover, this balanced approach shouldn't stop with instruction. The assessments we use should also be balanced. Written assessments, which depend on abilities for focused attention, should be supplanted with other forms of assessment—e.g., posters, presentations, models, movies, drawings, pictures, and stories—that draw on a more implicit understanding, and students should be judged on whichever approach shows them in the best light. Doing so, we are likely to discover that a number of the children in our classroom are learning disabled. And as teachers, we will begin to feel more successful in that we can reach all students in our charge.

The second point we can take away from the parable of the subway pertains to the very question of whether or not we as educators should be labeling such great numbers of our students as learning disabled. People who learn differently, such as those with dyslexia, ADHD, or autism spectrum disorders, and who tend to exhibit tremendous struggles while in school, sometimes go on to perform at extraordinarily high levels later in life. Once out of school, these individuals sometimes blossom. Some have become Nobel Laureates, distinguished writers, and successful business entrepreneurs. The fact that they succeed only after they exit the educational system is a sad commentary on how schools sometimes fail these people. This suggests that the assessments we are using in schools do not effectively judge the capabilities of our students, outside some narrow context that has meaning only in the classroom.

Both the parable of the subway and the story of Gallaudet, remind us that what we think of as an inherent deficit can be turned into an asset simply by changing the task we ask our students to perform. Therefore, it is entirely possible that many of those
students we now label as learning disabled, whom we perhaps think of as broken thermometers, fail to show their capabilities only because we are not offering assessments that reveal their strengths. In perpetuating labels such as "learning disabled," we do our profession harm by encouraging a way of thinking that actively neglects the capabilities these children possess. Instead of labeling the students as "broken," we as educators might think of ourselves as neuroscientists, and take careful note of the strengths we observe among our students who think differently. Knowing what these strengths are, recognizing that they may draw on capabilities that sit on a less familiar end of the seesaw of attention, we can then apply our creativity to find new ways to build upon these strengths. Doing so, we not only might uncover ways to help all students learn and achieve, but also might further our own creative potential as professionals who are carrying out cutting-edge work at the intersection of neuroscience and education.

Success Story: Dr. Temple Grandin

Dr. Temple Grandin is associate professor of animal science at Colorado State University, Fort Collins. Diagnosed with autism at the age of two, Dr. Grandin is considered one of the top advocates of... View video

(Opened ScienceTalk sidebar)

Dyslexia: An Example

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Dr. Matthew H. Schneps is the George E. Burch Fellow in Theoretic Medicine and Affiliated Sciences at the Smithsonian Institution, director of the Laboratory for Visual Learning at Harvard-Smithsonian Center for Astrophysics (CfA), and executive director of the Science Media Group at CfA.

Neuroscience research in the field of dyslexia has concentrated primarily on trying to understand the reasons for impairments in reading and spelling. Consequently, research into how dyslexia may provide advantages for cognitive functions in fields other than reading has lagged behind, and only recently has research begun to emerge suggesting that dyslexia may be linked to advantages for tasks that are important in science, mathematics, art, and other visually intensive fields. Here, we will briefly review some of the evidence suggesting that dyslexia may be linked to advantages, and look at how instruction can build on these strengths.

Peripheral Recognition

MIT researchers Gadi Geiger and Jerome Lettvin observed that when a pair of letters is separated by a large angle, people find it more difficult to name briefly flashed letter pairs when the angle is large. They found that people with dyslexia were able to name the letter pairs at larger angles (in one case about twice as far out) compared to people who were typical readers. The effect was more pronounced on the right side in people who were English native speakers and on the left side for people who were Hebrew native speakers. This work suggested dyslexia may be linked to advantages in the periphery, in situations where attention is divided between the center and the periphery, and that this phenomenon may be linked to hemispheric differences tied to experience with reading.
Peripheral Reactions
Andrea Facetti of the University of Padova, Italy, observed that people with dyslexia respond more quickly to an unexpected flash of light in peripheral parts of the visual field, especially when the flash occurs on the right side. This suggests that people with dyslexia are more sensitive to the occurrence of unexpected peripheral events, and that there may be hemispheric differences in this response.

Holistic Processing
Psychologist Catya von Karolyi of the University of Wisconsin showed that people with dyslexia are faster (compared to typical readers) at spotting logical errors in geometric drawings known as "impossible figures." These are line drawings that, if imagined as a three-dimensional object, would be physically impossible to build. Determining whether a drawing is "impossible" calls upon abilities to simultaneously compare information across a broad expanse, suggesting that people with dyslexia have strengths for this form of peripheral visual integration.

Learning Scenes
A team of researchers led by Matthew Schneps of the Harvard-Smithsonian Center for Astrophysics and James Brockmole from the University of Notre Dame measured how well students were able to implicitly learn the spatial layout of blurry photographs resembling medical x-rays or radiograms. They assembled hundreds of photographs of natural scenes—pictures of cityscapes, buildings, countryside, and so on—and blurred these pictures so that most of the details in the photographs were no longer recognizable. They found that while both people with dyslexia and typical readers could learn the photographs equally well when the images were sharp and detailed, only the people with dyslexia showed evidence of learning when such photographs were blurred. This suggests that people with dyslexia have advantages for learning from blurry information characteristic of information visible in the periphery. Try this for yourself!

Peripheral Integration
An investigation by researchers from the Harvard-Smithsonian Center for Astrophysics (Schneps, Rose, Greenhill, and Pomplun) tested astronomers with dyslexia and those without for their sensitivity to an underlying double-peaked pattern obscured by visual noise in a graph (characteristic of emission...
from a black hole). The research team found that the astrophysicists with dyslexia were more sensitive to the pattern, and better at detecting it, when the peaks were separated by a large visual angle. This experiment, based on a real-world task important in astrophysics, demonstrates that scientists with dyslexia have advantages sensing subtle visual patterns in the periphery.

Overall, this research suggests that dyslexia may be linked to advantages in perceiving global information relevant to learning visual gist, sensed by the periphery. While it may not be immediately obvious how this might be important in contexts traditionally valued in schools, it’s not difficult to imagine how such advantages might be important in many real-life situations, especially in careers related to science, mathematics, art, or other visually intensive pursuits.

For example, the ability to rapidly sense and respond to something unexpected, noticed out of the corner of one’s eye, could be useful for careers related to biology, where an ability to notice a predator rustling in the bushes might help a researcher understand some animal’s sudden change in behavior.

Abilities to rapidly spot "impossible figures" might be helpful for careers in mathematics, engineering, or physics. Impossible figures underlie the fanciful drawings of M. C. Escher that defy the laws of physics. Looking at these, perhaps you can imagine how an ability to sense logical errors in such images might be helpful in these fields.

Left: Relativity, by M. C. Escher. Lithograph, 1953.

Likewise, advantages in learning the spatial layout of some blurry image could be a skill important to a radiologist searching for a tumor in an x-ray. Here, an ability to learn and compare one x-ray to another, and notice subtle changes in a blurry-looking picture could have lifesaving consequences for a patient.

Perhaps the most direct evidence that dyslexia can lead to visual advantages that are important in science comes from the study of the astronomers with dyslexia. Astronomers use these graphs to search for black holes (collapsed stars whose gravity
is so strong nothing, not even light, can escape). Astronomers search for black holes deep in space by looking for a characteristic double-peaked pattern emitted by material orbiting the collapsed star. If the emission is strong, the pattern is obvious, and the black hole is easy to spot. But, usually these patterns are weak and noticing the presence of the subtle pattern can be difficult. A heightened sensitivity for this kind of visual processing could be valuable for people involved in such scientific research.

Though these differences have been found in research, the differences in neurology responsible for such advantages is not yet understood. A likely possibility is that these visual advantages result from differences in abilities for attention that, as we discussed earlier, can lead to advantages sensing visual gist, and in responding to unexpected events.

We emphasize that this research is only in its infancy, and much of this work remains to be confirmed. For example, researchers do not yet know whether such advantages apply to all people with dyslexia, or only some subset of those who are struggling readers. However, the trend is clear: Dyslexia appears to be linked to visual strengths in observing the gist of a scene, or noting information that occurs unexpectedly in the periphery. Such abilities are clearly valuable in real-life situations. Even though these individuals may perform poorly when asked to read in school settings, the situation is different in scientific careers. These dyslexic scientists can perform at very high levels, so long as they manage to advance to careers for which they can build on their strengths. It appears that they can even outperform those who generally are considered "unimpaired."

Glossary

**autism spectrum disorders**
A diagnostic category describing a developmental disability that primarily impacts socioemotional functioning. Clinicians rely on criteria described by the Diagnostic and Statistical Manual of Mental Disorders (DSM), most typically, in three categories: social interaction, verbal and nonverbal communication, and repetitive behaviors or interests.
**dyslexia**
A term describing a learning disability that is defined by difficulty with single word reading, often impacting negatively text comprehension. Other secondary associations include difficulties with processing sounds of language accurately or automatically and socioemotional challenges.

**attention deficit hyperactivity disorder (ADHD)**
A diagnostic category describing a developmental disability that primarily impacts attention capacities with secondary difficulties most often observed in behavior and learning environments. Clinicians rely on criteria for reaching a diagnosis of ADHD using the Diagnostic and Statistical Manual of Mental Disorders (DSM), most typically.
Q: What can teachers do about learning differences in the classroom?

Let us review the steps that educators can take to honor and build upon the learning diversity in their classrooms.

- **Whether or not a person is considered to have a "disability" depends on a dynamic interaction between the demands of the task and the strengths of the person.** Sometimes, a person who appears impaired in one context will perform at superlative levels when the context is changed. Teachers can improve the performance of their students simply by changing the context of their teaching and by giving students opportunities to find alternate ways to learn, even if these alternatives may not be traditionally used in schools.

- **Labels such as "learning disabled" can hurt,** and can trigger an automatic neurological reaction associated with negative emotions that further impairs learning so as to deepen the struggles a student may face. Using negative labels creates a threat based on a negative stereotype, which interferes powerfully with school success. Be supportive and encourage the student to work with you to find a solution: "Of course this is hard, and of course you will be able to do it. But we're going to have to get creative with how we approach this, and I need you to work with me to help figure out the best way."

- **If students struggle with certain ways of thinking, the task we are asking them to do is probably not well matched to their neurology.** As a consequence, if we are asking students to do something that was never designed for their brains, they will have to work very hard. As a teacher, it's important to respect the extra work the student is going to have to do. For example, the task of reading was designed over the centuries to work well with a certain set of neurological capabilities. If a student's neurology is not well matched to this task, this student will need to force her or his brain to perform in ways that are less than optimal. This takes work, and the student will have to work harder than most other people. Teachers can recognize this extra effort by accommodating for extra time or allowing the use of calculators, which are not cheating. Help the student feel comfortable accepting this compensation.

- If students don't pay attention, it does not necessarily mean they are being disrespectful or
lacking in discipline. Yelling at students to "pay attention" is not likely to help, and will probably hurt. Attention is a semiautomatic neurological response that helps people deal with the overwhelmingly vast amount of information constantly bombarding their senses. **Though people can control some aspects of attention, many are automatic and outside a person's control.** Traditional approaches to learning place strong demands on attention and short-term memory. People can become "learning disabled" by overloading their capacity for attention or memory. Teachers can help people learn more effectively by eliminating any unessential demands on attention or memory and by generally revising instructional methods so that the demands on attention and memory are minimized.

- Some forms of learning, such as learning the gist of a sound (implicit learning needed to distinguish a banjo from a guitar), occur with little conscious awareness, and do not place the same demands on neural networks for attention. **Such forms of learning, though not emphasized in schools, are vitally important in many aspects of life.**
- **People vary in their abilities for attention**, and people are sometimes very sensitive to changes in their environment, while others may not notice such changes. Some people who have difficulties with the forms of learning that place heavy demands on attention may not experience difficulties with the forms of learning that are associated with "gist."
- **Attention networks act like a seesaw, by enhancing some information while inhibiting other information.** Focused attention can inhibit peripheral awareness and reduce a person's awareness of gist. Therefore, strong abilities for attention can hinder learning of gist, leading to a situation where a person who is "learning impaired" outperforms the person otherwise considered "unimpaired."
- **New research suggests that people with dyslexia sometimes exhibit enhanced abilities for peripheral awareness that lead to advantages important in fields such as science, mathematics, or art.** Many people with "learning disabilities" perform at very high levels in careers where their special abilities are well matched to the demands of the field. **Educators can reach and help many more students to learn by emphasizing skills that are important and valued in real-world contexts,** as opposed to "school science" contexts that tend to be artificial and overemphasize demands on memorization and attention.
- **People learn in many different ways;** therefore, teachers should devise assessments that encourage alternate ways to show individual competencies and progress, and that honor each student's own strengths and approach.
Reading with Half a Brain

Brooke Smith had the left side of his brain removed at age 11. Phonology is believed to be located in the left side of the brain. Therefore, it is astonishing that Brooke is able to read. Using...

View video
Resources


UNIT 5: BUILDING NEW NEURAL NETWORKS

Section 1:
Such stuff as schools are made on

Q: Why do I have to keep teaching the same things over and over?

