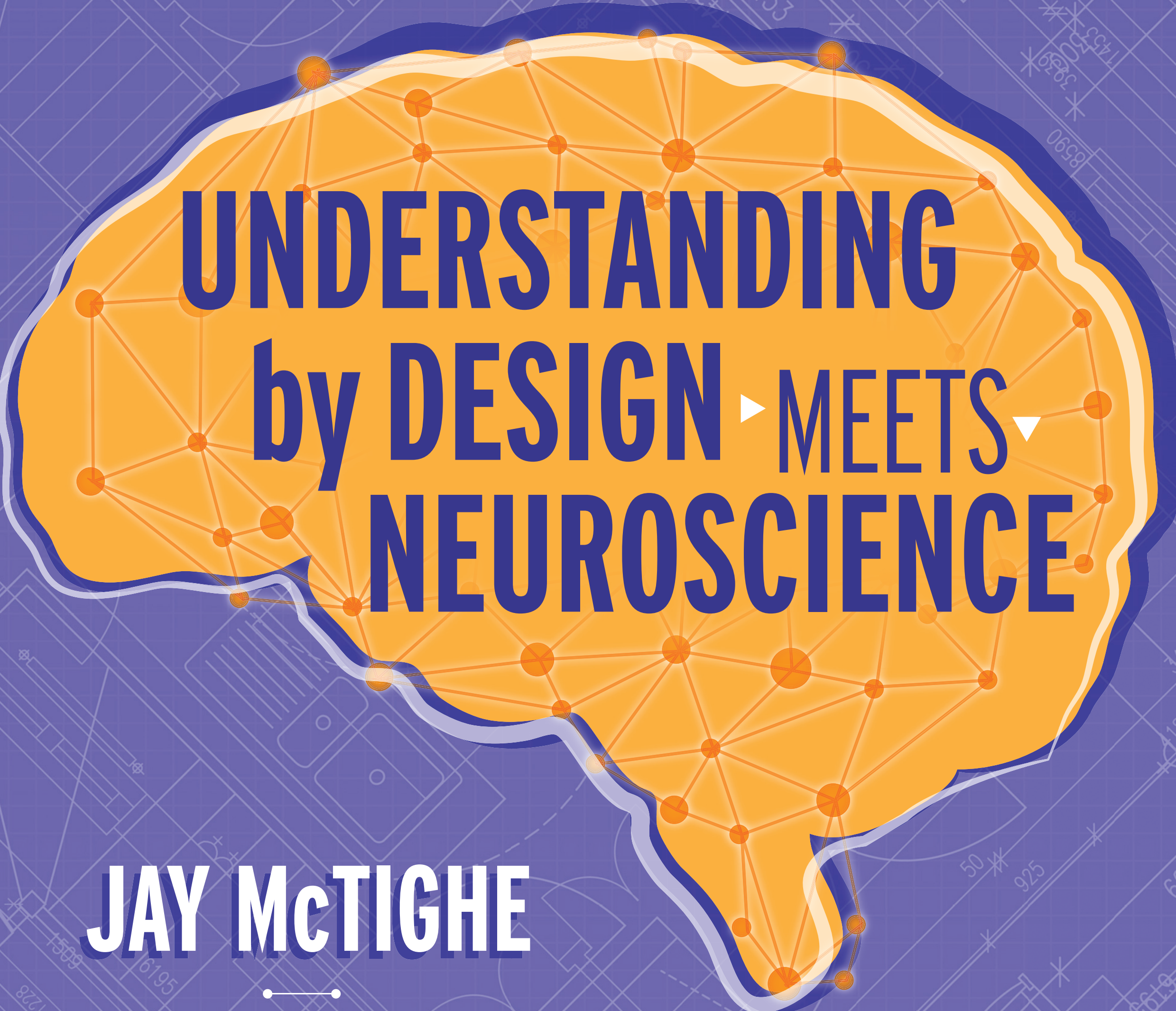
Upgrade Your Teaching



UNDERSTANDING by DESIGN MEETS NEUROSCIENCE

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Upgrade Your Teaching

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Introduction

Imagine that you are a builder who has been contracted to construct a high-rise building. You would not simply order a bunch of building materials and have the workers go at it. Instead, you would start by meeting with the clients to find out what they want and need in the building and then with the architect who will develop a detailed blueprint of the proposed structure. The blueprint provides a concrete vision of the building and guides the construction workers as they build.

