Rishi Sriram explores the concept of intelligence and describes 10 important strategies for supporting student learning.

By Rishi Sriram

Learning about Learning

OUR SOCIETY IS OBSESSED with the concept of intelligence. Parents want to know if their children are smart. Schools try to detect the intelligence of children so that they can separate them into "gifted and talented" programs on one end of the spectrum and remedial programs on the other. Employers want to know if they are hiring the smartest people. Colleges, however, may be the place in our society where our obsession with intelligence peaks. In *Are You Smart Enough?* Alexander Astin offers a blunt critique of this obsession:

> The traditional assessment practices of college and university faculty suggest that they value *being* smart much more than *developing* smartness. They reward their smartest applicants with offers of admission and scholarships, and they reward their smartest enrolled students with honors programs, dean's lists, and honors at graduation. And all the while they seem content not to have good information about the learning process. (p. 41)

The irony is that our society is obsessed with intelligence while simultaneously possessing little understanding of intelligence. We emphasize intelligence and deemphasize learning. The purpose of this article is to explain what intelligence is, where it comes from, and why learning is a skill that can be improved through specific, scientifically based steps. As Astin suggests, we need good information about the learning process.

Defining Intelligence

LET US BEGIN BY DEFINING INTELLIGENCE, as it is a relatively new concept emerging over the past century. As Rudolph Hatfield explains in *Essentials of the Brain*, the word *intelligence* comes from Latin. *Inter* means "within" or "between." *Legere* means "to pick out" or to "catch with one's eye." Bringing those words together, intelligence literally means to "see into," "perceive," or "to understand." Richard Nisbett, author of *Intelligence and How to Get It*, offers the following definition:

> Experts in the field of intelligence agree virtually unanimously that intelligence includes abstract reasoning, problem-solving ability, and capacity to acquire knowledge. A substantial majority of experts also believe that memory and mental speed are part of intelligence, and a bare majority include in their definition general knowledge and creativity as well. (p. 4)

Many experts divide intelligence into two categories: crystalized intelligence and fluid intelligence. Crystalized intelligence pertains to knowledge that one acquired through learning and experience. Fluid intelligence is the ability to perceive relationships and acquire knowledge. Although some researchers have identified as many as 70 specific abilities related to intelligence, Charles Spearman found that they all fit under the same overarching umbrella. He called this umbrella the "general factor" of intelligence, commonly referred to as simply *g*.

Those who study intelligence understand its complexity. For the sake of simplicity, I define intelligence as *the ability to learn*. If I know how to speak Spanish, for example, and you do not, it is not reasonable to conclude that I am smarter than you. I have knowledge that you do not have (crystalized intelligence),

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but smartness pertains more to the ability to acquire that knowledge (fluid intelligence). We determine that animals such as dolphins, dogs, apes, and elephants are intelligent not because of what they know but rather because of their ability to learn things that we try to teach them. If intelligence is the ability to learn, where does that ability to learn come from?

Rethinking Intelligence

WITH ADVANCES IN NEUROSCIENCE and how technology is helping us analyze and measure the brain, we are in a period that is quickly shifting us from one of the spectrum (intelligence is an inherited trait) to the other (intelligence is a learned skill). Even as recently as the late 20th century, most experts on intelligence believed that intelligence was inherited, directed by genes, and hard wired. Experts today fall into more of the half-and-half ratio, believing that intelligence is 50 percent nature and 50 percent nurture.

Even as recently as the late 20th century, most experts on intelligence believed that intelligence was inherited, directed by genes, and hard wired. Experts today fall into more of the half-and-half ratio, believing that intelligence is 50 percent nature and 50 percent nurture.

I think we will eventually reach the point of understanding that intelligence is 100 percent nurture. How can I say that? From a big picture and a small picture perspectives, it is the most logical conclusion I can make. Let us start with the big picture. Formal schooling in the United States is a relatively young institution. In America in 1900, the average child completed seven years of schooling over an entire lifespan. One out of every four children completed four years or less of schooling over an entire lifespan. As a reference point, my children completed four years of schooling at about age seven. In the United States today, Nisbett observes, the average person completes high school plus two additional years of schooling, for an average of 14 years of schooling over an entire lifespan.

