The Sciences of Teaching

The fields of neuroscience and psychology, when paired, offer new insights on the principles of effective instruction.

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For much of the time teaching has existed as a profession, the concept of "good practice" has been informed by two sources: wisdom handed down to less experienced teachers by more experienced ones, and the common sense and observational prowess of the teacher. Those two "inputs" continue to be worthy guides—if the sources consulted are worthy and if the teacher systematically hones both observational skills and common sense. Only in about the last half-century has the field of psychology begun to inform education practice through research findings. That layer of added knowledge has provided invaluable guidance about which classroom practices will likely boost the capacity of students—and teachers.

More recently, educational neuroscience has emerged as an additional source of research-based guidance on effective classroom practice. We find this development exciting. We believe that—as has been true with psychology—over time, findings from neuroscience that pertain to teaching and learning will grow in depth and breadth.

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Indeed, the psychology-neuroscience pairing is rich with potential for many reasons, one being the specific role each domain plays in informing classroom practice. It's quite rare for research findings from education neuroscience to contradict research findings from psychology; rather, that newer field often helps us understand the physiology *behind* the psychology. This linkage gives educators an additional level of assurance about commonly used practices or new practices educators may be considering trying. Neuroscience can help us understand why particular education strategies might, or might not, support learning.

Let's look at four examples of how this pairing of knowledge from psychology and neuroscience gives us insight into popular education approaches, discussing specific findings from each area that can and have guided teaching.

1 Why Does a Growth Mindset Boost Motivation?

For one example of brain science providing insight into *why* a principle derived from research in psychology works as it does, consider the broadly accepted practices associated with "growth mindset" (Dweck, 2006). The theory of growth mindset—itself supported by neuroscience—begins with the understanding that the brain is quite plastic; it can grow significantly in capacity over time. When learners understand and act on the premise that they can "build" brain capacity, similarly to how people build physical capacity, they're more likely to persist in learning and less likely to be deterred by setbacks along the way. For instance, in a recent study, psychological researchers studied more than 12,000 9th graders. They found that even a short intervention that taught students that intellectual abilities can be developed improved lower-achieving students' grades (Yeager et al, 2019).

Meanwhile, recent scanning investigations in neuroscience have explored the brain regions that respond to components of a growth mindset, such as corrective feedback and error monitoring, and to those of intrinsic motivation processing, such as response to reward. Although these regions are largely separate physically, there are two activated areas associated with both growth mindset and intrinsic motivation (Ng, 2018). Researchers theorize that because of the brain's plasticity, cerebral changes resulting from growth mindset interventions may also affect the neural regions responsible for intrinsic motivation.

These findings provide insight into the physiological basis of a psychological theory. They also remind us that, while educators teach students, we also teach brains—and those brains will likely change, for better or worse, as a result of how we envision and support the learning process.

Tapping This Finding to Inform Practice

To draw on these findings to promote growth mindsets in students, educators might:

- Explain, teach, and reflect often with students on the key aspects and benefits of growth mindsets.
- Teach students the skills, attitudes, and habits of mind that help someone develop a growth mindset. Dweck cautions that a growth mindset not only requires a person to work hard, it also requires them to work *wisely*. Hard work in the absence of intelligent work is like beating one's head against a stone wall.
- Establish a classroom culture of achievement and quality work. There is no magic bullet for this. But when students are part of a group in which peers pull together for mutual growth and success, it's far more likely that individuals will believe in their ability to succeed and will work toward

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such success.

■ Understand your *own* mindset. Observe yourself in action. Reflect on which students you easily respond to with interactions that foster confidence and an expectation of improvement, and which students you find it more challenging to believe in. Then grow, as you hope your students will grow.

■ Know that *teaching* with a growth mindset also involves belief, hard work, and smart work. Wanting to believe in the capacity of each student in your care is a great start. Enacting those beliefs is tougher; it involves ensuring that, every day, each student moves one step beyond where they began the day or class period. Your students must consistently observe themselves progressing, which will fuel their motivation and effort. Such progress can only happen when we begin where a student is currently functioning along their trajectory of learning. You will face the challenge of learning to help each student move ahead starting from *that* learner's point of entry into the lesson—what John Hattie (2012) calls "plus one teaching."

2 Linking New Knowledge to Prior Knowledge: Why It Works

Studies in neuroscience reveal the strong influence past learning has on the acquisition of new learning. Cognitive psychologists refer to this principle of learning as *transfer*, and some teachers tap into it almost instinctively. Some studies in neuroscience suggest that when new learning is connected to past learning and presented in a novel way, the likelihood of students remembering that learning significantly increases (Fernández & Morris, 2018). Imaging studies have even revealed which parts of the brain are involved in making these connections, such as activity often commencing in the hippocampus and extending to long-term memory areas for encoding. This is further evidence that the more teachers can do to connect new learning to students' past learning, the greater the chance students will understand and remember that new knowledge.