Jeff had a plan. He would teach his eighth-graders to write a paragraph in two weeks. He spent the first week reading and discussing paragraphs, presenting models from books of essays and from his file of successful student writing. He talked about topic sentences, supporting evidence, sentences that tied evidence to the topic idea, and summary sentences. In the second week, he led the class through the creation of a couple of group paragraphs, which he wrote on the white board as the students shouted out suggestions. They really seemed to get it. On Thursday, he assigned each student to write a paragraph to share with the class on Friday.

Following Friday's class, Jeff walked into the English department office and threw the papers on his desk. "You'd think they'd never seen a paragraph before," he shouted, his voice crackling with anger, defeat, and despair.

Jeff's voice is part of a choir of frustration heard in many faculty rooms and classrooms. "I keep having to teach the same thing over and over again." "We studied all that last semester. Why can't you remember it?" "They had that yesterday, and all but two failed the test today." "People, this should all be review. I haven't got time to teach it to you again."

These voices reveal some basic, usually tacit assumptions about learning, assumptions that have been passed on from generation to generation of teachers. They form the basis of how teachers have been taught to teach. For example, learning is the result of teaching. I taught paragraph writing—or addition or the Civil War or the preterit—last semester; therefore, my students have

(End of first column online)

learned it or should have learned it. Frequently, teaching and telling are used as synonyms. Many teachers talk about entering the profession motivated by the generous desire to "share their knowledge" with students; they want to tell students what they know so that students will know those things. And, often, everyone (teachers, parents, even students) substitutes some form of the verb "have" for "learn" or "know" or "understand." Bill "had" it yesterday, as though a skill or concept is an object that is fixed and can be held or possessed like a pencil or a book. These voices also suggest that if students could perform some skill they "had" yesterday, like writing a paragraph or solving an equation, then they ought to be able to perform the same skill just as well or better today.

All of these assumptions suggest that learning means knowing stuff and doing stuff and that we can judge the knowing and doing using various tools (tests for concepts, or exhibitions for skills like writing). Traditionally, schools treat this stuff as isolated bits that can be retrieved from memory, rather like pulling
an apple from a bag. Once it's in the bag, it is accessible. Those who fail to access it are lazy; those who fail to put it in the bag in the first place are stupid (usually couched in a more acceptable euphemism—challenged, working below grade level, less able, differently abled). Despite the progress of advocates for constructivist approaches to the classroom and for differentiated instruction, the persistence of the language that dominates the lamentations of teachers like Jeff, who struggle endlessly to design effective lessons, reflects the persistence of traditional assumptions about learning. "They had this stuff last week. They can't remember anything, and I can't teach it again."
UNIT 5: BUILDING NEW NEURAL NETWORKS

Section 2:
Neural paths to understanding

Q: What is the difference between teaching and learning?

Based on research that reveals the connection between emotion and learning, we know that real, durable, meaningful learning is much more complicated. Although the process and experience of learning suggest the impossibility of separating emotion from thinking, it can be useful to explore and discuss cognition separately. Many scientists have done so for several decades, such as Kurt Fischer and his colleagues in the Mind, Brain, and Education Program at Harvard University.

These scientists theorize that learning anything requires that the learner build a new neural network. Understanding the Civil War, for example, requires building new neural networks for the Civil War, not just opening a conduit from the teacher's mouth to the student's memory bag and filling it with facts about the Civil War. This idea that learning skills and concepts involves the same process of building neural networks is essential to understand. Teachers have tended to distinguish between skills like writing an essay or solving for x and concepts like the causes of the Civil War—concepts that have traditionally been presented as "facts." Researchers suggest that conceptual understanding is a skill, rather than a thing. We may be able to memorize that osmosis is the passage of water through a semi-permeable membrane or that emotion is the rudder for thinking; but to develop a meaningful understanding of these concepts, an understanding that enables us to use the concepts creatively and in new contexts, requires that we build and rebuild the concepts, as well as build and rebuild understanding.

To develop meaningful, internalized skills, learners must actively build neural networks, a time-consuming process that results from the effort required for repeated trips over the same ground—to lay out the routes, mark them, clear them, create foundations, pave them, roll them several times, connect them, and add the signs, lines, and railings that will guide us when we revisit them. Each time we cover this ground, each time we rethink our way through the Civil War or try to write a paragraph, the network becomes...
more defined. Sometimes, progress is slowed by obstacles—a new idea or an old idea we thought we understood but didn't, or an inability to focus—but, over time, our understanding or skill deepens and improves. And because we are building these neural paths, these abilities, in our own brain, we must be active and persevere. No one can think or act for us (which further suggests the need for the goal to matter to us—to be emotionally relevant). Being told is not a substitute for learning.
UNIT 5: BUILDING NEW NEURAL NETWORKS

Section 3: Performance and context

Q: How do they understand it in class and fail the test?

Although this process of building new neural networks takes time and requires individual effort, it is also heavily dependent on the context in which the individual works—especially, the social and emotional supports in the environment. In schools, surprisingly, teachers often look at performance alone, independent of context. Jeff's frustration over his students' inability to write a decent essay at home after seeming to understand the process in class illustrates this tendency to judge performance separately from context. Jeff lost sight of the supportive context that he had created to enable his students to perform the skill in the classroom, so he didn't appreciate the debt their skill level owed to the conditions he had set up.

Jeff supplied critical help to ratchet his students' understanding and skill to a level they couldn't sustain without his support. He provided examples of good paragraphs and identified the elements that made them good: the topic sentence, the evidence, and the way all the sentences worked together. He gave them other examples and provided a structure and guidance to help them identify the elements that made these paragraphs effective. He is an energetic, entertaining teacher who cracked jokes and had selected paragraphs that were provocative or amusing, so the students were having fun. Then he prompted them through the creation of a group paragraph that he wrote on the board. In short, he raised them to a level of performance built on the scaffold of several elements: his presence, his doing much of the actual intellectual work involved in creating a paragraph, his priming key ideas and components of the paragraph, the collaboration of the other students, and a classroom atmosphere conducive to doing intellectual work.

(Opened ScienceTalk Sidebar)

Zone of Proximal Development

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Dr. Joanna A. Christodoulou works at the intersection of education and neuroscience with roles as a scientist (Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology), clinician (Children's Hospital, Boston), instructor/professor (Harvard University: Department of Communication Sciences and Disorders at MGH Institute of Health Professions), and practitioner.

Imagine that you are in the company of a skilled teacher who makes concepts seem incredibly accessible and apparent. You leave a session with this teacher, attempt to explain what you learned to
Then quite suddenly, he pulled the scaffold away by sending each student home to write a paragraph alone. Writing a paragraph is a complex skill composed of many smaller skills: the ability to conceive of a topic, to organize an argument, to write sentences, to keep ideas in mind, to connect ideas, to recognize and use evidence, and many more. As teachers, we need to know what skills are embedded in our goals, what skills students bring to the task (likely somewhat different for each student), what skills they can reasonably be expected to do on their own, and what skills we are actually doing for them in the classroom. Could Jeff's students write a paragraph?

(End of first column online)

Well, yes and no. In the scaffolded context of the classroom, the students as a group, relying heavily on the teacher's support, could write a paragraph. But alone at home, they could not.
Most adults know, at least intuitively, that performance depends on context. For example, perhaps we have attended a lucid lecture about a complex topic, like the connection between emotion and learning. A good lecture provides an intellectual scaffold that enables us to begin to understand a new concept. It's as though we are hoisted onto someone's shoulders so that we can see beyond the usual crowd of familiar ideas and glimpse a new vista; we see it with exciting clarity—but only for as long as we stand on those shoulders. As soon as the lecture ends, as soon as we are put down again into the crowd, the vision begins to dissipate. In the excitement of the afterglow, we rush back to our school and attempt to explain to a colleague what we have seen, and it all falls apart. "It's so great. Emotion is so important to how we learn. It's like the rudder for thinking, so you really have to get the kids to be more emotional. But, no, I'm not really sure how it works with learning math."

The lecture allowed us just barely to begin to build the new neural network; it led us to the path and showed us its shape. But we must return to it again and again, building and rebuilding the concept a bit more facilely each time. We have to reread our notes, listen to the lecture again, read articles on the subject, discuss it with more knowledgeable people, try again to communicate to others our growing understanding, use the ideas to invent lessons, see what worked and what didn't, reread the articles, and go over our notes. Eventually, we may develop a decent neural network for this concept, but each time we need to use it, we must re-create it—reactivate it, rethink it. Although we become increasingly skilled, complex concepts must always be reconstructed. Building knowledge is a dynamic process, not a collection of static things that we store in a memory box.

And each time we reconstruct a skill, we do so in some sort of context that offers varying degrees of support for its reconstruction and various opportunities for reinterpretation (understanding it in new ways). If we are relaxed and talking with a colleague who is exploring the same idea, our reconstruction might result in new discoveries and a more substantial understanding. If we are being attacked by a parent who belittles the notion of any connection between emotion and reason, if we are late for a meeting, or if we just had a fight with our spouse, any weaknesses in our basic understanding will tend to loom larger and may undermine our attempts to reconstruct the pathway.

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Glossary

**neural networks**
A term describing a conceptualization of how brain systems operate, which can refer to either biological systems of neurons or computational models of how biological systems operate.

**scaffold**
A term describing support offered by a learning partner (mentor, teacher, more experienced peer, or parent), which structures the context and environment in a way that facilitates learning for the student.
Q: How can I get students to do their best?

A lot of what happens in school involves measuring student understanding or performance, and most people view performance as a simple linear progression, a straight line that should rise steadily each time we perform. But it is important to consider the variability introduced by changes in context: Performance will vary as conditions change, so what does performance actually look like when elicited in a context? Kurt Fischer offers some useful models for understanding context-dependent skill fluctuation. The first captures the variability in performance over a relatively short period of time, whether 20 minutes, a week, or a few months.

When the context supports performance, our skill level increases. The context includes external factors (like the environment, the materials we have to work with, the amount and quality of help available) and internal factors (like motivation, mental and physical readiness). As these factors fluctuate, so does performance. In a context offering high support (either scaffolding that actually does some of the work for us or the optimal conditions for performing a particular skill), we will perform at high skill levels. At the scaffolded level (like Jeff’s classroom), the amount of sustained support leads to intermittent, unsustainable breakthroughs in the level of skill performance. At the optimal level (providing the most supportive conditions for a given task), the amount of support results in a high level of fairly sustainable but effortful and varying performance. In contexts of low support (the conditions of normal daily life with all its distractions and imperfections), we perform at a level that reflects the degree to which a particular skill has become stable and automatic—our functional level, the level that most resembles a linear progression.

The functional level is how we perform a skill in our daily lives in the world, without any special support and without any major impediments. For example, once we have learned to drive a car, the various skills involved—steering, pushing the pedals,
knowing what's around us and the traffic laws—become largely automatic and stable. Over time, we become increasingly skilled, so our change in ability level, from a long-range view, resembles a steady linear improvement. However, if conditions change sufficiently—a blizzard, a fight with someone sitting next to us—our driving can suffer, and we will have to concentrate more to compensate for the change in conditions and to maintain our skill level. When conditions change dramatically, for example, if we are asked to drive a backhoe (to transfer the skill from the car domain to the backhoe domain), the new condition may prove so challenging that our ability to drive virtually disappears and must be rebuilt, with great effort, in the new context.

The optimal level reflects our best performance, the best we can do, because the conditions are the most supportive. Consider Joan, who is just learning to drive. At her functional level, she is able to start the car, put it in gear, and slowly drive from her garage 100 straight feet to the point at which her driveway meets the street, where cars whiz by in both directions. So, she stops, shifts the car into park, and lets her father take over. When her father creates the most favorable driving conditions by taking her to a clear, fairly straight, dry, well-lit, empty road and adjusts the seat and mirror to her needs, Joan can drive more skillfully—a bit faster, able to steer gradual turns and to vary her speed accordingly. It is these experiences of practicing the skill in the most supportive conditions that most improve her performance when she returns to the functional level.

(End of first column online)

At the scaffolded level, we are really just beginning to learn a skill or understand a concept that is beyond our current ability. Joan might have started to learn to drive as a young child by sitting on her father's lap and turning the key while he worked the gas pedal. She might have shifted into drive while he braked and then placed her hands over his as he steered. "Wow, look at you driving," her father might have said, but her functional level at that point was to sit in the car with the engine off and turn the steering wheel from side to side while making engine noises with her lips.

So, performance is always dependent on the context in which learners perform. The better the conditions, the better the performance—whether the performance is driving a car, regulating our emotions, writing an essay, or understanding a concept. In school, teachers constantly work to improve student performance; so, they tend to create conditions that result in optimal or scaffolded performance in the classroom in order to improve functional performance in the world. However, it's essential that teachers understand the differences in these performance-context relationships, and it is helpful for students to understand them, as well. Much of the frustration experienced by both teachers and learners results from failing to distinguish between what can reasonably be expected in each situation.

It takes time for a learner to build a new skill or understanding and become able to move from requiring scaffolding to performing skillfully without scaffolding. Teachers see this variability between optimal and functional frequently in the classroom. The teacher comes close to the student, gives a hint or two, and
the student's performance rises to optimal level. Then the teacher moves away, the hint-effect dissipates, and the student's performance drops to a lower level. Understanding the process by which skills gain stability—understanding why students appear more able when teachers provide support and expecting regression when they withdraw the support—can greatly reduce frustration.

