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How the Brain Learns

Revisiting Effective Teaching

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New research in neuroscience validates long-held theories of effective teaching.

Those of us who have worked in schools for a while have watched a lot of programs, theories, and innovations come and go. Many experienced teachers, frustrated with the pendulum swings, have adopted a wait and see, or "this too will pass," attitude. But I wonder whether too often we have eliminated very effective practices in favor of the newer innovations on the block.

Participants in my workshops frequently reinforce this thought as they point out or ask about the connections between Madeline Hunter's Elements of Effective Instruction (1982) and current brain research. I can frequently point out how neuroscience research has validated one or another of the practices Hunter espoused. And it's not just Hunter's work that participants ask about, but that of John Dewey and Alfred North Whitehead in the early 1930s; Jerome Bruner's writings in the 1960s; and the findings from Jere Brophy, Barak Rosenshine, and others whose work we studied under the heading of Effective Teaching research. These studies focused on what teachers did that resulted in increased student learning. We seldom hear much about these findings anymore, but are they really outdated or have we been too quick to look for something new? Is it possible that the effective teaching strategies of 20 years ago are still relevant today and that we can look to current cognitive and neuroscience research to help us understand why they are?

Setting the Stage for Learning

Let me begin with a relatively simple and familiar example from Hunter's work. Hunter talked about the importance of an anticipatory set, a way of helping students attend to the relevant data of the upcoming instruction. She admonished us to ask focusing questions, have students recall previous information, state the objective, or otherwise assist students in focusing on information that they would need to be successful. This emphasis on setting the stage for learning fits precisely with the research on the attentional mechanisms of the brain.

The only way to get information into the brain is through our senses. At any one moment, our sensory receptors (the retina of the eye, the tympanic membrane in the ear, and so on) are simultaneously bombarded with an enormous amount of data. If we were able to pay conscious attention to all this sensory information, we would go stark, raving mad. To keep us sane, our brain immediately starts sifting and sorting through all the sensory input and gets rid of irrelevant material. This initial processing step is unconscious and appears to be accomplished by the brain as it searches through previously stored information and looks for relevant hooks for the new information. There is actually no such thing as a student who is not paying attention. The student's brain is always paying attention to something, although it may not focus on relevant information or on what the teacher intends.

For example, if I begin describing a train trip and tell you how many people entrained or detrained at each stop, your brain may search for and retrieve information about previous trips taken. If your brain picks up on the numbers, you may begin mentally to add and subtract the number of people on the train. When I reach the end of the story and ask how many times the train stopped, you probably won't have a clue because your brain had attended to the wrong information. The brain constantly searches through existing neural networks to find a way to make sense of incoming data. An anticipatory set increases the possibility that the brain will search through the right networks and attend to the information that is relevant for a particular topic or issue.

The Learning Environment

The effective-teaching research resulted in a great deal of information about the effects of the learning environment on student achievement. Hunter helped clarify our understanding of the effects of the environment as she discussed levels of difficulty and levels of concern. I don't see many articles in current educational journals or teachers' magazines that use the phrase "level of concern," but I do see a lot written about how a classroom needs a learning atmosphere that is high in challenge but low in threat. Is there a big difference? I don't think so.

Hunter told us that if a task is either too difficult or too easy, we will have little motivation to continue. She also pointed out that a level of concern (or stress) either too high or too low will interfere with efficient learning. Sounds pretty simple, doesn't it? But is it true? Does current research help us understand why stress or level of concern enhances or inhibits learning?

Again, let's consider the pathways that information takes as it enters the brain. As part of the initial sorting and sifting process, the brain sends information coming in through the senses to several organs deep within its center. One of these is a small, almond-shaped structure named the amygdala.

The amygdala could be called the psychological sentinel of the brain. Part of its role is to check out information for its emotional content. Is this information potentially threatening or aversive or is it something I like? Should I run away from it or run toward it? If the brain determines that the information is threatening, it immediately sends chemical messages throughout the body to prepare the organs to adjust their activity level to match the demands of the situation.