As educators, we are builders of knowledge—cognitive contractors, if you will. Accordingly, we must think of our students as our clients and begin by considering what their brains need and want in order for them to effectively construct knowledge. Then we need a blueprint to guide our construction of the curriculum, the associated assessments, and the necessary learning experiences to bring the vision to life. Understanding by Design (UbD) offers such a framework. Although the UbD framework was originally conceived in the 1990s to reflect the understanding about learning emanating from cognitive psychology, it is now also supported by emerging insights from neuroscience about how the human brain best learns.

Like two streams merging into a river, this book presents the confluence of neuroscience research with the Understanding by Design framework to offer educators a unique blueprint to use in guiding students' construction of knowledge. The book begins with two introductory chapters. The first provides an overview of the neuroscience of learning, and the second provides an overview of the principles and practices of the UbD framework. Subsequent chapters describe their intersection. As you explore the UbD process for curriculum, assessment, and instructional design, you'll simultaneously be guided to construct and deepen your own understanding of the brain processes that you are facilitating at each stage of backward design—and your students will be the beneficiaries as their knowledge and understanding increase.

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How the Brain Learns Best

The brain is always changing, as a result of environment and experience. Every lesson, assignment, and interaction shapes your students' brains. Understanding how the brain converts information into learning provides keys to the best instructional strategies and learning experiences.

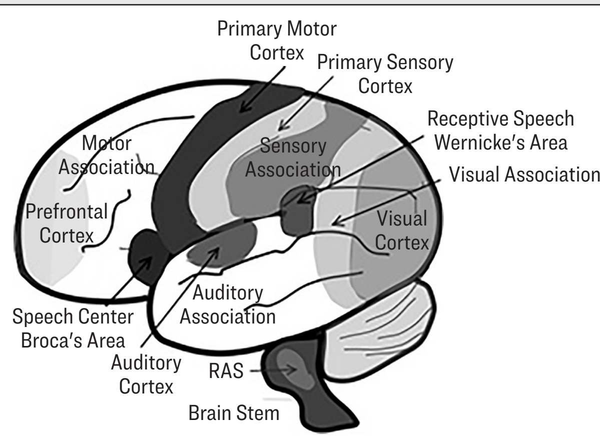
As a result of breakthroughs in neuroscience research, including neuroimaging and neuroelectric monitoring of neurons (brain cells) firing, we now can observe how the brain responds during learning. These technologies provide visible representations of the brain's response to instructional practices, revealing neurological activity as information travels from the body's sensory intake systems through the attention and emotional filters, forming memory linkages and activating the highest cognitive networks of executive function. This research has illuminated our understanding of how various factors—classroom environment, activation of prior knowledge, attention-getting techniques, use of graphic organizers, mental manipulations, and others—influence the transformation of sensory information into networks of durable long-term memory and conceptual understanding.

As you build your knowledge of the strategies that promote optimal brain processing, you'll recognize that neuroscience research may well support strategies you've already found most successful in your experience as an educator. Our goal is to help you increase your understanding of why "best practice" strategies and tools work at the neurological level.

The RAS: The Brain's Attention Filter

All learning begins with sensory information. Our brains are constantly bombarded with information from the body's sensory receptors. Continuous data reports flow from specialized sensory systems (hearing, vision, taste, touch, smell) and from the sensory nerve endings in our muscles, joints, and internal organs. These receptors do not evaluate the data. They just transmit constant status reports. Of the millions of bits of sensory data available each second, only about 1 percent are admitted to the brain, whose various areas are associated with different functions, as shown in Figure 1.1. Once information enters the brain's processing systems, it is relayed by numerous "switching stations." Ultimately, conscious or higher-level processing takes place in the outer covering of the brain, called the *cortex*.

Figure 1.1 Functional Areas of the Brain



One reason for restricting the enormous amount of sensory input is that the brain is rather stingy with its mental effort because it needs to preserve its limited fuel. Unlike other organs, it has no stored nutrients or oxygen. The average brain weighs only about three pounds, but it is so dense and metabolically active that it requires over 20 percent of all the oxygen and nutrients the body consumes. From a survival standpoint, it makes good sense for the brain to be a couch potato!