In scaffolded conditions, the teacher is actually doing some of the work for the learner—whether it's steering the car, writing the paragraph on the white board, or providing the reasoning that produces an understanding of a concept like emotional thinking. The scaffolded skill level is barely sustainable even when the scaffold is in place, falling and rising wildly and sharply, and it collapses completely once the scaffold is removed. Skilled teachers remove the scaffold slowly both by transferring more and more of the actual work to the learner and by providing practice in multiple contexts. In essence, these teachers transform scaffolded performance into optimal performance.

For example, Jeff might have continued having his students write paragraphs in class, weaning them from dependence on him. After the white-board exercise, he might have asked them to work in small groups or pairs to create a paragraph. Then they might have worked alone, though still in the optimal conditions of the classroom, where they could ask a question and where others around them were engaged in the same sort of work. During this weaning process, their homework might have been simply to write topic sentences or to write a simple idea and illustrate it ("My brother is mean. Yesterday, for example, he tripped me when I..."), something they could successfully achieve at their functional level. In short, Jeff's students might have been more successful had they transitioned more gradually from scaffolding at school to soloing at home.

When performing at the optimal level, the learner is doing all the work, but the conditions are the best they can be to support that work. That is, the key components of a complex performance are supported or primed. During a 50-minute class, the students' performance will fluctuate because the skill hasn't become stable; the students are still learning; and as the priming varies over the 50 minutes, so will the performance—though, unless all support disappears, the performance is unlikely to drop down to the functional level. When the class is over and the support conditions are missing (say, at home that night), the students fall back to their functional level.

Over several classes in conditions supporting optimal performance, the students' skill becomes more stable; so each time they drop back to the functional level of performance, that functional level shows improvement. They become more skillful. The result is that, to those seeing these students performing over time, without any special support, the skill level appears to be improving gradually in what seems to be a linear fashion. Eventually, their functional performance becomes as skilled as their optimal performance used to be, but now they don't need those earlier supports. It's important to understand that this steady line of modest functional improvement over time results from more skillful practice at the scaffolded and optimal levels.
Q: Why is the ladder a poor metaphor for learning?

Whether it's the expectation that skill development is a linear progression or the idea that skills are separately built "up," the ladder has long served as a metaphor for learning and development. For example, traditionally, writing an essay is presented as a simple ladder of hierarchical skill development: sentence → brainstorming a topic → finding evidence → topic sentence → paragraph → five-paragraph essay → research paper. Despite knowing that writing is an infinitely messier process, many teachers continue to create syllabi that assume the learner must climb this ladder. Dynamic skill theory suggests a more useful metaphor: the web, which more accurately captures what happens in skill development. Each strand in the web is meant to represent a particular skill that develops and changes over time and in relation to other skills.

Imagine that the web above represents Sarah, a high school junior who has become a good writer, and that this web provides a picture of the interrelated skills for her development as an essayist. At the top, perhaps in early adolescence, three separate skills are developing: writing, interacting with friends, and playing board games. What happens is that these skills, though perhaps starting to develop separately, branch out and intersect, helping to inform, develop, and support each other (and produce other skills unrelated to writing—for example, persuading her parents to give her more social freedom). Sarah writes pretty good grammatical sentences, and she develops a real knack for helping her friends, who tend to bring their social problems to her. She helps them solve interpersonal difficulties, such as what to say to parents who won't let them do what they want. It is this social skill, Sarah's ability to persuade, that comes to inform her understanding of how to use specific evidence to develop a paragraph topic and, thus, improve her writing skill. Meanwhile, her developing skill as a chess player begins to inform her ability to think strategically both in social situations and as a writer.
The ladder as metaphor fails in two main ways. It misses the variability involved in developing a skill like writing by presenting it as a single ability when, in fact, it is the result of the interaction of several developing strands of skills, some of which we might (erroneously) not even consider relevant to writing. The ladder also fails because it suggests that there is some universal, standard ("normal") way that a skill develops—one syllabus for all. In fact, although there may be many similarities in developing a particular skill, the differences are important.

Let's look at a typical situation. A history teacher assigns a research paper to her juniors. "Write a paper on Andrew Jackson and the significance of his policies when he was president." One student, Judy, has real analytical strengths. She has a knack for getting to the heart of arguments, and she is good at Latin and geometry. As a child, she enjoyed sitting with her parents and working on the household budget, an interest that led her to board games and an understanding of rules and procedures. Now, she enjoys reading about economics and has a growing understanding of people’s spending habits. As a result of this web of skills, she writes a strong analysis of Jackson's economic policies and their significance for the country.

Bob, another student, has very strong social skills. Not only is he a leader in school government, but he also shows real promise as an actor in school plays and is good at English, where his teacher praises him for his insights into character. As a child, he developed strong skills for taking the emotional perspectives of others and for understanding why people make the decisions they make. He enjoyed keeping an introspective journal and loved to play with words, eventually learning that people's words often reveal their motivation. His essay explores Jackson's personal life and the significance of his policies as a reflection of his character.

Both Judy and Bob used their strengths, their interests, and their way of seeing the world to solve the problem presented by the teacher's rather open-ended assignment. The result was two very different, legitimate essays. Had the teacher restricted the assignment—for example, to Jackson's military strategy—the challenge might have resulted in less success. Judy, especially, might have struggled, though perhaps she could have found a new entry point in her affection for and knowledge of board-game strategy. Bob might still have been able to see Jackson's character reflected in his military decisions.
Skill Web for Bob

In this second hypothetical diagram of skill interactions, Bob displays an alternative approach to an essay assignment on the impact of Andrew Jackson's policies. Unlike Judy, this student...

View larger image

Glossary

Dynamic skill theory
A theory put forth by Kurt Fischer and colleagues describing concepts (and methods) for understanding how cognition and emotion impact development and learning based on assumptions of individual variability and interactions with context and environment. In the context of learning, dynamic skill theory posits levels of development and dependence of performance on context.
UNIT 5: BUILDING NEW NEURAL NETWORKS

Section 6:
Skill development

Q: How do we build new skills and understandings?

Not only is a skill such as writing the result of an interaction of a web of skills that inform and support each other, but is also the result of a building process that resembles the classic children's construction game involving knobs joined by inserting sticks into holes to create various two- and three-dimensional structures.

Skill theory suggests that cognitive development involves building connections between skills and ideas, a process of coordinating skills into more complex mental units. For example, consider a baby learning to fill a cylinder with blocks.

Building a Skill System: Knobs and Sticks

As suggested by skill theory, cognitive development involves forming connections between units of skills to develop increasingly complex skills. The construction of a cube in the classic...

View larger image

Johanna and Her Mother

At less than a year old, Johanna demonstrates how simple skills are combined to build more complex skills and how our ability to perform skillfully depends on context. Watch this video twice, first...

View video

The process begins at the most basic level with simple independent reflexes like grasping, looking, moving, or vocalizing (making a noise that signals some sort of need). Then two reflexes are coordinated so that the baby grasps a block in order to look at it, or stops vocalizing in order to move the
block, or vocalizes in order to get mom to help. Then, with time, practice, and more development, the baby coordinates these so that she stops vocalizing and grasps in order to look and move the block to the cylinder—a more complex set of coordinated actions to accomplish her goal. Or she vocalizes to get help so that she can look and move the block toward the cylinder. Finally, she stops vocalizing in order to move the block to the cylinder and then vocalizes so that mom will dump the blocks out of the cylinder. Then the baby can begin the process of filling it again. The baby now has developed a system of coordinated activities, goal-directed actions that allow her to fill a cylinder and to get help from her mother for the steps she cannot complete alone. This system is represented by the cube in the picture above.

This process of building skills (abilities or conceptual understanding) becomes increasingly complex as we mature, moving from reflexes that are coordinated into actions (infancy), actions that are coordinated into mental representations (childhood into early adolescence), and representations that are coordinated into abstractions (early adolescence into early adulthood). Finally, in domains in which adults have significant expertise, abstractions can be coordinated into principles.

At each level, the process of building the system (the metaphorical cube) of coordinated skills is repeated so that at the start of each new tier, the cube from the previous tier becomes the single skill unit for the next tier. That is, simpler skills become absorbed or nested within more complex ones.

This model is intended to suggest that building new neural networks of skills and concepts depends on making connections between simpler elements in order to build more complex abilities and understanding. We move from perceiving and acting in the physical world, putting together several actions, to creating mental representations of the world that we can manipulate in our mind, and then move on to abstract concepts or principles that explain domains like algebra or the biology of learning. We move from actually adding blocks to a cylinder to being able to imagine putting blocks into the cylinder, at which point we understand the concept of blocks in a cylinder and can use language to refer to this concept. We move from counting the blocks as we put them into the cylinder to
mentally adding 2 + 2, to understanding the difference between adding and subtracting, to making sense of the relationship between the addition-multiplication concept and the subtraction-division concept, and then it's on to solving for x.

On the surface, this process may sound, again, like a simple ladder, but it's really more like a set of Russian nesting dolls—simpler skills nested within more complex skills. From the perspective of teaching, the key is to understand how more complex concepts and skills emerge from the connections between the simpler pieces that comprise them. In order to become a good writer, what skills have to work together along the way? In order to write an essay about the significance of the policies of Andrew Jackson, what teams of abilities and understandings do my students need to have yoked together? For example, have my students understood Andrew Jackson's actions and their impact on different groups of people in the short term and over time? Have they, in fact, developed a meaningful and useful sense of what "significance" even means?

Of course, as we have seen, students' ability to write this essay also depends on two other critical variables: the web of skills each brings to the task and the level of support of the context in which each works. Judy and Bob created very different essays based on their particular skills and ways of looking at the world that resulted from their experiences. These are part of the contexts responsible for the quality of their essays. There were other factors, as well. Perhaps Bob worked in supportive conditions—in a quiet library—while Judy worked in the less supportive conditions of home—in the kitchen with her three little brothers running around and the television blasting from the living room. Given all these factors, it's not difficult to understand the inadequacy of the ladder as an image for learning.
Regression: not failure but a critical component of building and rebuilding skills

Q: What is failure?

People hate failure. In school, failure is a major source of fear and frustration for students and teachers alike. Our attitude toward failure may well be the result of the ladder metaphor’s implication that good learning and, therefore, good teaching, are marked by steady forward progress toward mastery. “They learned this last week, and today it was as though they had never seen it before.” Yet, regression, or performance that is typically misinterpreted as failure, is both inevitable and necessary for learning.

Once we understand the connection between performance and context, the inevitability of regression becomes obvious, especially in school, where teachers work to create conditions that support scaffolded and optimal performance. If conditions change, for example when the support of the teacher is no longer available or motivation wanes, performance falls back to the functional level. Moreover, conditions constantly change. Sometimes, they change within us, when we don't get sufficient sleep or become upset or bored. Even our most basic skills, like our ability to walk, can regress under the pressure of traumatic conditions. Some parents, for example, at the funeral of their young child have fallen to the ground and crawled because they quite literally lost the ability to walk for that moment, reminding us that in extreme conditions even seemingly simple automatic skills degrade into their underlying basic skills.

Sometimes, conditions change because the domain in which we are asked to perform changes: driving a backhoe is not the same as driving a car. Although a skilled adult driver may more quickly learn to operate a backhoe, at first he may look like a child—exploring the various levers, lurching forward, and stalling the engine. Furthermore, writing a science lab report is not the same as writing a history paper or when trying to compose a letter explaining personal feelings to her father.

Even when teachers sustain or successfully re-create highly supportive conditions within the same domain, their students’ performance will fluctuate, showing signs of improvement and regression—two steps forward, one step back. That’s the rhythm of learning, the rhythm of constructing new neural networks. It’s a process of building and rebuilding that allows us to continue to improve, each time advancing a bit further from a more solid base. Integrating skills into increasingly complex systems of representations and then abstractions is difficult work, involving considerable trial, success, and error.
Each success brings us closer to the limit of our ability or understanding until we stumble, go back a bit, and start again—learning from both our progress and regression and slowly building stable neural networks.
Q: What is a teacher's job?

Principles to consider:

- Teachers cannot transmit knowledge to learners.
- Learning is a dynamic process of building and rebuilding new neural networks.
- Performance depends on context.
- Students need to learn to create contexts to support their own learning.
- Skills tend not to be isolated abilities learned in a linear fashion but webs of interrelated abilities.
- Learning new skills and concepts depends on coordinating more basic skills to form increasingly complex skills.
- Regression is essential to learning.

Teachers cannot transmit knowledge to learners. Knowledge isn't an object that can be passed on or held. The idea that concepts are skills that need to be built and rebuilt is fundamentally different from the idea that concepts are static things that can be placed in our memory for future use. Although memorization may sometimes be useful, it cannot substitute for building the neural pathways that create understanding. So, the student's job is the building, or the learning. The teacher's job is to create the conditions that support learning. If we think of schools as contexts for learning instead of places for teaching, we might effectively imagine new approaches not only to the classroom, but also to all aspects of schools—the physical and social, the policies and practices, the attitudes and metaphors. We need to replace the language of teaching with the language of learning.