Most of us are familiar with this reaction, commonly called the fight or flight response. The heart beats faster, lung capacity increases, palms become sweaty, and so on. But in addition to these familiar responses, other less noticeable reactions occur. The immune and digestive systems are suspended; blood-clotting factors increase; and the conscious, rational, thinking part of the brain, the cortex, becomes much less efficient, in a sense "downshifting."

If you've ever been insulted and couldn't think of a response until the next day, you've experienced downshifting. Similarly, downshifting occurs when you forget what you studied for an important test, when you cannot remember what you were going to say as you stand in front of an audience to give a speech, or when you are so angry that you engage in irrational behavior. Anything that an individual brain perceives to be threatening can slow the creative, rational processing of information.

Emotion is a double-edged sword. The brain is hardwired for survival. If the event or information has little or no value, the brain has a tendency to drop it. If the emotional content is too high, downshifting can occur, and the conscious, rational processing becomes less efficient. I think these reactions are exactly what Hunter was describing when she talked about level of concern. Every teacher has seen examples of these behaviors. What research is contributing is an understanding of why they occur. This understanding can help us select appropriate strategies for dealing with them.

Task Analysis and Memory Research

One of Hunter's Elements of Instruction that teachers often found difficult was task analysis. Basically, the idea is that the teacher breaks a task (such as identifying the main idea in a story, solving an equation, or shooting a basket) into its essential components to have guidelines for planning instruction. This process increases the possibility of addressing all necessary elements to complete a task successfully. In practice, however, teachers found task analysis arduous and often were not able to complete an analysis. Again, research from the neurosciences helps us understand why task analysis is so necessary, yet so difficult to accomplish.

The brain stores different types of memory in different ways. Most neuroscientists distinguish between two major types of memory, declarative (explicit) and procedural (implicit). Declarative memory consists of semantic information (facts, places, names) and episodic information (episodes of one's life). Both types of declarative memory can be "declared," or stated, and are believed to be stored in the outer layer of the brain, the cortex. To declare information, we must retrieve it and bring it into consciousness.

Procedural memory consists of information or procedures that we have learned at the automatic level, that we most often gain access to without conscious attention. For example, most of us have experienced driving a car over a familiar route, arriving at our destination, and having no conscious recollection of driving there. The processes involved in driving, especially on that route, have become totally automatic. Other examples of procedural memory include remembering how to walk, write, tie a shoelace, decode words, or pass a football. I suspect that many procedures used by teachers in classrooms are also carried out automatically.

Neuroscientists believe that the physiological process underlying procedural memory is one in which brain cells (neurons) that "fire together, wire together." In other words, circuits or networks of neurons that are used over and over get accustomed to firing together and eventually become hardwired and fire automatically. It is interesting to note that Madeline Hunter used the phrase "Practice doesn't make perfect; it makes permanent." If we practice something incorrectly, our neurons don't know the difference and make the permanent connections incorrectlyÑas anyone knows who has attempted to master a task without expert assistance or coaching.

Why would the brain's design allow us to perform certain tasks automatically? The reason is probably connected to survival, giving us the ability during danger to run without having to think consciously about which muscles to move. Procedural memory appears to involve structures deep within the brain, mainly the hippocampus and cerebellum, that allow us to perform procedures without using the limited conscious-processing space.

Whatever the origin, being able to get some of the basics of a skill at the automatic level is necessary for us to move to higher levels of functioning. (Comprehending what you are reading now would be nearly impossible, or at least laboriously slow and inefficient, if your decoding skills were not automatic.) I recall reading an article in this magazine many years ago in which Benjamin Bloom discussed how individuals become experts in various fields. He labeled procedural memory "automaticity" and stated that it is the "hands and feet of genius."

On the surface, procedural memory appears to be the marvel of the brainÑuntil we try to change an automatic procedure or to teach it to someone else. Witness our difficulty in teaching children how to decode. The process is automatic to us, and it is extremely difficult to explain the processes that we use to do it. The same is true of any skill or procedure that we have developed to this level, such as swinging a golf club, regrouping in subtraction, or performing an experiment in chemistry.