Because it is impossible for the brain to consciously sort through all the sensory information that is available every second, it is programmed to prefer selected input. To deal with this selection, the brain has a sensory intake filter, called the *reticular activating system* (RAS), in the lower part of the posterior brain (see Figure 1.1). The RAS determines what the brain attends to and what information gets in. Its involuntary programming gives priority to sensory information that is most critical for mammals to survive in the unpredictable wild. Any change in the expected pattern can signal a threat of death or, alternatively, a source of nutrients that can help ensure survival. This "hard-wired" criterion of selection for entry is essentially the same for humans as for other mammals; the brain gives priority admission to sensory input about change in the expected pattern—what is new, different, changed, unexpected.

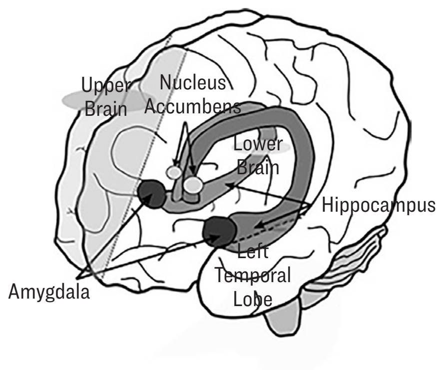
Students are often criticized for not paying attention, but we now know that failure to focus on a teacher's instruction does not mean the student's brain is inattentive. A student's RAS is always paying attention to (letting in) sensory input—but not necessarily the input being taught at that time.

The Amygdala: The Brain's Switching Station

Deep within the brain is the emotionally responsive *limbic system*, which includes two structures (one on each side of the brain) called the *amygdalae*, which direct communication between the *lower brain* and the *upper brain* (Figure 1.2). The lower brain is the more primitive control center that directs bodily functions that are largely automatic, such as breathing and digestion, as well as reactions that are largely involuntary, such as the *fight-or-flight* response. The upper brain, known as the *prefrontal cortex* (see Figure 1.1), is where memory is constructed and neural networks of executive functions guide voluntary behavior with reflective, rather than reactive, choices.

The amygdala can be thought of as the switching station for traffic flow between these upper and lower structures in the brain. After sensory information is selected to enter through the RAS, the level of activity taking place in the amygdala determines whether the information will travel down to the lower, involuntary, reactive brain or up to the reflective and memory-storing "thinking brain" (the prefrontal cortex).

Figure 1.2 The Brain's Limbic System



Information perceived as possibly threatening is directed through the amygdala to the reactive lower brain. Input passing through the amygdala to the prefrontal cortex finds the home of logical thought, judgment, emotional self-management, and other executive functions needed to generate more accurate predictions about new information and direct more considered responses.

When a mammal is in a state of actual or perceived stress, new information does not freely pass through the amygdala's filter to gain access to the prefrontal cortex. Instead, input is diverted to the lower, reactive brain, which has a limited set of behavioral responses that can be summarized as involuntary survival responses to a perceived threat. In fact, it is these primitive mammalian responses that we are likely to observe in students when they are highly stressed by fear, frustration (e.g., as a result of repeated failure to succeed in a task or subject), alienation, anxiety, or sustained boredom (e.g., when they are asked to do lessons or drills on topics they have already mastered or that they see as irrelevant). Here are some examples of specific school-related stressors that can trigger the amygdala to send input to the lower, reactive brain:

- Anxiety related to speaking in class, answering questions, or oral presentations
- Fear of being wrong
- Physical and language differences
- Test-taking anxiety
- Boredom as a result of prior mastery or absence of personal relevance to the material
- Frustration with material students believe exceeds their understanding
- Feeling overwhelmed by the demands of school assignments
- Inability to effectively organize time in response to the demands of academics, extracurricular activities, and out-of-school chores and jobs
- Feelings of isolation or lack of acceptance by peers or teachers

During these states of stress, students are likely to display involuntary lower-brain responses, manifested in acting-out or zoning-out behaviors.