In just over a century, we have doubled the average years of schooling for people in the United States. If intelligence was an inherited trait, the development of a system of education should not affect intelligence. As philosopher and IQ scientist James Flynn first observed and discusses in his book, *What Is Intelligence?*, intelligence has increased significantly in the United States during the last century. IQ scores are designed so that the number 100 *always* represents average intelligence. No matter what, the average IQ score is set to 100. For the mean score of 100 to remain, the IQ test is revised with items that are more difficult. Flynn observed that IQ scores have increased by 9 points every 30 years. To put this in context, a person who had an IQ score of 100 (average) in 1900 would now receive a score of 70. A score of 70, by today's standards, is low enough to be considered intellectually disabled. Average intelligence in the year 1900 would be considered an intellectual disability today. This increase in intelligence, dubbed the Flynn effect, exists in nations all over the world. From a big-picture perspective, we are becoming smarter because education is getting better.

How Education Makes Our Brains More Intelligent

NOW LET US EXAMINE how intelligence might be 100 percent developed from a small-picture perspective. When we talk about intelligence or talent, we are talking about the thoughts, feelings, and actions of human beings. Every time you think something, every time you feel something, every time you do something, your brain sends electricity through hundreds of miles of wires (neural fibers) that are composed of neurons. So, when we talk about intelligence, we are really discussing brain signals. These connections determine the brain's ability to function. What if there was something in your brain that helped these connections? What if some connections were stronger, faster, and better than other connections? The result would be thoughts, feelings, and actions that were stronger, faster, and better.

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And this is what some white stuff in our brains called myelin does.

When electric signals are sent through a neuron repeatedly, something magical happens. A white, fatty sheath begins to form around the axon (sending wire) of the neuron. This myelin sheath resembles elongated pillows or sausages down the length of the axon. The myelin acts as an insulation, allowing the signal to travel stronger, faster, and better. The electric charge jumps (quite literally) across these gaps as it travels down the axon.

There are three vital things to know about myelin: (1) Humans are born with essentially no myelin. (2) The speed at which axons (neural fibers) conduct a signal is directly related to the amount of myelin (white, insulating material) around the axon. (3) The development of myelin comes from the repeated activation of neurons.

When you understand how and when the brain develops, the nature versus nurture question becomes much clearer. It's nurture. Thoughts, feelings, and actions all come from brain signals. Brain signals depend upon the neural connections of the brain. There are two times in our lives (around ages 2 and 12) when the number of connections in our brain (synapses) double. These so-called critical periods make enormous differences in skills (talent) depending upon what we are thinking, feeling, and doing in those critical periods. The last critical period is in our 20s.

When you examine normal, healthy brains, there is only one logical reason why one brain should do some things well and another brain should do other things well: learning. The brain cannot do what the brain has not learned.

Brain signals are made stronger, faster, and better with the accumulation of myelin around neural fibers. And humans are not born with myelin. Nor is there any evidence that some people are born with better myelin building abilities than others (unless we are talking about someone with a demyelination disease, such as multiple sclerosis). The neural connections that we keep during the pruning phases are those that we use. The neural connections that we use (by repeatedly firing those brain signals through our thoughts, feelings, and actions) are those that develop the most myelin. And those neural fibers that are well myelinated send signals up to 1,000 times faster than those not myelinated. When you examine normal, healthy brains, there is only one logical reason why one brain should do some things well and another brain should do other things well: learning. The brain cannot do what the brain has not learned.

In one sense, the idea that these processes are inherited is true. We all have the inherited ability to learn and develop our brains. The notion that nature is the reason—or even part of the reason—that we see differences in talent among people is illogical and unproven. It is illogical because it steps outside of what we know regarding how the brain grows and develops. Brains are not born with the connections and signals to do math well. Brains do not even know that math exists. The brain cannot do what the brain has not learned. Brains are not born with the connections and signals to perform athletically. Brains do not even know that baseball exists. Moreover, muscles have little to do with it. There is no such thing as muscle memory, for example. Your muscles are quite stupid (no offense). Muscle memory is a term we made up, but what it is describing are brain signals that are so well myelinated that you can perform physical tasks without consciously thinking about them. That is myelin magic, not muscle magic.

I should note, once again, that most experts believe intelligence is half nature and half nurture. I depart from this tradition because the evidence itself, on both a big-picture level and a small-picture level, indicates that intelligence is fully nurture. We learn from environmental stimulation. We increase our ability to learn (intelligence) through environmental stimulation. This is why education is so important. This is why developing a formal system of education in the United States has made us all much smarter. Education challenges our brains at critical periods, leading to stronger, faster, and better brains. From the moment we are born, we have an ability to learn that cannot be fully comprehended. We are born geniuses. What happens from day one determines where that intelligence goes.