Whether we can do something depends on the context in which we do it; whether we know something depends on the context in which we think it. In a world preoccupied with assessment—a world in which grades are the coin of the realm, traded for access to colleges and the jewels of capitalism—teachers need to consider carefully exactly what they assess and what factors have produced the test, lab, or essay in front of them. Let's look back at the essays on Andrew Jackson written by Judy and Bob.

Each essay emerged from a different web of skills that resulted in different approaches to the problem of making sense of Jackson's policies, an assignment that the teacher left typically vague—"Write a paper on Andrew Jackson and discuss the significance of his policies when he was president." Judy's essay was quite analytical and looked at economic policies and their effect on subsequent events. Bob was more interested in the man himself. Bob discovered significance in Jackson's policies as a reflection of character. It would be nice to believe that the teacher could see the merit in both approaches,
but the teacher, too, brings a web of skills and a way of looking at the world (too often unexamined) and probably had an ideal essay in mind. The grades of the two students will likely reflect the interaction of the teacher's web and the students' webs, and Bob might not fare as well as Judy.

Other factors will also affect the quality of the two essays and the perception of the quality. How developmentally ready are Bob and Judy to write an essay of this complexity? What level of performance is each capable of under supportive conditions in each of the skills required to produce such an essay? Has the teacher consciously identified those skills and helped Bob and Judy identify them? How developed is each student in terms of making conceptual links between and among the more basic skills embedded in the larger skill of writing a research paper in history? Has the teacher aligned his expectations with the contexts in which Judy and Bob worked and helped those students learn to build supportive contexts for themselves?

Another critical job for teachers is to help students learn to create for themselves the conditions that support their own learning. For example, Laura Moore, an English teacher in Massachusetts, has worked for years helping students to become "attuned to their own writing process, to become increasingly aware of it, and to become adept at manipulating it, an effect which is achieved through daily self-assessment, introspection, and reflection. I tell them to pay attention to how, when and where they do their work; what kind of work they do in those conditions; and the successes and failures of that use of time. Some students find they write best in the early mornings or in the afternoons, in the back of the library, or late at night at Barnes & Noble." See article, "Student-as-Text: A Sustainable Philosophy for the 21st Century English Curriculum: Timeless Lessons in the Fully-Examined Life."

Frequently, students with some sort of diagnosed learning difficulty have been taught to ask a teacher for certain "accommodations" that will enable them to perform successfully. They understand their own brain, understand their need for more time, a quiet place to work, or a certain structure that will help them complete a long, complex assignment. Many adults eventually learn what conditions support their best work. In fact, some adults have learned to create scaffolds for themselves: They let spell-check recognize errors that they are unable to see for themselves; they let the computer voice read documents to them; or they design organizational templates to use whenever they tackle a large project. Schools might profitably spend more time helping all students explore, discover, and create the conditions that enable them to do their best work.

Perhaps the largest ethical issue is the challenge of how to grade regression. Although this cycle of moving forward and backward and forward is the natural rhythm of learning, many teachers perceive regression as failure and a source of personal frustration. For the most part, grading systems reflect the traditional models of education, which do not take into account productive regression. If assessment is continuous rather than just an end-point to mark that learning has occurred, regression becomes natural and expected, and a learner's skills can be assessed in a more process-oriented way.

The new models of cognitive development—the web, the connection between performance and context, the tiers of development from reflexes to abstractions, the more basic skills connected and nested within more complex skills, and the necessity of regression—are rich in implications for schools, but fundamentally they suggest that learning is slow and hard. It takes time. The old linear models—the ladder, the isolated skills, knowledge as objects stacked in memory boxes, performance as a steady rise
regardless of context, and teachers talking—imply that learning can move along pretty quickly and that everyone can move at pretty much the same rate. The clash between these models presents exciting opportunities for rethinking how schools manage and use time.

Finally, it's essential to remember that, although we are looking at cognitive aspects of learning in this unit, emotion remains an equally critical factor. Research into the processes of learning suggests that learners must do the work of learning, the hard work of building neural networks. At the same time, we know that people tend to work hard only when the work matters to them, a trait that reminds us that cognitive development must always be considered in the context of the emotional goals it serves.
UNIT 5: BUILDING NEW NEURAL NETWORKS

Section 9:

Resources


UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 1: A reminder

Q: What should I do with all these ideas?

As promised, this unit does not presume to tell you how to change your school or classroom. Although what we are learning about learning certainly suggests a need for change, every school and every classroom present different circumstances. From the beginning, our goal has been both to help you internalize and understand new ideas and to reinforce or support discoveries that derive from your own classroom experiences. The purpose is to enable you to create and experiment with ways to improve the learning of your students. Now, we offer a few illustrations of how some teachers have applied the principles of this course to their classrooms or schools. Some of these changes have been modest, while others have been systemic.

For example, Nick and Martha, the two teachers about whom you will read in Sections 3 and 5, don’t start as revolutionaries, though they certainly evolve in that direction. Nick begins with a desire to offer more choice to the students in his English class; he was simply looking for a way for his students to feel connected to literature. Martha starts with an idea about how to reduce the fear of and focus on grades in her history classroom. This is how change begins. Someone faces a problem, invents a solution, and gives it a try. Other teachers might begin with even more modest changes, though they often feel very big to the teacher. One might decide that he is going to stop lecturing and let his students talk more, and find out what they think before telling them what he thinks. Another might decide to spend more time getting to know her students as people and create emotional connections on a personal level. One thing leads to another, and slowly these teachers influence other teachers or, eventually, become leaders—department chairs, division heads, principals—and these modest changes spread. All that matters is that you continue to think, imagine, invent, and experiment.

There are thousands of good teachers and many good schools in this country, all deeply committed to young people. Interest in research, attendance at professional conferences and workshops, and willingness to try out promising ideas—such as constructivism, understanding by design, and differentiated instruction—are evidence of their presence. But good teachers and good schools continue to struggle against 19th-century assumptions about how learning happens. The larger system doggedly clings to untenable traditional assumptions about learning. Today, the growing alliance between educators and researchers offers a real opportunity to challenge these assumptions.
UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 2: Everyone's talking at me

Q: What's the answer?

People are natural meaning-seekers. From Aristotle to Alfie, our most persistent question remains, "What's it all about?" That's just the way our brains are wired. "Why me?" we cry, when misfortune strikes. What seems also true, based on all the research contained in this course, is that for meaning to become meaningful in the nuanced, personal way that enables us to use it creatively, we have to construct it for ourselves. And this takes work. Of course, humans also tend to be a bit lazy, and it's certainly easier to get answers to life's persistent questions from someone else than to grapple with them ourselves. As a result, plenty of people are always eager to think for us—people looking for ditto-heads to follow them—and many people are always happy to follow.

So, while people are meaning-seekers, they are not necessarily meaning-makers (independent thinkers)—in the rich, dynamic sense suggested in this course. Although the professed and desired outcome of education is to develop meaning-makers, too many of our schools tend to fall short of this goal. Students are told what novels and poems mean, the causes of wars, the "right" way to solve math problems, and what to believe about global warming or other cultures. Facts get all mixed up with adult opinions. The result is that rote memorization replaces the hard work of building new neural networks rich with personal meaning.

(Opened TeacherTalk sidebar)

Finding Answers: Developing student voices, developing social emotions, and guiding children to discover their own answers to their questions

Julia Volkman is a Montessori mentor who works with the Springfield, Massachusetts Public Schools.

Preschoolers and kindergarteners are famous for tattling. They notice absolutely everything that goes on in the classroom, and they want to make sure we notice it, too. What they really want is to know two things: Is something okay, and if not, how should one respond to that? So we've developed a tier of interactions for responding to the tattlers.

First, we turn the tables back to the person involved. If they tell us that Robert cut in line, we say, "I cut in line?" They inevitably answer, "No, Robert did." "Oh," we reply, "you should talk to Robert about
Despite all the research and all the insights we have gained into the complex mysteries of the brain and how it learns, this picture continues to capture the essence of education in too many classrooms. Teaching is telling or talking at; learning is listening. Kids not learning? Talk louder. Meanwhile, the students tune into more personally meaningful things—creating their look, downloading their music, or texting their friends.

What is the role of schools in shaping what we become? Should schools aspire to turn out meaning-makers? If the system is built on the assumption that teaching means passing on to students the meanings that teachers have discovered, and if students become so accustomed to having teachers tell them what things mean and then being tested on how well they can parrot those meanings, perhaps it is unreasonable to expect many of them to become meaning-makers. Perhaps we shouldn't be surprised that so many students seem so passive.

Research suggests that active engagement is the result of very different conditions. Emotional relevance and a solid platform of self will motivate learners and will develop their ability to empathize with others and to become creative problem-solvers. When learners can pursue their interests, when they can study what matters to them, and when they can engage deeply with other learners and teachers, they are more likely to do the hard work of meaningful learning.

So, what are schools to do? How can

(End of the first column online)
which educators and researchers work together to enhance learning and teaching (Chen, 2006; Hinton, 2008; Hinton and Fischer, 2009; Hinton and Fischer, 2010; Kuriloff, Richert, Stoudt, and Ravitch, 2009). As part of this movement, researchers from Harvard Graduate School of Education (HGSE) and educators from St. George's School created a partnership to collaborate on school-based research. The first phase of this research, spanning one academic year, focused on student engagement. The team of researchers and educators was driven to find out why students are engaged and how this engagement occurs.

To do this, they created a questionnaire that addressed engagement in various aspects of student life at St. George's School. Results revealed that students at St. George's School are highly engaged, with most of the sample stating they are “very” or “a good amount” engaged. An analysis of the results provided recommendations for ways in which educators can work to enhance student engagement. The recommendations varied from providing more choice for students to helping students understand that intelligence is flexible to giving students a sense of autonomy, competence, and relatedness. The educators at St. George's School have begun to incorporate the recommendations into practice by restructuring certain lessons and assignments. This essay will describe the structure of this research-school partnership as well as the research carried out by the team.

St. George's School is a college preparatory school in Newport, Rhode Island. It is a private, grades 9–12, co-ed boarding school. The members of the community are integrated in almost every aspect of daily life; students, faculty, and staff live together, work together, and dine together. Student life at St. George's is characterized by a strong focus on academics, competitive athletics, a school-wide spirituality program, and diverse travel opportunities, including a semester at sea and a global studies program.

The partnership between HGSE and St. George's grew out of a research initiative at the Merck-Horton Center for Teaching and Learning, a grant-funded research center at the school. The Center's mission is to support effective teaching and learning through professional development, innovation, and participation in scholarly research. Its mission is well aligned with the research school movement (Chen, 2006; Hinton, 2008; Hinton and Fischer, 2009; Hinton and Fischer, 2010; Kuriloff, Richert, Stoudt, and Ravitch, 2009). Researchers from HGSE involved with the St. George's partnership are committed to this initiative and have built research school partnerships with several schools, both public and private.

Researchers from HGSE met regularly over the course of a year with a group of educators at St. George's who voluntarily participated in forming the research-school partnership. The team of researchers and educators worked together to shape a school-based research project that would be both relevant to St. George's and grounded in the literature on research in education. Initially, the first several meetings were used primarily to familiarize the researchers with St. George's culture and allow the educators to become acquainted with the concept of a research school. The educators helped characterize the school culture and shared anecdotes of typical pedagogical practices at St. George's, while the researchers provided examples of what some previous research-school partnerships have focused on. During these initial discussions, the team brainstormed potential topics of research at St. George's. The conversations began to narrow to specific ideas for exploration, ranging from collaboration among students to technology usage in the classroom. Eventually, the team settled on the topic of student engagement. The choice of this topic was driven primarily by the teachers' interest
in this area; they felt the school and their own teaching would benefit greatly from knowing more about what engages their students.

With this topic established, the team generated the following research questions:

1. To what degree are St. George's students self-directed learners?
2. What are the factors that contribute to this engagement?

The language used to form these questions stems from Ryan and Deci's (2000) self-determination theory (SDT). This theory describes a spectrum of motivation placing extrinsic motivation on one end and intrinsic motivation on the other end. Intrinsic motivation arises from a genuine enjoyment in an activity. When students are intrinsically motivated, they have an internal drive to learn about something. They want to learn about it simply for the sake of learning. Extrinsic motivation, by contrast, comes from a force outside of the student. When students are extrinsically motivated, they are working to gain external rewards or avoid punishments. External rewards can take many forms, including good grades, prizes, money, special privileges, or praise from parents, teachers, or peers. When students are intrinsically motivated, they are more likely to have higher academic achievement and become lifelong learners. Movement toward intrinsic motivation is supported when autonomy, competence, and relatedness are the focus of learning. The first research question aimed to identify where students at St. George's fall on this spectrum of motivation; the second question focused on what contributes to this degree of engagement.