The Brain and Mindset

Because the brain seeks to preserve its limited energy resources, it directs its behaviors based on the probability that the effort expended will result in success. Understanding this survival programming provides new perspective about students' choices and responses. It is now evident that low intelligence, lack of initiative, or laziness may not be the most likely reasons students don't always remain fully attentive, remember everything they are taught, persevere at tasks, or manage their emotions. A more fundamental explanation for nonproductive student behaviors is rooted in the brain's design, which focuses sensory intake, reacts to stress with survival responses, preserves its resources, and minimizes outputs of effort.

The brain's expenditure of voluntary effort is linked to the expectation of positive outcomes. If students fail after repeated efforts to achieve goals and academic challenges, their willingness to put forth effort will decline. These negative self-expectations can grow progressively year after year with repeated failures, further compromising the likelihood of academic success. Psychologist Carol Dweck (2007) has coined the phrase *fixed mindset* to characterize the conviction of those learners who do not believe that their effort can lead to achievement and is therefore fruitless. This contrasts with a *growth mindset*, which attributes success to effort, perseverance, and use of strategies.

In survival terms, withholding effort when past experiences predict failure is beneficial for animals in the wild. Consider a fox living in a region where prey is limited and whose den is surrounded by three hills. One of those hills is particularly steep and covered by dense underbrush where the prey hides. To repeatedly chase prey up that hill is to exert effort—in this case, energy—without the likelihood of achieving the goal of an energy-restoring meal. In the interest of survival, the fox's brain ultimately develops a mindset that deters it from chasing prey up that particular hill.

As students' efforts toward achieving a goal repeatedly fail, they might develop the fixed mindset that their intelligence and skills are predetermined, limited, and unchangeable. They become less likely to expend the effort necessary to persevere on challenging learning tasks, and they fall behind academically. Without the needed foundation of knowledge and skills to understand subsequent instruction, the gap widens further and they become even more susceptible to the stress-related blockades.

Seeking Patterns to Make Predictions

The brain's programming promotes survival of the animal and the species. This programming has guided mammalian development and adaptations for survival in the unpredictable and perilous environments in which most mammals live. The human brain continues to follow two prime survival directives: to seek *patterns* and *pleasure*. These directives drive the brain's memory, effort, and actions.

Patterning refers to the brain's meaningful categorization and organization of sensory data based on relationships or commonalities. The brain stores new information by linking it to patterns of related information already stored in neural circuits of existing memory. These clusters of related information stored together in memory are what psychologist Jean Piaget (1957) described as cognitive frameworks, or *schemas*.

It is through this pattern matching with previously constructed and related neural networks that our brains recognize and make meaning of the thousands of bits of sensory input received every second. By linking information newly stored in memory networks with relevant prior knowledge, the brain can sift through the barrage of ongoing input to make sense of the world. Storing information in memory by relationship patterning allows for easier, more efficient retrieval of information, which is essential to interpreting and predicting, and enacting the best response to something new.

All animals must make predictions to survive. For example, based on frequent links between cold temperatures and the behavior of the local rabbits in its hunting territory, a fox's brain might establish a memory pattern. The memory would result from frequent repetition of the pattern of cold temperatures linked to rabbits entering their dens earlier in the evening. Therefore, on a cold evening, the fox might predict that the time to catch its dinner is earlier than usual, perhaps just as the sun goes down.

When presented with novel sensory input, such as change, unfamiliar questions, or choices, our brains rapidly self-scan the related patterns for those that match the new information. Our brains activate these stored memories to relate to the new input and to make predictions and choose actions guided by those memory patterns.

Prediction is successful whenever the brain activates enough information from a patterned memory category to interpret the pattern of the new input. For example, if you see the number sequence 2, 4, 6, 8…, you predict the next number will be 10 because you recognize the pattern of counting by twos. Depending on the result of the prediction, the existing patterns relied upon to make the prediction are extended, fortified, or revised.

Through observations, experiences, and feedback, the brain increasingly learns about the world and can make progressively more accurate predictions about what will come next and how to respond to new information, problems, or choices. This ability for prediction, guided by pattern recognition, is a foundation for successful literacy, numeracy, test taking, appropriate social-emotional behavior, and understanding.