Tapping This Finding to Inform Practice

■ When you conclude the exploration of a topic during a class period, resist the urge to move immediately on the to the next topic. Give students time to talk with peers about the new learning, to facilitate the brain's consolidation process. Quickly moving to something unrelated may slow down or stop this important activity. Students' new learning may just fade away.

■ Work to know your students as individuals. Through conversations, interest surveys, observation, and formative assessment, develop a good sense of your students' varied backgrounds of knowledge, strengths, and interests. Knowing what your students bring with them to class provides you with a sense of their past learning—and how to connect it with new learning.

■ Keep in mind that knowledge must be extended at least "plus one" for student growth, and that students will have varying degrees of prior knowledge. As you connect to each learner's prior knowledge, ensure you're *building* on it, not just reviewing what's already mastered.

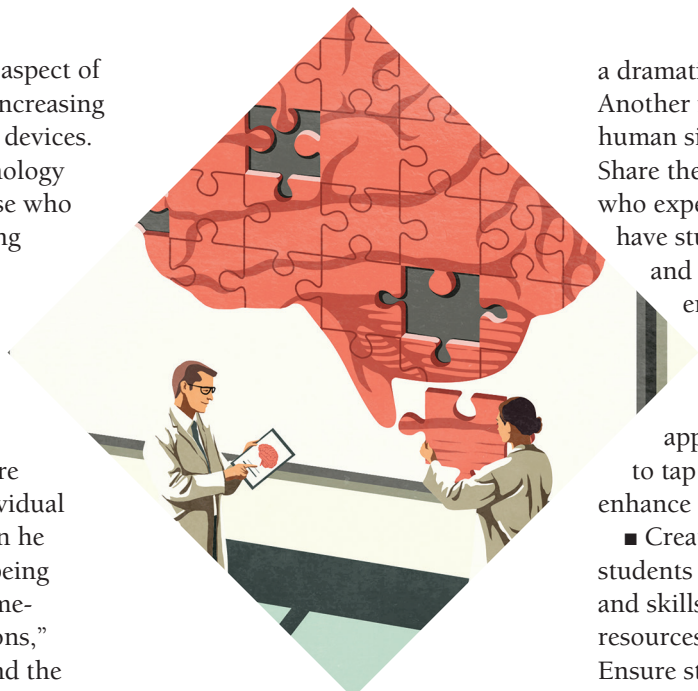
3 The Importance of Social-Emotional Skills

Research in psychology points to the importance of interactions with others in promoting learning. Vygotsky (1934, 1986) found that learning benefitted from a student working a bit ahead of his or her current readiness level *while interacting with peers or others* who could help the student surmount the task difficulty. More recently, one of the American Psychological Association's Top 10 Principles from Psychology for PreK–12 Teaching and Learning (2015) states, "Interpersonal relationships and communication are critical to both the teaching-learning process and the social-emotional development of students"—a principle noted in other seminal psychology publications.

Neuroscience research confirms

the importance of the social aspect of learning, a finding that has increasing urgency in this era of digital devices. Research suggests that technology is rewiring the brains of those who spend many hours connecting to the world through electronics rather than through people, or connecting with others only through screens (Sousa, 2016). Brains have specialized cells called mirror neurons that are activated both when an individual performs an action and when he or she observes that action being done by another person. Sometimes called "empathy neurons," these cells help us understand the intentions of others and are active during social encounters. Scanning studies show that these neurons can help our brain synchronize with the brains of individuals around us. So a group of students working on a project together may find their brains synchronizing with each other, supporting and even extending their learning (Dikker et al., 2017). However, some research suggests that frequent contacts with technology at the expense of face-to-face interactions may affect the mirror neuron system in developing brains (Dickerson, Gerhardstein, & Moser, 2017).

Much recent research in neuroscience has focused on the influence emotion has on learning. Structures in the limbic system generate emotions, which are then moderated by the frontal lobe's control functions. Emotions have a strong influence on attention—and attention drives what the student's brain decides to learn or ignore. Emotions also modulate long-term memory, and thus can enhance or impair what is stored there. When



new learning has minimal or no emotional component, the chances of long-term memory consolidation and storage are low (Tyng et al., 2017).

Said a bit differently, emotions are a gateway to cognition and learning. When curriculum and instruction evoke enjoyment, surprise, empathy, personal relevance, and so forth, the gateway opens and learning is likely to proceed more effectively and durably.

Tapping This Finding to Inform Practice

To strengthen learning by activating the social and emotional aspects of students' lives—and brains:

■ As you plan for instruction, move beyond teaching information to understanding the affective significance of what you ask students to learn. Help students connect their emotions to what they're studying. One way to do this is by encouraging students to use the arts in learning, such as by writing a song or portraying what they've learned through a dramatic monologue or skit. Another is to teach content with its human significance foregrounded. Share the personal stories of people who experienced historical events, have students probe the motives and feelings of characters in literature, or enable students to see ways in which science can improve people's lives. Such meaning-rich approaches are far more likely to tap into student emotion and enhance learning.