To address these research questions, the team of researchers and educators created a questionnaire that was disseminated to students at the school. Questions were co-constructed in order to fit the context of St. George's culture and reflect relevant research in student engagement. The questionnaire addressed engagement in all aspects of student life: academic, social, residential, athletic, extracurricular, and spiritual. Targeted themes included general reflections on engagement, extrinsic and intrinsic motivation, identifying motivating factors (i.e., grades, personal growth, etc.), challenge, relevance, autonomy, competence, collaboration, theories of intelligence, and metacognition. In addition to Ryan and Deci's (2000) self-determination theory described above, the questionnaire drew on other theories related to engagement such as Csíkszentmihályi's theory of optimal experience and Dweck's theory of intelligence (Csíkszentmihályi, 1991; Dweck, 2002).

A total of 108 randomly selected students participated in the questionnaire. The sample had an equal distribution across grade level and gender. Formatting of the questions varied from multiple-choice to short answer, and the questionnaire was to be completed in approximately 20 minutes. The data were analyzed using quantitative and qualitative methods. After the researchers performed an initial analysis, the results were shared with the educators. The discussions around the findings grew very rich and prompted further analyses of the data. This collaboration allowed the analysis to be tailored so that it would be most useful to the educators and school. For example, the educators were specifically interested in correlations between effort and performance, level of challenge and engagement, as well as evidence of developmental trends in students' concepts of intelligence. The researchers then went back through the data to run analyses in these areas of interest.

The yearlong project culminated with a two-day summer institute at St. George's School, which approximately 25 educators from the school attended. On the first day of the institute, researchers from HGSE presented key topics of research in education and provided an overview of the study on student
engagement. During the presentation of the study results, recommendations for practice were made based on each of the findings. Day two of the institute focused on applying these recommendations to practice. Educators worked together by department to enhance assignments from their courses by incorporating recommendations into the structure of the assignment. For example, one teacher used the recommendation, *focus on the process of learning*, to create a formative assessment for her students. It will be given to her students at different points throughout a long-term project and will inform her of changes in students' understanding of the key concepts related to the project. This assessment will be different from a typical quiz or test in that it will not be used to grade the student, but rather to direct the teacher and her students in guiding learning along the way and identifying next steps.

The consistent collaboration between researchers from HGSE and educators from St. George's over the course of the year was vital to building a foundation for the partnership and carrying out effective research. Both the researchers and the educators were involved with each phase of the project, which enabled the topic and results of the research to be relevant and useful to the school. This partnership can serve as a model to other educators and researchers who are interested in collaborating on school-based research and effectively applying the research to practice.

REFERENCES


Glossary

**Ryan and Deci's self-determination theory**
Edward Deci and Richard Ryan put forth SDT as a theory of motivation and personality that highlights the role of intrinsic beliefs, abilities, knowledge, and desires of individuals in the context of environmental influences.

**Metacognition**
A term describing personal knowledge about one's thinking processes, often in relation to learning.
more teachers translate scientific theory into effective classroom practices? The premise of this course is that learners and circumstances differ, so finding a universally applicable approach is unlikely. In addition, one size, one approach, limits the scope of learning in its Procrustes-like aspirations for cookie-cutter standardization; and providing answers to students short-circuits the process of learning. Of course, as it is for students, so it is for learners who also happen to be teachers: One of the goals of this course is to avoid giving answers, lest they be construed as definitive and universally applicable. Instead, our goal is to provide provocative information— theories, concepts, and ideas. By building new neural networks to internalize and understand this information, you will be able to identify and analyze the issues at your school and in your classroom. That way, you can discover your own answers, ones that address your unique circumstances, culture and population.

One of the most tenacious and admirable characteristics of teachers is their desire for autonomy. It is this independent spirit that this course addresses—even if that spirit is hobbled by intolerable conditions. Our intention is to reach independent, creative educators who are eager to engage in new ideas about learning and to use these ideas to invent solutions to problems they and their students encounter. Changing mindsets is not an easy process. Most of us tend to teach as we were taught; it's what we know. So seeing some examples of different approaches invented by teachers who have applied this research to their classroom can be useful. For the sake of illustration only, let's start by looking at just three of the many principles that emerge from the research and see how two teachers have transferred each to particular schools—both to the classroom and to the larger school as a whole.

**Csikszentmihályi's theory of optimal experience**
Mihály Csikszentmihályi's theory of optimal experience describes the concept of "flow" as an optimal state of experience in which attention, effort, and motivation are focused on a task such that the individual is engaged and at a steady state of comfort between being challenged and threatened.

**Dweck's theory of intelligence**
Carol Dweck advanced a theory of intelligence with two broad categorizations of how people perceive intelligence explicitly or implicitly. Incremental theorists subscribe to a concept of intelligence that is dynamic, changeable, and responsive to efforts toward improvement. Entity theorists attribute intelligence to a fixed property of the person that is static.

**Metacognitive strategies**
Target ways to self-scaffold and improve learning purposefully.

**Csikszentmihályi's theory of optimal experience**
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**Emotional Connections in Math and Science**
Dr. Gary Scott, assistant professor of clinical education in USC's Rossier School of Education, taught high school and middle school math and science. He discusses how neuroscience will provide...

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UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 3:
Principle: We think in the service of emotional goals

Nick was a high school English teacher and an administrator responsible for the school's curriculum. For years, Nick had known that emotion played an important role in learning, but he assumed that the intellect and emotion were separate functions. In his junior English course, Nick worked to get students to understand literature both intellectually and emotionally, “to find themselves in what they read,” as he put it. He also asked them to write about not only what they thought to be true, but also what they felt to be true. Still, his insisting that they check their emotional problems at the classroom door so that they could do intellectual work revealed his conception of the separation between heart and head.

Once Nick discovered and began to understand that emotion is the rudder for thinking, he thought that he might have found the key to motivation: Our needs and interests are rooted in our emotions, which motivate us to think and act. We choose to learn when we need or want to learn. So, Nick decided that if he wanted his course to be emotionally relevant to his students, he needed to give them more choice over what they studied—get them more invested in what they read, discussed, and wrote about. At the same time, he worried that such freedom might result in their failing to learn what they needed to know, especially for their college aspirations.

Saying "Hello": Meeting children where they are emotionally, creating emotional connections

Julia Volkman is a Montessori mentor who works with the Springfield, Massachusetts Public Schools.

In our mixed-age preschool-kindergarten classrooms, we know that the needs of the children vary from day to day. Sometimes, they arrive fresh and ready to return to the addition work they started the day before. Other times, they arrive emotionally charged because they were rushed through their morning routine or had a power struggle with a parent. We found that if we make a point to sit at the classroom door and greet each child upon entry, it gives us a chance to touch base with each student. Then, we can adapt to meet the children where they are. This greeting ritual also helps children to transition from their morning routine to their school routine—it serves as an emotionally relevant context cue that the school day is beginning and that their focus should switch from the parent to the teacher.
Ultimately, Nick devised a solution and decided to try it out. He would keep his focus on the skills he needed to teach—reading, writing, and thinking—and let the students decide what they would read, write, and think about. Nick’s only criterion for a student’s selecting a piece of literature was that it be or become personally meaningful to the student; the student must care about the work because it expresses some truth about living as the student has experienced it. However, he didn’t feel the students were prepared to make such a leap from the traditional classroom, in which the teacher chooses the content, to choosing for themselves, especially if the selections had to have some sort of...
personal meaning. So, he started slowly by asking all students to bring in something—an object, a song, a quote, anything—that meant something to them and share it with the class.

Once they became accustomed to talking about personal meaning, Nick provided books and lists of works that might resonate with them. Because some of his students already enjoyed reading outside of school, he didn't limit them to his lists. Instead, he suggested a process for selecting a work: read a few pages to see if it grabbed them. If it didn't, move on to another work. And so he proceeded from there through a crazy-quilt of the year's reading list—from Dante to V. C. Andrews. Sometimes, Nick ran his classes like a book club, with students taking turns selecting the poem, short story, play, or novel that everyone would read. Whoever selected the work would lead the discussions. At other times, he let them read whatever they wanted to read, so everyone was reading something different; in class, students focused on each other's writing issues—sharing personal and literary essays and discussing strategies for solving communication problems. [The selection of Dante's *The Inferno* reveals something about this population of students (motivated, college-bound) and suggests a reason that Nick's solution might be impossible or look very different in different circumstances—a different school with a different population. For example, the range of works suggested by the teacher would change in order to increase its likely appeal to that population of students.]

**Engaging Native Alaskan Students**

Native Alaskan teachers work to reduce the 50 percent dropout rate of native students. After learning about the connection between emotion, learning, and the self, these teachers began to create a...
UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 4:
From one classroom to the whole school

The experiment succeeded in getting the students much more engaged in the class and in improving their skills. But Nick wasn't satisfied, for he did not believe the students had fundamentally changed their attitude about school. When he visited other classes, he noticed the usual signs of disengagement: the dead eyes, the yawning, the staring out the window, the endless side conversations, and other distractions. And, if he were honest with himself, these symptoms were not entirely absent from his own classroom. Beyond its social aspects, school still didn't matter deeply to most of these young people. He needed to find a way to expand the notion of emotional relevance and increase the likelihood of a connection between the students' felt needs and the academic day. Nick had the quixotic notion that students could experience school as a place where they could pursue personally meaningful learning goals, but knew that he would have to win the hearts and minds of his colleagues to initiate more substantive changes.

He led the curriculum committee (the department chairs and other academic leaders) through an exercise. "Forget you are teachers," he said, "and remember yourselves as learners. Think back to the time you did your best learning, whether in or outside of school. And write down the conditions that you believe were most responsible for your success as a learner." As people read their lists, he wrote on the board the conditions that appeared more than once. Next, he had them look at the assumptions about learning that seem embedded in the practices and policies of their school. (Before you read these two lists (pdf), try the exercise yourself.) The contrast was sufficiently striking that the committee agreed to rethink the school, a process that resulted in the creation of a new experience for all ninth graders and that then expanded through the other three years of high school in different ways.

Essentially, an interdisciplinary (science, history, English, the arts) program focusing on skill development rather than a set, universally required body of "facts" allowed ninth-graders considerable latitude to pursue their interests. As Nick had done in his English class, the team of ninth-grade teachers worked to develop their students' specific skills—reading, writing, thinking, speaking, listening, studying—even grading these skills instead of giving grades in English or history, and encouraged the students to apply them to issues significant to them. Ninth-grade students spent the final two months of the year deeply immersed in applying their skills to a
project that they designed with faculty guidance.

The approach led nicely to a program that later enabled some of these students as seniors (or even, under some circumstances, as juniors) to build their entire curriculum around a central interest. The students applying to this program needed to meet only two criteria: a demonstrated passion in some area and the ability to work independently. Students went through a rigorous application process (that included their parents). They presented to a faculty panel specific evidence of their deep interest and independence, and found a teacher to sponsor and help them design their curriculum.

For those admitted, any remaining graduation requirements and the traditional five-course load were waived (typically, these students had already met most or all of the basic requirements). Students built their program to support their central interest—usually a combination of one or two regular courses at the school, professional off-campus internships or apprenticeships, courses at nearby colleges, and independent studies. The range of interests pursued was impressive: genetics, architecture, astronomy, math, writing, music, visual art, teaching, environmental science, foreign languages, philosophy, and history.

The idea was simple. Interest motivates, and one thing leads to another—interests usually lead learners to discover they need skills or knowledge that are often cordoned off into separate departments. For example, one student developing her interest in music and song writing, created with an English teacher an independent study in writing personal essays because she believed this skill would improve her ability to write lyrics. These were not programs designed for "at-risk" students, though this population was not excluded. Colleges gladly accepted seniors whether they emerged from this program or from the more traditional one.

Montessori and Dynamic Skill Theory

One finding linked to Kurt Fischer's Dynamic Skill Theory is that student performance does not increase steadily but goes up and down, depending on context. Even though they were developed long...

Technology for Every Student?

Todd Rose talks about the incredible flexibility...
What did it take for Nick and his colleagues to improve learning in their classrooms and, ultimately, their school? An interest in considering new insights into learning offered by neuroscience, the imagination to wonder "what if," and the courage to give it a try. And a lot of really hard work. What they created was a solution that worked at that time in that school with those kids and those parents. Under different circumstances, the solution to the problem of creating conditions to increase the emotional relevance of school for students would look very different.
Martha loved teaching history, and she loved the fall. The start of the school year seemed crisp with promise. The kids had grown tired of summer and enjoyed the return to school and renewing friendships. Despite a slight chill in the anxious anticipation of new classes and unknown teachers, they entered the classroom sunny with optimism and even eager to learn. For the first three weeks, the students seemed interested in reading about and discussing social contracts and democracy; they engaged in the writing exercises preparing them for their first essay; and the atmosphere was a relaxed mixture of serious intellectual work and banter.

But experience had taught Martha that this annual honeymoon wouldn't last, and she steeled herself for the day when she would have to grade and return the first set of papers. Her reputation as a rigorous teacher was based on high expectations, and she could never bring herself to lower her standards by awarding honors, or even passing, grades to poor work. She did her best to warn her students: It was just the start of the year, and they shouldn't expect to be skilled writers yet. Of course, the warning was futile. The day arrived, and she watched their faces cloud with anger or frustration or fear as they hurried past the pages containing hours of her marginal notes and stared at the grade for a few seconds before wadding up the whole thing. Hours of work, the students' and Martha's, tossed aside, plunging everyone into a winter of discontent.