Successful prediction is one of the brain's best problem-solving strategies. To ensure that we will repeat the actions arising from accurate predictions, the experience of making accurate predictions stimulates a pleasure response mediated through the release of the neurochemical *dopamine*.

Dopamine: The Brain's Pleasure Drug

If you know pleasure, you know dopamine. Seeking and experiencing pleasure are innate survival features of the brain. When dopamine is released throughout the brain, it promotes feelings of pleasure, a deep satisfaction, and a drive to continue or repeat the actions that triggered the pleasurable response.

You might already be familiar with dopamine in its other function as a neurotransmitter. Neurotransmission involves *axons* and *dendrites*, two kinds of extensions of neurons that act as senders and receivers, respectively, of neural electrical signals. Dopamine carries these signals from the axons of one neuron, across a liquid-filled gap called a *synapse*, to the dendrites of another neuron.

The action of dopamine that is relevant to the pleasure or reward response derives from triggers that stimulate its release from a holding center called the *nucleus accumbens,* found near the amygdala (see Figure 1.2). This increase in circulating dopamine is seen in all mammals and activates those feelings you experience as intrinsic pleasure and satisfaction.

Making correct predictions is one of the strongest dopamine elevators. The dopamine-reward response to making accurate predictions promotes survival in mammals because the intrinsic pleasure that comes from accurate predictions drives the brain to remember and use memory circuits that have guided previously successful predictions. Experiencing accurate predictions and the resulting satisfaction of goal achievement leads the brain to remember the related choices, behaviors, actions, decisions, and responses and to seek more opportunities to repeat them. Concomitant effects include enhanced attentive focus, motivation, curiosity, memory, persistence, and perseverance.

There are intrinsic impediments to optimally processing learning through the brain. As you've read, the RAS and the amygdala are filters programmed to determine what information gets through and where it is directed.

To further optimize students' success in school, you can engage the dopamine-reward response to motivate the brain to put forth the mental effort needed for new learning. This is true even for things that are not immediately recognized as relevant or pleasurable. Academic effort can be stimulated by tapping into the brain's programming to focus attention and apply effort when pleasure is the anticipated expectation.

By showing students that they have the power to improve and by providing opportunities for them to see progress toward goals, they'll come to understand that their own effort may control the outcome. In subsequent chapters we'll suggest strategies for enhancing student engagement; reducing stress; boosting memory, motivation, and perseverance; and promoting growth (versus fixed) mindsets designed with the dopamine-reward response in mind.

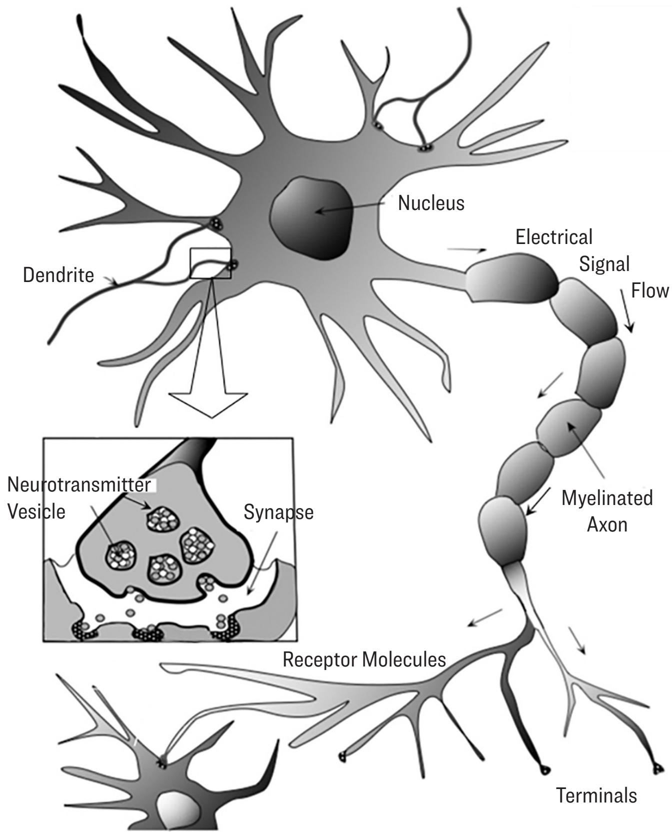
The Brain's Neuroplasticity

A long-held misconception asserted that brain growth stops with birth, only to be followed by a lifetime of brain-cell death. Now we know that although most of the neurons where information is stored are present at birth, there is lifelong growth and expansion of the abundant connections through which neurons communicate. *Neuroplasticity* refers to the brain's continuous capacity to generate new neural networks in response to stimuli.