■ Create assignments that call on students to use essential knowledge and skills to solve problems or use resources productively—*together*. Ensure students work with a variety of peers so they can learn from the thinking representative of the class as a whole. Help students understand, practice, and sharpen the skills of collaboration.

4 Neuroscience and Diversity

One of the challenges (and opportunities) of contemporary classrooms is the broad diversity of experiences, languages, identities, strengths, and needs our students represent. Research in psychology has long indicated that treating students of a given age as though they were essentially alike is likely to fail many, if not most, students. In diverse classrooms, especially, we must individualize how we teach learners.

Teaching and learning practices that promote student success in diverse classrooms—and are informed by research in psychology and neuroscience—share three attributes: Educators create positive classroom environments that propel learning, recognize the importance of attending to learners' varied readiness levels, and plan instruction with

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students' interests in mind.

Creating classroom environments that are accepting, affirming, challenging, and supportive for each learner has long been supported by research in psychology. Now neuroscientific research has found that negative emotions often shut down cognition so the brain can focus its energy on protecting its owner in the face of a threatening event. Conversely, positive emotions associated with learning can reinforce or strengthen memory, enhancing learning (Desautels, 2016). We now know that the nature of the environment, as a given learner experiences it, literally alters brain chemistry—and, as a result, brain functioning.

Tapping into This Finding

■ Provide opportunities for students to use and build on their strong points. Offer consistent support for working through learning difficulties.

■ Practice empathy. Make a consistent effort to see the classroom through your students' eyes, and plan accordingly.

■ Make students your partners in creating a learning environment that works for them. Regularly seek feedback on how the class is going for them.

A second critical area for teaching in diverse classrooms relates to providing students whose needs differ varied entry points into any lesson. Once again, on this principle of instruction, psychology points to what teachers need to do to honor different readiness levels, and neuroscience illuminates what happens in a student's brain in response to work that is consistently too demanding or too easy for that student—as well as why differentiation, or providing work at just above a learner's current level of performance, is effective.

Psychology has provided us with the concept of a learner's "zone of proximal development" (Vygotsky, 1934, 1986), meaning that new challenges are necessary for growth in learning, and that each new challenge must be slightly ahead of a learner's current proficiency. Scaffolding helps the learner traverse the gap of uncertainty that separates the old learning from the new. That theory, now over 80 years old, continues to be affirmed in ongoing research and guidance on teaching with readiness in mind.

More recently, neuroscience indicates that when a task is within a student's zone of proximal development, and thus feels "accessible," the learner feels less stressed and more motivated to tackle the task than if it felt out of reach. When support exists to help a student achieve at the more complex level, the student is more likely to perceive the process as pleasurable, and to learn (Baars & Wijnia, 2018).

To draw on these principles as you plan instruction:

■ Don't equate readiness with ability. Readiness is fluid and has to do with where a student is relative to a task at hand. Ability is a much more pervasive notion, at best very loosely linked with any given assignment.

■ Use ongoing assessment that's tightly aligned with learning targets to understand a student's development through a learning progression.

■ Create flexible teaching and learning routines so each student has ample opportunity to work with the teacher independently or with small groups of peers. This allows students to work on different tasks and at various levels of difficulty, so each learner's assignment can most often be in that student's zone of proximal development.

Finally, psychology and neuroscience both indicate that linking learning with students' interests is not a luxury, but a necessity. For years, psychology has pointed to links between connecting learning to an individual's interests and increased motivation to learn, pleasure in learning, productivity, and achievement (Csikszentmihalyi, 1990). Neuroscience research

reinforces these conclusions. One imaging study identified the area of the brain (the putamen) where motivation is activated and concluded that activity in the putamen may be critical to academic achievement and success (Mizuno, et al., 2008). So it's essential to boost achievement by connecting to students' interests and agency in various ways.

Besides making it a priority to know students and their interests:

- Provide frequent opportunities for student voice and choice. Offer options for ways students can demonstrate learning, help students form interest-based inquiry or reading groups, or create expert groups though which students can investigate particular aspects of a class-related topic and share findings with the class.
- Build teaching and learning around big ideas or key concepts of the discipline and invite students to make interest-based connections with those concepts as well as cross-disciplinary connections.
- Regularly include interest-based groups in plans for flexible grouping.

Deeper Learning

The partnership between psychology and neuroscience, in terms of research revelations, gives us deeper understandings about what works in learning—and why. Teachers shape young lives and build young brains every day. The more we know about the how and why of doing those two things, the more the learners in our care will benefit. EL

REFLECT & DISCUSS

This article recommends explaining to students the "growth mindset" concept. Have you explained to students what a growth mindset is and talked with them about how adopting this idea might benefit them?

What's one thing you could do to create a classroom culture in which "peers pull together for mutual growth and success," as Tomlinson and Sousa say is key?

As an educator, do you feel hopeful about the convergence of neuroscience and education psychology? How do you think it will affect teaching in the future?

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