Learning How to Learn in 10 Steps

IF INTELLIGENCE IS DEFINED as the ability to learn, and all talent is learned, then improving our ability to learn will improve both our intelligence and our ability to become talented. Astin remarks that "Developing students' talents is, after all, the principal mission of any educational institution—to help students learn, grow, and develop into competent and responsible citizens, parents, employees, and professionals" (p. 1). Educators have a responsibility not only to help students learn but also to teach students *how* to learn. Intelligence is the great talent amplifier.

But how do we improve this ability to learn? According to those who study the science of learning, there are distinct differences in approaches to learning and the outcomes that result from those approaches. Better strategies lead to better learning. Some of these strategies are extremely practical, while others are a bit more conceptual. But they all help. Our colleges already have the structures in place to teach students how to learn: professors in their classrooms, academic advising sessions, success or remedial programs, orientation programs, supplemental instruction sessions, or programming that occurs in residential communities. Through these current curricular and co-curricular structures, we can offer students a curriculum on how to learn.

To help us, as educators and learners in our own right, understand better ways of learning, I offer 10 steps, or concepts, based on findings from multiple research studies. A recommended resource for these studies is a book called *Make It Stick* by Peter Brown, Henry Roediger, and Mark McDaniel. Because science tells us that we learn and retain new ideas better if we chunk information and create mental models (as I outline below), I offer these concepts for learning using the acronym, GHOST RIVER. While not a "how to" guide for the classroom or co-curricular environment, these steps offer general insights into learning that educators should consider when developing, reflecting on, or revamping our pedagogy and practice to enhance student learning.

*G*HOST RIVER. G Is for Generation

In order to learn something, it might make the most sense simply to begin. Cognitive science, however, offers an important step to take before learning begins—guessing. The technical term for this is generation. Generation is trying to know or do what you are trying to learn before you learn it. The reason that generation creates stronger learning is that it irritates the brain in a good way because it does not like not knowing. Therefore, when we make the brain aware of what it does not know by making it try to answer something or do something it has not learned, it will soak in that knowledge better when it is time to learn. So before teaching students a concept, ask them to make some guesses. For example, when teaching about the Pythagorean theorem, a math teacher could ask students to try to figure out how to determine the third side of a triangle when they know the length of the other two sides. Then, the teacher should teach the formula and concept. The generation effect will deepen that learning.

When we begin a new sequence of actions, neurons connect to one another in new ways. If these brain signals fire consistently, myelin will begin to form around the nerve fibers to make these signals stronger, faster, and better.

G*H*OST RIVER. H Is for Habit

When we begin a new sequence of actions, neurons connect to one another in new ways. If these brain signals fire consistently, myelin will begin to form around the nerve fibers to make these signals stronger, faster, and better. When myelin develops, the brain converts the series of actions into one, fluid, automatic routine. This process is known as *chunking*. When children first begin to read, they start with the first letter of a word and then move on to the next letter. But later, they stop reading letters. They just skip to reading the words themselves. This is chunking in action. Chunking is a key reason why repetition is so important for learning. And we have our own, everyday term to describe chunking: habits.

GH*O*ST RIVER. O Is for Organization

As scientists have studied experts in a variety of fields during the last few decades, they discovered that the notion that experts know more does not fully explain the difference between experts and novices. It is not just that experts know more. It is that they know better. Experts categorize their knowledge into a framework, or scaffold, which allows them to draw from their learning in more efficient and effective ways. In other words, an expert and a novice might know the same thing, but the expert will be able to more quickly identify the need for that knowledge, retrieve that knowledge, and use that knowledge. When we try to learn something, there are two issues at hand: storage strength and retrieval strength. Storage strength is the brain's ability to store the information. Retrieval strength is the brain's ability to retrieve the information when it is needed. What is fascinating is that neuroscientists have yet to discover a limit on how much information our brains can store. As far as we know, the ability to store information in our brains is limitless. We have infinite storage strength.

Accessing that information is a completely different matter. And this is where a key difference is found between experts and novices in any given field. Experts access their information better, and they do that by organizing their information better. Experts have better retrieval strength than novices do. They also have found ways around the limitations of working memory and attention. The trick is chunking information into broader categories. These categories are referred to as mental models or mental representations.