The expression "neurons that fire together, wire together" refers to the process by which the brain constructs neural networks. The increased strength of the connections between neurons that sustain memory derives from the repeated activations of those networks. Every recalled memory or memory-directed pattern activates electrical signals (firing) from neuron to neuron to stimulate a constructive process that strengthens the memory circuit. This is an aspect of neuroplasticity—the enhancement or modification of memory networks through repeated activation. (See Figure 1.3.)

The neuroplastic response includes the building of more neuronal connections as well as the thickening of the layers of insulation, called *myelin*, around existing connections. A greater number of connections among neurons in a circuit means faster and more durable communication efficiency, just as adding lanes to a highway improves traffic flow. The addition of layers of myelin around the axons increases the speed of information travel and protects the circuit from being easily eroded through disuse.

Figure 1.3 The Neuroplastic Response



Through the neuroplastic response, the brain strengthens the circuits used most frequently, enhancing their speed. Strengthening and speeding neuron-to-neuron communication provides longer-term durability and access—that is, memories are accessed and retrieved more efficiently and they last longer. For example, when children are learning to tie their shoes, they repeatedly practice the steps. In so doing, the associated neurons repeatedly activate in sequence, strengthening the circuit of connected neurons each time. Practice results in the establishment of a "shoe-tying" network. The abundance of dendrites, enhanced by thick layers of insulating myelin around the axons, allows that behavior to become increasingly efficient and, eventually, automatic. Through neuroplasticity, the brain is molded by experience to reshape and reorganize itself so that we awake with a "new" brain each morning!

Another side of neuroplasticity, beyond building and strengthening myelinated connections, is known colloquially as the "use it or lose it" phenomenon. Without the stimulation of the electrical activity generated by use of a network, there is a gradual loss of connecting dendrites and thinning of the myelin, eventually leading to their dissolution, or pruning. Teachers are familiar with this mental pruning in a form that is often referred to as the "summer slump." Without regular use, students are likely to "forget" what had been previously taught and will require considerable review and even reteaching to reacquire their previous learning. Another example of pruning is experienced when we don't remember the foreign language we studied in high school if we don't use it regularly.

Although it may seem unproductive for the brain to prune things that have been learned, recall the brain's high metabolic demands. Without this pruning, the brain's limited resources would be spread too thin to support its efficient operation.

The major roadways of neuron-to-neuron connections are in the cerebral cortex, and there are not many branching connections between them. The pattern is comparable to a view of the major cross-country highways from five miles above Earth, without the side streets. The filling in of the brain's cognitive map takes place over time as students actively engage in mental manipulations of information. Key learning activities planned through the curriculum planning framework Understanding by Design (described in the next chapter), such as exploring essential questions and engaging in authentic tasks, build and expand the cognitive networks needed for conceptual understanding and transfer.

How the Brain Remembers

New memory construction takes place after new sensory information leaves the amygdala and enters a brain structure called the *hippocampus* (see Figure 1.2), whose name derives from the Greek word for *seahorse*, because of its resemblance to that creature. This structure is where new sensory intake connects to a bit of pre-existing memory and consolidates from immediate into short-term memory.

None of our memories are held in single neurons. It has been a momentous evolutionary extension that has enabled communication among hundreds and thousands of neurons, each holding tiny memory pieces, to recall even the simplest concept or perform the most basic tasks, such as clapping one's hands.

Memory is stored in separate hemispheres of the brain, based on the sensory modality (e.g., vision or hearing) in which it is experienced. These multiple storage areas are linked by dendrites and axons (see Figure 1.3). The brain develops stronger and extended memory circuits when new learning is connected to multiple circuits by recognizing the common threads among existing circuits or experiencing the learning through multiple sensory modalities, such as vision, hearing, and movement.