The truth was that Martha had always hated grades. She dreaded their effect on students and on her relationship with them, but they were part of the system, like nitrogen in the air. And Martha believed that grades stood for something; they reflected a level of skill or knowledge, and she was not going to pretend that a poor essay was a good essay. So, if the school insisted on grades, she would use them honestly and work with her students to improve their skills and their grades. That was her job.

Then Martha stumbled upon a couple of research essays, one of which was "Webs of Skill: How Students Learn," and her thinking changed. She developed a more complex understanding of skill development, performance, and assessment. Although she had always treated skill development as a process, she had tended to look at it as a linear movement of steady improvement. Martha realized that she had ignored the inevitability and necessity of regression and the intimate connection between performance and context. In fact, the way she graded her students' essays entirely negated the notion of process by treating them only as products.

Assessment Feedback: Heading off testing anxiety by helping students
What was extraordinary to Martha, however, was that the ideas these researchers presented did not seem new to her. Reading them was like slowly realizing that she was hearing the idealistic voice of her younger self. Of course performance depends on context; of course regression is inevitable; of course grading a student essay is far more complex than simply measuring it against something written by Esther Forbes.

Martha recalled the young revolutionary who, as a new teacher, had railed against grades. That had been she. Somehow, her rookie conviction that grades transformed a classroom into an arena that "turned collaborators into combatants" had gotten crushed beneath the juggernaut of the system. The research gave her the courage to reconsider her practices. Could she create an approach to grading that diminished the fear and loathing and enhanced learning? Martha decided to make the focus of her assessments clearer to the students by increasing the number of grades she used.

Instead of simply holding essays to her forehead, like Carmac the Magnificent, and coming up with one grade, she began giving separate grades to content, organization, mechanics, and progress. Explaining her new approach to her students not only refocused Martha on the process of writing, but also helped her students see writing as a process and encouraged them to engage in it.

Because she wanted to reduce the students' anxiety, she also decided to give them much more control over their grades. They decided when they felt an essay was ready to grade. At any time, they could give
an essay to Martha and ask her to read it and not grade it. As a result, they really focused on the comments she wrote, greatly reducing the frustration for Martha. They could also ask her to grade an essay but not record the grade. When they eventually decided the essay was ready for "the grades that count," if they did not like those grades, they could rewrite the essay, and the old grades would be thrown out and the new recorded.

Finally, Martha also wanted to give them more control over the conditions that produced their essays, so she encouraged them to create their own calendar of due dates for submitting essays. Instead of plugging a single date into the syllabus for all students to produce an essay, she suggested they pick their own dates depending on other demands in their academic lives—when they had major projects or tests in other classes, for example.

Note: If your student load is 125, chances are good that you are reading about Martha and thinking, "No way I could ever do that." And maybe you are right—and maybe not. But the point of these stories is not to suggest that you implement these specific solutions. The point is to illustrate a thought process—how teachers can interact with research ideas and think their way to solutions to specific problems they face in specific circumstances. Different circumstances require different solutions, but the process of finding them is pretty much universal. What is important is not what we can't do but what we can do.

Although these solutions helped (student anxiety dropped; engagement and the quality of the work improved), Martha eventually rediscovered her youthful conviction that, as a general practice, grades are an impediment to the intended learning simply because they disrupt the natural alliance between student and teacher and shift the focus from learning to the grade. Her conviction became stronger following an experience teaching students in a program that had no grades. Andrea, one of these students, articulated the advantages of eliminating grades entirely: "I could focus on areas that I felt were a weakness and not feel anxious about earning letter grades. I was taking classes that I wanted to take and learning more because I did not have the pressures of worrying about grades." The lengthy narrative assessments filled with explanations and illustrations helped Andrea develop her skills while grades left her frustrated and lost. It was this experience that motivated Martha to begin a campaign in her school to do away with grades, a goal she has not yet achieved, though a few other schools have. See article, "From Degrading to De-Grading."

**Glossary**

**Esther Forbes**
Esther Forbes was an American novelist, historian, and children's writer. She received the Pulitzer
Prize in History for her 1942 biography, *Paul Revere and the World He Lived In*; and the 1944 Newbery Medal for her novel, *Johnny Tremain*. 
UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 6:
Joining forces

Nick (Section 3) and Martha (Section 5) are part of an army of teachers that has been growing for decades—teachers committed to finding ways to improve a badly flawed system, teachers who have found allies in researchers who are studying the brain and how we learn. Some of these teachers have joined forces under different banners: multiple intelligences, the Coalition of Essential Schools (CES), constructivism, differentiated instruction. But you can also hear their individual, often isolated voices as you walk down the halls of different schools, voices that echo various principles emerging from neuroscience.

"Something's not right here. What is it?" asks Krista stepping back as she works through the problems that her tenth-grade math students have put on the white boards around the room. She looks at the numbers as students shout suggestions. "OK," she says, "so 16x to the sixth is the variable expression for the area, and what happens when we plug in 5? Why isn't Karen's answer coming out right?" A cacophony of suggestions, all of them focused on possible errors Karen has made, and Krista stands quietly looking at the numbers.


"I knew it," shouts one of the boys, who is followed by a chorus of "I got it right."

Krista turns to them. "So why didn't you say so? Why did you assume I was right? I make mistakes, but you just assumed the teacher must be right, didn't you?"

Krista works hard to get her students to think like mathematicians, to understand the importance of noticing errors, and to begin to trust their own powers of emotional thinking—to question answers and explanations, even those emanating from authority. By drawing attention to their emotional responses ("I knew it"), Krista helps her students trust their emotions and develop the skilled intuition that will make them successful problem-solvers.

Down the hall, Meghan, a Latin teacher, encourages her students in the same direction. "Kids seem to do much better with concepts and ideas when they have to figure them out on their own and put them into their own words." So she has her students teaching gerunds and the gerundive to each other. "It's very interesting to listen to the kids talk about grammar concepts in their own words. Often, they make discoveries or come up with ideas that are advanced and complicated. I think the class went quite well, and I was pleased to hear two grammar topics being discussed in six different ways." Through teaching each other, these students are building richer, more robust neural networks for grammatical concepts. Meghan also taps into the social nature of learning and helps align the goals of learner and teacher: In this exercise the learner is the teacher, and the teacher is the learner.
Upstairs, Laura turns off the lights and asks her English students to close their eyes and recall something that frightened or delighted them as children, something to rekindle a strong emotion from childhood. Then she asks them to imagine what sort of animal this emotion might resemble, and they move on to create descriptive poems about these animals in preparation to read Emily Dickinson's "Hope," "a thing with feathers."

"I recruited their emotions to get them in the right mindset to address the ideas in the poem," Laura explains. "Then I had them try to do the same things Dickinson had done in her poem [use language, imagery, metaphor] so they would be less intimidated by the poem itself. They would have done the same thing on their own already and would have some understanding of what she was trying to do in her poem. Then I had them read the poem and try to understand it, analyze and interpret it." Not only are her students emotionally prepared for Dickinson's poem, but they also are invited to come to the assignment using their own emotional experiences and their own understanding of the world. Laura recognizes that each of her students is inevitably going to perceive the poem differently.

Across the campus in the science classrooms, Michael is having his students "design and carry out an inquiry-based lab on enzymes." Jim's room is empty because he has taken his chemistry students off campus to a local stream to analyze the degree of pollution and determine its sources in preparation for meeting with the town's conservation committee. These science teachers understand that doing real science to achieve important, meaningful goals increases the likelihood that their students will experience their education as emotionally relevant. They also know that having to explain the results of their inquiries to a committee of non-scientists will build strong neural networks.

These efforts to help students think like scientists, writers, mathematicians, historians, and artists reflect the work of thousands of other good teachers all over the country in all sorts of schools. They are the fruits of years of struggle to reform these schools, to graduate skilled students who can think creatively instead of giving diplomas to parrots. These are teachers courageous and honest enough to admit the failures of the deadening lecture—regurgitating traditions of schooling—and are intellectually alive and curious enough to search for better ways to promote deep, lasting learning.

More and more teachers are attending workshops on learning, teaching, and the brain. More are trying to...
out new ideas in their classrooms. Partnerships among college education departments, neuroscience labs, and K-12 schools are forming. And most important, supported by a growing body of research, teachers like Nick and Martha are becoming more confident and venturing outside their classrooms to share their successes with their colleagues and to take leadership positions. It's about time. Innovative, imaginative teachers deserve the support of innovative schools and real systemic change. They deserve to work in conditions where their goals and understanding of learning are aligned with those of their schools.

Glossary

**Coalition of Essential Schools (CES)**
An organization focused on educational reform and practice following the perspective of Theodore (Ted) Sizer as expressed in his books, including *Horace’s Compromise.*

**constructivism**
A theory and perspective that describes how an individual learns as a function of building (constructing) knowledge from existing ideas and new information. Salient themes include an active role of the learner; learners do not come to tasks as clean slates; and context plays an important role. Major early contributors included Jean Piaget and Lev Vygotsky.

**differentiated instruction**
Approach to (or philosophy of) teaching that allows for individual students' learning needs and interest to dictate the educational direction to allow for different learner profiles to be successful in a classroom.
UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 7: Lessons learned

Q: What can I do to bring this research into my classroom and school?

Nick (Section 3) and Martha (Section 5) are two teachers who studied the research, extracted principles that resonated with their experiences, looked at their students and classrooms through these new lenses and developed solutions to problems they experienced. They created answers to their own questions, and they worked to change not just their classroom, but also the school itself. Their solutions succeeded for them in their specific situations—their population of students, their colleagues, their parents, and their resources. The solutions they found may not work at another school in different conditions. It is the process they used to find the solutions that is important, not the solutions themselves.

We recommend a similar process to those working through this course: Make sense of the concepts about learning. Articulate the principles that resonate with your experiences not only as a teacher, but also as a learner. And look specifically at issues in areas that are important to you, both those in your classroom and those systemic assumptions about learning that restrict what you want to do in your classroom. For example, take some belief you have developed about learning, and use it as a lens through which to look at one of these areas:

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<tr>
<th>CLASSROOM:</th>
<th>SCHOOL:</th>
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<td>Homework</td>
<td>Graduation requirements</td>
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<td>Teaching methods</td>
<td>Schedule</td>
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<td>Lesson plans</td>
<td>Student course loads</td>
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<td>Memory issues</td>
<td>Departmental organization of schools</td>
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<td>Tests and quizzes</td>
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<td>Expectations and rigor</td>
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How does the connection between performance and context affect the way you might approach homework assignments? How might it affect your school's policies about homework and what your parent body needs to know about homework? Invent something. Try something. Take a step, however small, in a new direction.
Alden S. Blodget is director of Heads Up Collaborative, bringing teachers and neuroscientists together to explore the implications of research for classroom practices and school designs. He was a teacher and an administrator for 38 years.

The principles or major ideas identified in each unit are intended to provide lenses through which you can examine real teaching and learning problems. Rather than responding to questions with universal answers that pretend to apply in all contexts, this course offers tools and an approach designed to help you answer your own questions that arise from your unique set of circumstances. This sidebar offers an illustration of an actual problem and some of the various approaches used to analyze it.

The problem: "I teach math, and I find that students take good notes in class and are able to complete practice problems when supervised. Then, they go home, never think of consulting their notes (some of them, not all, luckily), and just come in the next day to say, 'I couldn't do the homework.' I also have had trouble with students who have been unable to recall information when faced with an assessment. If they are just given a problem in class, they are fine; but the second the pressure is on, they blank. Both of these seem to revolve around students putting information into memory and then retrieving information from memory when necessary."

Initial analysis: Like many teachers, Gretchen initially believed the problem to be relatively straightforward: memory and retrieval. Some of her students were not doing the work (reviewing their notes and engaging in the homework) that she felt needed to be done to "put" the information into the memory box. For other students, the problem had an emotional component: faced with the anxiety of a test, they were unable to retrieve the information. This analysis left Gretchen feeling that there was little she could do to solve the problem other than continue to exhort her students to consult their notes, try harder to do the homework, and relax during tests.

After taking this course, Gretchen began to look at the problem from several different perspectives. Each one suggested changes she could try in order to help her students. What follows is a brief sketch of some of her subsequent analyses using four specific principles from the course.

Learning is a dynamic process of building and rebuilding new neural networks (Unit 5)

The image often associated with memory and retrieval is a box, a container for holding things that we know or know how to do. Memorization is the process by which we put things in the box. Once in, all we need to do is open the box to retrieve them when we need them. In contrast to this image is the notion that learners must build conceptual understanding and other skills by building new neural networks. Subsequent use of these concepts or skills requires rebuilding them, an effortful process that results in increasingly stable networks. And the more stable the network, the more functional it
becomes, even under reasonable pressure.

This analysis allowed Gretchen to focus on the process of constructing understanding and skills. She began to explore the components of the concepts she was teaching—to see how they fit together into increasingly complex structures so that she could help her students build and rebuild their understanding.

**Regression is essential to learning** (Unit 5)

Gretchen also recognized that the process of building and rebuilding skills involves necessary regression. Some students built an understanding at one point in class; then it fell apart when they tried it at home; then it was reconstructed again if they used their notes to remind themselves of the components and got all the pieces back into mind so they could understand again. And each time these students’ knowledge fell apart and was effortfully rebuilt, the more solidly and facilely they were able to rebuild it. Gretchen tried to design a class that was supportive of this regression and rebuilding cycle.