Let me offer an example. If I gave students 10 seconds to memorize these letters, how would they do? *Golehtnotasgodsihdnayobeht*. Now, what if I asked them to memorize these letters in 10 seconds? *The boy and his dog sat on the log.* They are the same letters. But one task seems impossible, and the other seems laughably easy. Did students' intelligence increase from one task to the next? Sort of. How they used their intelligence increased, thereby increasing their ability to learn. With the second task, they could easily take the letters and form them into words (chunking) and then visualize a boy and his dog sitting on a log (mental model). Once they have a mental representation of the letters, reciting them becomes almost effortless. This is exactly what talented people do in their fields. They create mental models to retrieve memories effectively.

GHO*S*T RIVER. S Is for Spacing

Spacing, the idea of distributing practice evenly over time, might be the single most important step we can take to improve learning and, therefore, talent. The brain can only absorb so much learning in one given session. Over time, the return on investment of that learning diminishes. At some point, we are wasting our time trying to add more. Imagine that the brain is a tub. The tub is the short-term memory, and the drain is the long-term memory. The water is what we are trying to learn. Therefore, the water that is in the tub is in the short-term memory. The water that goes down the drain is in the long-term memory. If we start pouring in water faster and longer than the small drain can handle, water will eventually overflow the tub and start pouring out onto the floor. This is what happens when we attempt to cram lots of information into the brain in one sitting. On the other hand, if we pour that water slowly and take breaks so that it can go down the drain before adding more, there is no limit to how much water can go down the drain into the long-term memory.

Whenever researchers take two groups, give them the same amount of total learning time, but have one group space out their learning time and the other group not, the results are always the same. The group that spaced out their learning performs significantly better.

The process of converting short-term memories into long-term memories (water going down the drain) is called *consolidation*. Learning occurs through a cycle of encoding, storing, retrieving, and forgetting. That's right, forgetting is an important part of learning. Therefore, spacing out practice helps in two ways. First, it gives the brain the chance to consolidate short-term memories into long-term learning. Second, it gives the brain the chance to forget. When we forget and then try to remember something, it sends a signal to the brain letting it know that what it forgot is actually important. Therefore, the brain will, over time, make it easier to remember by myelinating those brain signals.

Whenever researchers take two groups, give them the same amount of total learning time, but have one group space out their learning time and the other group not, the results are always the same. The group that spaced out their learning performs significantly better. These types of studies have been done for more than 100 years with the same results. Spacing improves learning.

GHOS*T* RIVER. T Is for Testing

Short exercises, or drills, are an important part of learning. Imagine students flipping through flash cards or running sprints. However, we can drill ourselves to death without ever practicing in the same way that we must perform. This is where testing comes into play. It is important for learning to practice in the same way we will be tested. For example, students preparing for a test should practice using or retrieving the material in the same way they will be tested. If it is a multiple-choice test, they should create practice tests and take them. If the test includes essays, they should actually write essays as part of their practice. This is easy to understand with classes, but the same idea can be applied to any area of talent development. If students are training to become baseball pitchers, they should practice pitching to actual hitters. If it is speaking, give the speech in front of real people. If the speech will be followed by questions, have a practice audience ask spontaneous questions at the end and answer them. The important principle here is that testing is not only a method of evaluating our current level at a skill: testing improves the skill itself. Testing is learning.

GHOST *R*IVER. R Is for Retrieval

One of the primary reasons testing is beneficial is that it forces retrieval. As previously mentioned, forgetting is an important part of learning. The brain chooses to forget as a default in order to survive. There is too much information to take in. If the brain decided to remember everything, it would be overload. It would also be an incredible waste of time and energy. The brain is about efficiency, and one of the most efficient things it can do is discard everything.

At first, the brain's desire to be efficient is a disadvantage to learning because it throws everything out (forgets). The act of forgetting and retrieving signals the brain to myelinate those specific neural pathways to make those signals stronger, faster, and easier to retrieve. The brain's desire to be efficient causes the things that are important to an individual to be easy to remember. Practically speaking, this means that the harder a task is to perform, the more learning we get out of it. Difficulty is desirable because the brain is going to do whatever it needs to do to make what was once difficult, easy.

To apply this idea with students, we could suggest that they take out a blank sheet of paper and write down everything they know about what they are trying to learn. It will be agony. It feels much better to them (and all of us) to simply review notes of what they want to know rather than create them. But the agony they feel when trying to retrieve the knowledge without the use of any aids is exactly what they need to learn it better.