Here's an example: If students learn about the positive and negative charges of magnets and relate the information to other memory circuits that include the concepts of positive and negative (evident in things such as emotions, electricity, numbers, or economic influences), they will store and can retrieve what they learned about magnets through multiple pathways. If positive and negative magnetic forces are further related to a story in which opposites attract, thinking about that story can retrieve an even more detailed memory of facts related to magnets.

Storage of memory in neural networks based on patterns (relationships) has evolved into a very effective system in which the brain accesses prior knowledge to enable it to make connections to new information and situations. For example, memory based on patterns and relationships guides children to avoid objects designated as hot. It takes only one or two negative experiences of feeling the discomfort of touching a hot stove or campfire, along with hearing the word *hot* or seeing flames, for their brains to construct the relational memory cementing the notion that the word *hot* stands for things that should not be touched. In short, they learn.

Have you ever read aloud a familiar story or poem and left out a word or phrase that is often repeated or rhymed? If so, it is likely that children have jumped in to complete that sentence. Their action reflects the brain's use of patterning. In mathematics, pattern recognition is what allows students to predict the next number in a sequence or to recognize which procedure to apply when word problems use phrases such as *all together*, *remaining*, or *left over*.

Activating students' existing relevant prior knowledge takes place when they understand a framework into which the new learning belongs. This awareness guides the brain to recognize connections with existing memory networks in the hippocampus. Knowing how the brain makes connections can help teachers maximize learning in their classrooms, especially because students themselves do not always make connections between what they already know and new information being taught.

To ensure that there is related existing memory in the hippocampus to link with the new input, it is essential to help students become aware of their prior knowledge. When new information is presented with some foundational pattern recognized by the brain, memory networks incorporate it more efficiently. For example, when students are learning about triangles, you can start by reminding them about other shapes with which they are already familiar, such as squares and circles. Illustrating how a square can be cut or folded to create a triangle and how two equal triangles can be put together to create a square will promote the linking of the new (triangle) to the known (square). With a successful pattern match, the new information encodes into a short-term memory circuit. Strategies to ensure activation of prior knowledge include the use of pre-assessments, advance organizers, essential questions, concept maps, graphic organizers, and "hook" activities. (These and related strategies will be described in greater detail in later chapters.) Such strategies make it more likely that students will link the new information to their prior knowledge to both consolidate and expand memory circuits.

Long-Term and Concept Memory Construction

Not all activations of memory circuits stimulate the neuroplastic response equally. Less neuroplastic growth occurs if circuits are activated only by multiple repetitions of the same information in the same format—for example, writing a word 10 times or solving 30 equations using the same formula. Rote memorization produces isolated and somewhat feeble circuits unlinked to other networks. Such shallow memories only allow learners to "give back" what was taught, mirroring the way it was taught. This limits their ability to transfer—that is, to apply their learning to new situations beyond the original context in which it was learned.

Once encoded, short-term memory requires mental manipulation of the new information—it must be thought about or applied—to form richer and deeper connections and ensure its place in long-term memory storage. Without this mental manipulation, the short-term memory fades in less than a minute. Indeed, practice really does make permanent, as long as the practice involves active mental manipulation, construction of new ideas, and opportunities to apply the newly acquired knowledge and skills in different ways than they were originally learned—all tenets of the UbD framework.

The Video Game Model

What can we do to motivate sustained effort from a stingy brain and improve the mindset of students, especially those who have experienced failure and the erosion of their confidence in school? To answer this question, consider an activity that is popular among many young people and that leads them, despite repeated failures, to persevere—video games!

The video game experience models effective learning by the brain and thus offers a guide for effective teaching strategies. We have identified four elements of this model that educators can replicate to enhance the learning of their students: (1) establishing a desirable goal, (2) offering an achievable challenge, (3) providing constant assessment with specific feedback, and (4) acknowledging progress and achievement en route to a final goal.

Desirable Goals

Whether it is saving Earth from a devastating asteroid collision, slaying a dragon, or finding a lost treasure, a video game player knows the ultimate goal of the game. Players participate in the game because they enjoy the challenge or because friends or other people who are playing think it's cool. They buy into the goal of the game, even though it is merely fantasy.