**Performance depends on context** (Unit 5)

In reviewing the idea that our understanding or skill level depends on the degree of support provided by circumstances (the difference between driving a car on a clear, dry day and driving during a blizzard or while emotionally upset), Gretchen realized that her students’ ability to perform “when supervised” might inevitably outstrip what they could do at home on their own. She discovered that their “good notes” reflected what she had written on the board—not necessarily what the students had understood.

As a result, she became more conscious of the contexts she created in her classroom—of the high levels of support she offered (scaffolded, optimal) and the low level that her students would likely face at home. She helped her students to understand these differences and suggested ways for them to create circumstances that would support their efforts at home. She created more time in class for students to try problems using just their notes so that she could see who did and did not understand the notes. She consciously and gradually removed the supports she offered as she built not only her students’ understanding and skill level, but also their ability to support themselves. For example, Gretchen developed an activity in which students took their own notes, then worked in groups to compare differences in notes and compile and justify to each other an optimal set. Each group presented its notes to the class, using them as a scaffold for reconstructing and explaining the material.

**Motivation is rooted in emotional relevance** (Unit 2)

Gretchen also discovered an emotional component to her problem in addition to the fear of failing a test. Initially, she was dismissive, frustrated, and even sarcastic about those students who “never think of consulting their notes.” Aside from realizing that, for some, the notes were incomprehensible, she also hypothesized that, for others, doing the homework really didn’t matter. So, she found herself inventing real-world problems in which to embed the concepts she wanted to teach—having the students figure out the most efficient approach to plowing the school parking lot in the winter, computing interest on a savings account or investing a year’s allowance for 30 years. Gretchen had some students work with partners to solve problems in class; she suggested they work together on homework if they lived close enough to each other. Gretchen worked to get to know her students better.
by asking them about their interests and plans, and tried to invent ways to tie the math to these. She gave the students more choice over the problems they would solve for homework and tests. Sometimes, she asked students to invent their own problems to solve.

As a result of these new lenses for viewing her teaching problem, Gretchen succeeded in finding her own specific solutions that worked for her particular students in her particular school. The seemingly typical problem that she brought to the course lent itself to further analysis using other principles. Each analysis revealed aspects unique to her students and sparked more ideas that she could try. In turn, her attempts to support more active, dynamically constructed learning processes in her students enabled her students to become more aware of their own learning processes, to try new ways of studying, and to make suggestions to Gretchen based on their experiences grappling with the concepts.

Look, too, at the claims your school makes about its beliefs and goals. Consider the conditions that support or contradict these claims through the lens of the principles about learning that seem to emerge for you from the research presented in this course. Too many of these claims tend to be disconnected from careful scrutiny: We encourage risk-taking. We value creative, independent thinking. We graduate good citizens ready for democracy. We believe in cooperative learning and strong teamwork. We nurture curiosity. "We" may believe in these goals, but do the practices, teaching methods, and policies of our school move students toward these goals?

And, finally, don't set unreasonable expectations for yourself. The changes Nick and Martha created, both in their classrooms and their schools, took years to accomplish. Each of them worked with colleagues to develop strategies and plans. Although Martha was able to effect change in her own classroom very quickly, she continues the struggle to convince her school to abandon grades. The program that Nick helped create for ninth graders developed over many years and included two years of a pilot program before the full idea was launched. You can only do what you can do.
Q: How can I transform my classroom into a research lab?

John Dewey’s vision of real lab schools in which teachers and researchers collaborate to improve student learning remains an ideal that may, finally, after more than a century of sporadic talk and considerable sighs, be inching closer to reality. Eventually, partnerships between universities and K–12 schools may look like teaching hospitals: "Researchers and practitioners collaborate in a cyclic process to integrate theory and practice. They develop theoretical models, implement practices based on these models, systematically track progress, adjust models based on classroom results, and so forth. Researchers and teachers continue this cyclic process for each theoretical model until it is aligned with classroom results. They then disseminate findings to other schools, universities, and policy agencies." (Hinton, C. and Fischer, K., "Research Schools: Grounding Research in Educational Practice," *Mind, Brain, and Education*, Blackwell Publishing, 2008.)

Although the ideal may be for teachers and researchers to work together, teachers don’t have to continue to wait for Godot. Teachers can become researchers. They can work with their colleagues or even alone in the laboratory of their school or classroom. In many ways, consciously or unconsciously, teachers already have much in common with researchers. They analyze problems, formulate hypotheses, implement practices, assess their results, and make adjustments. Often, all that separates a teacher from a teacher-researcher is a bit more intentionality and mindfulness. Here are some practices you might consider:

- Study, understand, and internalize available research about how the brain learns—for example, take a course like this one, read relevant studies, or discuss theories about brain function with colleagues
- Develop questions—Why did Susie not understand today’s lesson? Why are my students not more engaged in this material?
- Formulate hypotheses—potential answers to these questions that link your understanding of the research to your understanding of the question
Engage in systematic discussion with colleagues—or write in a journal—about the questions and hypotheses

Articulate the models or metaphors implicit in your thinking about students' problems, strengths, and learning—a helpful resource is *Metaphors We Live By* (Lakoff G. and Johnson M., Chicago: University of Chicago Press, 1980)

Identify specific learning outcomes—skills and understanding—and conduct pre- and post-lesson assessments using clear rubrics

Identify independent variables like the students' freedom to pursue their interests—and dependent variables like the degree of engagement in the course

Field-test an innovative technique—a lesson design or a teaching strategy

Collect the data and record the results

Use the results to refine the hypothesis or adjust the practice

Disseminate the results with your colleagues for further discussion

Perhaps the most important part of whatever you try is to keep a good, brief record of your work. Adjust your expectations of yourself to the reality of the demands on your time. Maintaining a teacher's journal can be very valuable and, ultimately, save considerable time in the future as it becomes a personal collection of methods and lessons that do or do not work—a reference and a reminder.

**Glossary**

**John Dewey**
Prominent figure in education, psychology, and philosophy in the 20th century with prominent achievements in advancing child-centered and progressive education, highlighting the interconnectedness of society and education, and advocating pragmatism, among many other contributions.
UNIT 6: IMPLICATIONS FOR SCHOOLS

Section 9: Resources


Collins, K. "Beauty in the Beast: Falling 4 Math." *ASCD Express*.


CONCLUSION: A COMMUNITY OF EDUCATORS

Section 1:
Tomorrow's baloney

Betty was impatient. It was 2:15 p.m., the end of a long day of classes before another long day, and she didn't have time for another committee meeting, especially one that asked her to rethink school. "More pie-in-the-sky," she whispered to a colleague. She had rethought school countless times before, imagining all sorts of improvements based on some new revolutionary theory, and had watched the ideas vanish in a fog of excuses—lack of funding, not enough teachers, no follow-through, and resistance from parents or the college office. Even when some new approach was actually implemented, it seemed to last only long enough to collide with "new findings" a few years later, and this rhythm had become depressingly regular over the past two decades of brain research. "Today's new theory about some aspect of brain function is tomorrow's baloney."

The frustration and cynicism that characterize the conversations of many veteran teachers reflect years of dashed hopes that some new theory will transform their students into eager learners. In a system built on answers, teachers want answers, too. So, it's easy to understand how some research can be popularized, morph into a panacea, and raise expectations that can't be met. Each new panacea fails. After a while, you feel as though you are in a pinball machine with ideas whizzing about like steel balls—new math, open classrooms, phonics, whole language, interdisciplinary studies, multiple intelligences, and lateral thinking. Lights flashing, bells ringing, and scores clunking up and down, until finally, you just come to dread the rattle of another idea hitting the chute. Yet this disappointment in research's failure to provide "The Answer," a method of teaching that will work for all, reveals the different perspectives from which teachers and researchers approach learning. Teachers want answers to questions about how to teach. Researchers want answers to questions about how to learn. One aim of this course is to explore how these two groups might help each other tackle these questions.
**CONCLUSION: A COMMUNITY OF EDUCATORS**

Section 2:  
Mind, brain, and education (MBE)

Fortunately, starting in the 1990s, researchers like Kurt Fischer at Harvard, Bruno della Chiesa in Paris, and Hideaki Koizuma in Tokyo almost simultaneously began a movement to bring together cognitive scientists, neuroscientists, educators, and students in the service of improving both research and education. Prior to this movement, researchers tended to explore in their labs questions that interested them, but their insights were rarely influenced by student behavior or teacher experiences in the classroom or even by questions raised by teachers. And, it was equally rare for theories developed by researchers to find their way into the classroom, either to be tested against or to influence reality. Those that did find their way into schools, such as, most notably, the theory of multiple intelligences, typically left the researchers at the door.

The inspiration for MBE was, and remains, the research development and practice model of the teaching hospital, where researchers work closely with doctors, patients, and interns to improve medical outcomes. Theory and practice, and models and reality, would finally inform each other in schools, as partnerships developed among researchers, graduate programs, and K–12 schools. At first, a few graduate schools of education offered interested students courses that integrated biology, cognitive science, and education, and researchers lectured educators at various conferences and workshops on learning and the brain. Unfortunately, too few teachers, aspiring or veteran, participated in those MBE programs. The interactions between researchers and teachers at conferences tended to be one-way affairs, leaving teachers excited but puzzled by the theories and with no idea how to implement them in the classroom. Predictably, commercial "brain-based" programs sprang up to fill the void.

Since those early days, the MBE movement has grown more robust, and real collaborations among teachers, students, and researchers are appearing here and there. For example, a group of college and K–12 educators led by researcher Donna Coch started a partnership in the Upper Valley region of Vermont and New Hampshire. Part of the program included opportunities for veteran teachers to enroll in graduate courses in MBE and invitations to teachers to develop experiments that they could conduct in their classrooms. To prepare themselves to become researchers, these teachers visited the labs at Dartmouth College, interacted with neuroscientists, and learned how to conduct...
rigorous research. At the same time, the scientists in this partnership learned more about the specific sorts of problems that teachers confront in the classroom—the sorts of errors students typically make in reading and math. The conversations also helped the researchers to develop new projects and to gain better insight into student differences, insight that further affected their research. For example, based on conversations with teachers, one researcher studied bullying in middle-school girls, and together the teachers and researchers developed and implemented a program to address bullying.

Another collaboration developed in Massachusetts when researcher Todd Rose approached teachers at the Landmark School with the goal of figuring out some of the processes behind the dyslexia that characterizes most of the students there. (Landmark specializes in students who experience "language-based learning problems.") Todd met with a number of the Landmark teachers to discuss their ideas about the reasons students struggle with reading and writing. He had particularly long and energetic conversations with Chris Murphy, a veteran teacher who had worked for several years with many dyslexic students. Todd talked a lot about "working memory," the number of items that people can hold in mind when they are reading or writing text. He proposed that working memory was the fundamental problem for students with dyslexia. They had trouble keeping enough items in their working memory to be able to understand text that they were reading.

Chris was not satisfied with Todd's explanation. He kept raising objections, asking questions based on his extensive experience with many dyslexic students. He doubted that working memory was so simple: It did not seem to him that all dyslexic students experienced the same kinds of problems with holding items in memory when they were reading or writing.

Back and forth the discussions went, with Todd pushing the argument that the fundamental limitation in dyslexia was working memory, and Chris arguing that many students with working memory limitations turned out to be skilled with reading. Based on all their debate, Chris and Todd realized eventually that they needed to separate working memory limitations from vocabulary limitations. Perhaps a student could have some problems holding items in mind but have a strong vocabulary so that in reading and writing the working memory limit was not a factor.

The result was a research hypothesis: Working memory limitations could lead to difficulties in reading and writing; but if a student had an extensive vocabulary, maybe the working memory limit was no longer an issue or at least less of an issue. This hypothesis formed the core for the research project that Todd designed for his dissertation.

Todd collected data from high school students attending Landmark, putting together scores from a number of standardized tests of working memory and vocabulary. He examined how these skills related to fluent performance in reading "connected text" (such as reading this paragraph). The findings strongly supported the complex hypothesis that Todd and Chris had built together.

This modest partnership between a teacher (Chris) and a researcher (Todd) illustrates how researchers can benefit from discussing their hypotheses with teachers. The direction of Todd's working hypothesis changed as a result of his debates with Chris, whose classroom experiences with students struggling to read challenged Todd's original theory and led to a more complex and nuanced understanding of these
struggles. The result was new insights into the relationships among working memory, vocabulary, and reading fluency in students with dyslexia. The beneficiaries of these sorts of partnerships are the students.

(Opened ScienceTalk sidebar)

**Practical Research for Sesame Street**

Dr. Kurt Fischer is the director for the Mind, Brain, and Education program at the Harvard University Graduate School of Education. He studies cognitive and emotional development and learning from birth through adulthood, combining analysis of the commonalities across people with the diversity of pathways of learning and development.