Although Madeline Hunter didn't have access to the information on the physiological underpinnings of procedural memory, she knew that teaching would be more effective and efficient if we could somehow "watch" ourselves complete an automatic task, delineate all the component parts of the task, and use that analysis to guide students through the "massed" and "distributed" practice necessary to form those permanent neural connections that are the foundation of procedural memory.

The Importance of Prior Learning

The link of prior knowledge to learning was emphasized often in the effective-teaching research; few of us would argue with its importance. Here again, new research increases our understanding of why prior knowledge plays such a crucial role. Information, neuroscience research explains, is not stored in a specific location in the brain. Rather, it is stored in various locationsÑin the visual, auditory, and motor corticesÑand is joined in circuits or networks of neurons. It appears that each time we recall an event or a previous experience, we literally reconstruct it by using the same circuit or circuits we used to store it. (The more modalities we use to store the information or experience, the more pathways we have available to access it.)

When we experience something new, the brain looks for an existing circuit or network into which the new information will fit. For example, a young child who has learned that a small furry animal is called a dog may, when seeing a cat for the first time, call it a dog. The child's brain searched through its neural networks to find a place to fit this new animal and selected the closest match. Likewise, if I am reading an article on applying quantum physics to managing an educational system, I will be hampered in my understanding if I lack previously stored information on physics. My brain can find nowhere in its previously constructed networks to fit the new idea.

Reaffirming Hunter

Teachers who have been exposed to no more of Hunter's work than the infamous "lesson design" and who view her work as simply a method of direct instruction may be surprised to learn that she was appalled at this application of her work. She emphasized over and over that teaching is decision making and that the more we know about the science of teaching, the better we can artistically apply that knowledge.

It appears to me that the study of brain research validates her position. Brain research is not a program to be implemented in schools; neuroscience does not prove that any particular strategy of method works. Rather, the research is adding to our knowledge base, helping us better understand how the brain learns, or doesn't learn, and why. We are beginning to gain a scientific understanding of the learning process, and from that understanding, we can make better decisions about how to structure learning environments and instructional practices.

Teaching is still decision making, as Hunter admonished us. Behavioral psychology was the foundation for the effective-teaching research and for Hunter's work. We did not have the tools to look inside the brain while it learns and had to rely on the observation of student behaviors to validate or reject our theories of learning. The absolute explosion of information from current research in the neurosciences is changing that scenario, but it does not necessarily indicate a rejection of the information that preceded it. What we have is a synthesis of psychology and biology that is giving us a new vocabulary and an ability to be more articulate when we talk about learning.

It is not surprising that the research coming from neuroscience parallels many of the earlier findings. Much of the effective-teaching research was based on observing teachers who obtained good results in student learning. While working with and monitoring their students day after day, effective teachers have always been on the front line of "research" about teaching and learning. On the basis of their observations and reflections, they have developed a wisdom of practice that warrants our respect. Theodore Marchese (1998) comments that many of the findings seem to confirm what we've already known, or at least theorized. "I'd be suspicious of any neuro-scientific theory of teaching," he says, "that was much at variance with what best teachers already knew and did."

It's time, I think, for all of us to step back before we embrace the newest thing coming down the pike. We need to give teachers time to reflect on their practice, to engage in substantive dialogue with others (including the researchers) about what they are accomplishing and why, and to assist teachers in carefully studying new research and innovations to determine whether they validate their practice, require them to rethink their practice, or both.

Brain Fact: Language Explosion

Most babies speak their first words at about 9 to

12 months, and by the time they are 15 to 20 months old, most have a vocabulary of about 50 words.

Then comes what Marian Diamond calls "a veritable language A-bomb." After learning the first 50 words or so, children begin learning new words at the astonishing rate of about 50 words a week, and this pace continues through most of elementary school. The development of grammatical skills, says Diamond, appears to be innate and programmed, appearing spontaneously around preschool age. By the time most children are 4, "the vast majority of their utterances are completely grammatical," says psychologist Karin Stromswold.

Source: Diamond, M., & Hopson, J. (1998). Magic trees of the mind: How to nurture your child's intelligence, creativity, and healthy emotions from birth through adolescence (pp. 170Ð171). New York: Dutton.

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