GHOST R*I*VER. I Is for Interleaving

Some of the best techniques for learning are counterintuitive. This can result in feeling like we are learning a lot when we are actually learning little. Vice versa, it can mean that we feel like we are learning little when we are actually learning a lot. Nowhere is this truer than when we interleave. To explain interleaving, Brown, Roediger, and McDaniel discuss in *Make It Stick* an experiment with two groups of eight-year-olds. The experiment was designed to help these eight-year-olds learn how to toss beanbags into buckets. The first group practiced tossing beanbags into buckets that were three feet away. The second group practiced tossing beanbags into buckets that were two and four feet away, alternatively. The two groups practiced with their set method for 12 weeks. At the end of the 12 weeks, they had a competition tossing beanbags into buckets that were three feet away. Which group do you think did better? As counterintuitive as it seems, the group that had practiced at two and four feet (but never at three feet) did far *better* than the group that practiced only at three feet.

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Interleaving is the act of mixing up one's practice. In studying, this might mean spending some time on chapter six of a textbook, and then spending some time going back and reviewing chapter two. Or, it might mean studying math for only 30 minutes before setting math aside and studying history. In basketball, instead of shooting 50 free throws in a row, it might mean shooting two layups, two three-pointers, and then two free throws over and over. With a presentation, interleaving could mean breaking up the presentation into sections and practicing those sections out of order.

GHOST RI*V*ER. V Is for Variation

An overarching theme for how to improve learning is to make it more difficult and less comfortable. Variation continues along this theme. Variation improves transfer. Transfer is the ability to apply a skill to different contexts. The way you learn to improve the transferability of skills is to practice those skills in varied contexts.

Different kinds of practice engage different parts of the brain. The more of the brain that is engaged, the deeper the learning. Also, research demonstrates that learning can actually be tied to the context in which something was learned. So, if students, for example, study in the library, they will remember what they learned better when they are in the library than when they are in the classroom. The problem is that they take the test in the classroom, so attaching their learning to the library can be counterproductive. To avoid this, they can change the time and place of their practice as much as possible. They should not always practice the same drills in the same order or practice in the same place.

GHOST RIV*E*R. E Is for Elaboration

Elaboration is the idea that incorporating more of our senses into learning will deepen the learning. We have five senses: vision, smell, hearing, taste, and touch. The more of the brain that we engage, the better the learning. A practical way to engage more of the brain is to engage more of the senses. For vision, we can use photographs and video, especially for physical skills. For nonmotor skills, we can use graphs and charts to visualize what we are learning. Stories and examples also fall into this category of using vision because they initiate the imagination. Of all five senses, vision is the quickest pathway to learn. We are all visual learners.

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GHOST RIVE*R*. R Is for Reflection

We are to the final letter of GHOST RIVER. Reflection is the idea that we should focus our attention on our mistakes. Reflection incorporates elements of learning that we have already discussed. The act of reflection uses spacing because we are thinking about practice outside of practice. Thinking about practice *is* a form of practice. Reflection also uses retrieval, because we have to retrieve knowledge and information from practice in order to think through what went right and wrong. It is far too easy to ignore mistakes while focusing on our successes. Help students set aside time for the sole purpose of correcting mistakes.

Do we, as educators, truly believe in the power of learning? To what extent do we limit the power of learning in the name of something else, like genetics or intelligence? In what ways do we suggest to students that their capacity to learn might be limited? Astin admonishes, "If you look at our higher education system from an *educational* perspective, this preoccupation with enrolling smart students makes little sense, because the emphasis seems to be more on *acquiring* smart students than on *educating* them well" (p. 25). In her book, *Mindset*, psychologist Carol Dweck discusses how the beliefs we possess regarding intelligence powerfully affect our own development and the development of others. She describes a fixed mindset as the belief that you are born with a certain amount of intelligence that does not change substantially. Those with a growth mind-set, on the other hand, believe that intelligence itself has the potential to change and grow in a person. A growth mind-set is not about self-esteem or confidence. It is about learning. What we believe about intelligence matters for society because it matters for learning. If we believe that one group of people is born smart and the other group is not, we will impede the learning of both groups. But if we understand that intelligence—and all talent, for that matter—is developed, then we can focus our resources on the one thing that will make our society better: learning.

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