In many industries and fields, such as cosmetics, chemistry, engineering, medicine, traffic safety, and meteorology, practice informs research, and research informs practice. Researchers and practitioners work together to do practical research that provides the basis for decisions about how to make and do things—build bridges, create face creams, design cars and highways, test medicines, and predict weather. Education needs this kind of practical research to determine what works in learning and how it works.

One of the best examples of this process in education is *Sesame Street*, which has used practical research from the beginning to make basic decisions about what works well in children's programs, what children actually learn from a program, how different kinds of teaching function better or worse with different children, and many other practical questions (Lesser, 1973).

One story about the early history of *Sesame Street* shows how important research has been for making decisions. At the beginning, the creators of the program believed that young children would be easily confused if Muppets such as Big Bird interacted with the human characters on the show. Based on this assumption, they designed the early versions of the program so that Muppets and human characters never interacted.

But research quickly showed that they had it wrong. Not only were children not confused, but they lost interest in the human segments unless the Muppets were there. The result was the invention of key Muppet characters, such as Big Bird and Oscar the Grouch, who regularly interact with the human characters, as well as with other Muppets.

Most of the research for the show was the work of Children's Television Workshop (CTW), which was specifically created for this purpose. CTW invented two effective tools, one called "the distractor" to measure children's attention to the show's content and another called "the engagement measure" to determine the depth of their actual engagement—laughter, moving to the music, and talking to characters. One segment, *The Man from Alphabet*, never aired because it failed to survive these tests. CTW also measured the effectiveness of the specific lessons by testing retention levels of children
Currently, these partnerships continue to form as researchers and teachers talk to each other. Some develop as a series of simple workshops and discussions. Others aspire to and may eventually become full-blown laboratory collaborations like those envisioned at the end of the 19th century by John Dewey. For example, Harvard Graduate School of Education has teamed with both Landmark School in Massachusetts and Ross School in New York to create research schools. Harvard researchers are also examining specific research questions with the Boston, Brockton, and Belmont public schools. A process called Instructional Rounds has been created in a number of schools to promote discussion among educators by focusing on individual student cases, in a manner similar to the way that doctors and researchers in teaching hospitals focus on individual medical cases. See book, *Instructional rounds in education: A network approach to improving teaching and learning*. Public schools in Boston and Texas are working with DiscoTest, an initiative to explore new approaches to standardized testing based on how students develop conceptual understanding. See article, "Redesigning Testing: operationalizing the new science of learning."

REFERENCES

CONCLUSION: A COMMUNITY OF EDUCATORS

Section 3:
Gaining some perspective

All this insight into learning and the momentum toward filling Dewey's vision of real lab schools makes this an exciting time to be in education. However, we must not let the fanfare and the cheering diminish the voices of the many teachers who, long before the fMRI supported their discoveries, challenged the same traditional assumptions and practices.

If you are of a certain age, you can go to your bookshelves and find the old Dell paperback (95 cents) of John Holt's 1964 book, How Children Fail. Holt was a teacher. Like many teachers, he drew his inferences and conclusions not from brain images but from the behavior of the students with whom he worked. The similarities between his insights and the implications of today's research are striking:

- The connection between emotion and learning, the importance of emotional relevance: "[What I was teaching] did not meet any felt intellectual need. ... The only answer that really sticks in a child's mind is the answer to a question that he asked or might ask of himself."

- The effect of fear on thinking and learning: "What I now see for the first time is the mechanism by which fear destroys intelligence, the way it affects a child's whole way of looking at, thinking about, and dealing with life. So we have two problems, not one: to stop children from being afraid and then to break them of the bad thinking habits into which their fears have driven them. ... What is most surprising of all is how much fear there is in school."

- The importance of attention and developing students' metacognitive skills: "Most of us have very imperfect control over our attention. ... Part of being a good

Dr. Todd Rose

"We've got to do a better job of recognizing just the natural variability that kids bring to the table and designing school environments that deal with..." — Dr. Todd Rose

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student is learning to be aware of that state of one's own mind and the degree of one's own understanding."

- The relation of context (scaffolding) to performance: "Would [my students] have discovered [the answer] if I had not paved the way with leading questions? Hard to tell."
- How grades (scores) come to replace learning: "We wanted them to figure out how to balance the beam, and introduced scoring as a matter of motivation. But they outsmarted us, and figured out ways to get a good score that had nothing to do with whether the beam balanced or not."
- The importance of regression (still confused with failure) in learning: "... perhaps we should see that failure is honorable and constructive rather than humiliating." "A baby does not react to failure as an adult does, or even a five-year-old, because she has not yet been made to feel that failure is shame."
- The need to link new learning to the real-world understandings brought to the classroom by different learners: "Between what he was studying for chemistry and the real world, the world of his senses and common sense, there was no connection."
- Issues of homework and rigor: "I have noticed many times that when the workload of the class is light, kids are willing to do some thinking, to take the time to figure things out; when the workload is heavy the 'I-don't-get-it' begins to sound, the thinking stops, they expect us to show them everything. Thus one ironical consequence of the drive for the so-called higher standards in schools is that the children are too busy to think."
- The danger of emphasizing coverage and testing as opposed to constructing conceptual understanding: "We do not consider that a child may be unable to learn because he does not grasp the fundamental nature of the symbols he is working with. ... [These children] would not be in the spot they were in if, all along the line, their teachers had been concerned to build slowly and solidly, instead of trying to make it look as if the children knew all the material that was supposed to be covered."
- The need to understand the knowledge and skills the learner brings to the classroom: "The reason this poor child has learned hardly anything in six years of school is that no one ever began where she was."
- And the great hoax of schools embedded in the emphasis on rote learning: "Even [young children] learn that what most teachers want and reward are not knowledge and understanding but the appearance of them."
CONCLUSION: A COMMUNITY OF EDUCATORS

Section 4:
Partners for change

Holt's book reminds us that good teachers know or have intuited many of the things that researchers are now "discovering." Too often, when teachers and researchers have come together, teachers have tended to sit mutely absorbing the lectures of the neuroscientists as though the teachers had nothing to contribute. Many of the neuroscientists have projected this attitude, as well. However, there are thousands of teachers like John Holt whose insights into how young people learn have guided their teaching, though their colleagues and administrators often dismissed them as cranks. One of the most important benefits of today's research is that so much of it supports the wisdom of the trenches. The John Holts have found allies in the lab.

As partnerships and discussions replace one-way lectures, teachers and scientists are learning from each other as they search for places where neural imaging resonates with student behavior, and where science supports intuition. After all, finding these places is one of the contributions teachers can make to researchers. Teachers know when behavior does or does not support theory, and researchers need to know when their predictions pan out in the very unlababoratory-like conditions of real classrooms filled with all those messy individual differences embodied in actual students trying to function in uncontrolled (even out-of-control) conditions.

(End of the first column online)

Teachers can also help scientists identify meaningful questions to guide research. For example, in two of the districts in the Upper Valley partnership, teachers identified an important issue that they were struggling to resolve: which of two approaches to teaching math and reading was the more effective. The researchers brought to the discussion neuroscientific data and their laboratory perspective; the teachers brought their experiences with students and the classroom realities that formed the basis of their current beliefs. Together, they found a way to discuss the issues without the usual level of tension and eventually resolved the issue. The conflict over whether to teach math using a curriculum based on procedures or a curriculum based on concepts, for example, disappeared as they developed a common language and realized that both partnership.
approaches could be useful depending on the circumstances.

Teachers constantly struggle with questions that would benefit from data gathered from research. For example, when is a learning disability a learning disability? If learning means building new, increasingly complex neural networks—a process dependent on establishing conceptual connections between bits of knowledge (like the relationship between addition and multiplication)—why couldn't what seems to be a learning disability instead be a failure to make the critical connection on which the more complex skill or knowledge depends? What about rote learning? Is there a developmental period when memorization without real understanding might actually lay a foundation for superior future learning? What about discipline policies—crime and punishment? If the ability to make good choices (by simulating cause and effect) develops late in adolescence, what are the implications for how we punish young people for their misbehavior? How realistic are our expectations for their behavior? Has any research been conducted on whether experience or guided simulations can speed up brain development and, hence, the ability to make good choices? Why do so many young people make perfectly good choices and avoid the trouble that seems to dog some of their peers?
CONCLUSION: A COMMUNITY OF EDUCATORS

Section 5:
What we have here...

What's the difference between Humpty Dumpty and Ludovic Lazarus Zamenhof? Their approaches to language. In a most unsatisfactory conversation with Alice in *Through the Looking Glass*, Humpty Dumpty declares, "When I use a word, it means just what I choose it to mean—neither more nor less." For Humpty Dumpty the goal is control, and language is the key to determining who will be master. Zamenhof, in 1887, began his crusade as Doktoro Esperanto (Dr. Hope) when he published his first book of what he hoped would become a universal second language, Esperanto. As a boy in Poland, he noticed "the misery caused by language division and [saw] at every step that the diversity of languages is the first, or at least the most influential, basis for the separation of the human family into groups of enemies." His idea was to create an international language to promote peace and the sort of understanding that enables people to work together to create a better world.

As educators and researchers come together to imagine and create better schools, we would be wise to resist the perhaps innate egotism of Humpty Dumpty and make our muse Dr. Esperanto—not his quixotic

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desire for one universal language but his desire to promote greater understanding.

The first task is to figure out how to communicate, which requires more than simply developing a common vocabulary—though it certainly includes that. Anyone who has been involved in change knows the difficulties of communicating and understanding. Not only do groups develop arcane jargon and have different understandings of the same word, but their perceptions of issues, problems, and situations are shaped by shared experiences and the emotional goals that guide their beliefs and behavior.
Meaning tends to be rooted in these experiences and goals. (In fact, these issues sound just like those facing teachers and students in a classroom.) For example, a proposal to study the correlation between student course loads and learning will receive very different responses in a school facing budget cuts than in one with a history of interdisciplinary studies. Perceived threats are particular factors in communication:

- This person wants me to change. I don't want to change.
- Who is she to tell me what to do? What does she know about my world?
- If I need to change, then what I've been doing all these years must be wrong.
- I am an expert in my field, not a learner.
- I'm not going to just give what I know to someone else.
- I don't have the time or energy to change.
- What if I can't change?
- Will this change eliminate my job or change my status?
- What I'm doing works fine.
- I've already tried that, and it didn't work.
- I already do that.

Finding strategies to address these very real emotional responses to change is as essential as finding a common language.
CONCLUSION: A COMMUNITY OF EDUCATORS

Section 6:
The readiness is all

June can be a giddy time of hope and despair in schools across the land, especially in faculty rooms as teachers don their robes and await their cue to participate in another graduation ceremony. They shake their heads, amazed that Joe or Sally is actually getting a diploma, and weep with laughter as they trade memories of the seniors who seemed most impervious to learning. "Joe had modern European history, and he had US history. So in my English class I felt safe in asking if anyone could tell me why so many Irish flocked to America. Joe raised his hand. 'A malaria epidemic,' he suggested." Big explosion of laughter from that corner of the faculty room. But filter out the laughter, and what remains is the frustration over the poor skills and knowledge of too many high school graduates. The senior class is a mirror into which teachers are uneasy gazing.

Better than anyone, they know that nothing is really amusing about education. From the rising tide of mediocrity to No Child Left Behind (NCLB) to the Race to the Top Fund to high drop-out rates, educators are reminded incessantly of the need for something better.

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Anyone interested in education—teacher, administrator, parent, student, researcher—knows that what we have isn't working as well as we want it or need it to work. We are in it together, and we will either solve our problems together or 100 years from now, people will continue repeating the same conversation that began in the 19th century. That's our common ground, our desire to make our schools better. Today we have the opportunity to look at education from all these perspectives, allowing us to unite experience and science, theory and practice, intuition and

Dr. Mary-Helen Immordino-Yang

"I'm hoping that we can really make rich conceptual advances for the role of emotion in learning and in education, because educational settings are social ones. The emotions that people..."

– Dr. Mary Helen Immordino-Yang

View larger image
insight—provided we bring to the endeavor certain traits:

- A desire to work with others, a belief in the power of many perspectives, and a belief that we can help each other
- An openness to accepting new ideas and to examining old assumptions
- A willingness to feel the points of view of others and open channels of communication
- The effort to understand and align our goals

The overriding purpose of this course is to stimulate conversation within this wide community of educators. Share your ideas and insights, and engage the ideas of others, by participating in online discussions (Note: On this Annenberg site, you will find a Teacher Talk list-serve. We hope you will use it to discuss with others your ideas and experiments.); joining the International Mind, Brain, and Education Society; attending and presenting at conferences and workshops; visiting one another’s classrooms, schools, and research labs; challenging the practices and policies that seem ineffective or counterproductive; inventing new approaches; and writing, sharing, and publishing your ideas.

Despite the struggle, perhaps we can come together as a people who speak one language and build the schools that embody our hopes.

Glossary

**No Child Left Behind (NCLB)**
United States Law passed in 2001 with the goal of closing the achievement gap through accountability for student achievement, reliance on educational tools that are scientifically supported, and availability of choices.

**Race to the Top Fund**
A competitive U.S. grant program introduced during the Obama presidency awarding funds to states that propose to advance education by improving practices and increasing student achievement with innovation and reform.
CONCLUSION: A COMMUNITY OF EDUCATORS

Section 7: Resources