Similarly, in the classroom, we need to make clear at the beginning of a new unit what the goals are and what it will take to achieve them. The brain's self-preservation programming means that it is most likely to apply its resources when it recognizes that effort will help to attain a desired goal. Accordingly, students will be more likely to engage and make an effort when they have clarity about the learning goal, evidence of its achievement, and an understanding of how a particular goal relates to them. In other words, goal buy-in is a critical component for all learning in order to motivate the brain to focus its attention, apply its energy resources, and persist when challenges arise. Like those that motivate avid video game players, goals need to be clear and relevant for students to have goal buy-in.

Achievable Challenges

Imagine the following scenarios:

- You are dropped off at the top of a ski resort's steepest run when you are only a beginner.
- You must spend your day on the bunny hill when you are an expert skier.
- You play a game of darts with the target 2 feet away.
- You play a game of darts with the target 20 feet away.
- You are a 3rd grade student trying to complete a crossword puzzle designed for adults.
- You are an adult trying to do a crossword puzzle designed for young children.

In each of these extremes, you would likely feel either frustrated or bored, depending on your level of mastery in relation to the challenge. Reflecting on those feelings helps us understand the stress students feel if they do not have the foundational knowledge to understand new topics or the skills required by a challenging task. Alternatively, consider how bored you feel when you are asked to spend time on a topic or skill that you have already mastered.

Engaging video games are designed around levels of difficulty (such as 1 to 10) and require progression through appropriate levels of challenge based on player mastery. When playing a game, players are usually working on a task at their appropriate challenge level and can progress only after achieving it. This same model of allowing game players to progress according to their individualized levels of achievable challenge is a key to reducing stress and sustaining motivated effort in the classroom.

Achievable challenge means that learning goals are clear and the learner embraces the expectation that success or mastery is within reach. Applying the video game model to classroom learning means planning goals that students accept as being within their range of potential. The famed Russian cognitive psychologist Lev Vygotsky (1978) coined the phrase *zone of proximal development* to characterize the importance of finding the balance point between learning tasks that are not at all challenging and those that are out of reach. When learners have opportunities to work toward desirable goals at their individualized levels of achievable challenge, their brains invest more effort in the task, remain more responsive to corrective feedback, and engage with the focus and perseverance akin to that of video gamers. As Goldilocks would say, the challenge needs to be "not too hard, not too easy, but just right!"

Constant Assessment with Specific Feedback

A central feature of video games is their feedback system. Players receive constant feedback as they play; they can then use that feedback to immediately make adjustments, alter their actions, and find out if these are successful. Gamers certainly make errors (incorrect predictions) on the way to mastery, but the most compelling games give feedback and unlimited chances to try again without pressure or the stress of boredom or hopeless frustration. When their choice or prediction is wrong, they know they will always have another chance. Solo players aren't receiving the negative message that they are alone in their confusion or experiencing the boredom of waiting for a class full of others playing the same game to catch up to their level before proceeding. Without those stressors, they remain comfortable trying other strategies or building skills needed for the designated task. Through experience, they find that despite frequent errors, if they act on feedback and persist, they will eventually improve and make incremental progress toward their goals. This cycle reinforces a growth mindset.

When the brain receives the feedback on progress that has been made, the associated memory, skill, or concept networks are reinforced. You can emulate the video game model in the classroom by providing your students with regular and timely feedback from formative assessments. The benefits of this practice have been conclusively documented (Black & Wiliam, 1998).

Acknowledgment of Progress and Achievement

It is interesting to note that video game players fail to achieve their goal as much as 80 percent of the time while playing. Why, then, do they persevere? Note that video games do not require mastery of all tasks at all levels; instead they highlight incremental progress. A player's advancement is noted via points, tokens, or graphics. Neurologically, each time a player's progress is acknowledged in the game, a small dopamine release occurs in the player's brain.

The motivation to persevere and pursue greater challenge at the next level stems from the brain seeking another surge of dopamine, which is the fuel of intrinsic reinforcement. This explains why players seek greater challenge at the next level. To keep the pleasure of intrinsic reinforcement going, the brain needs a higher level of challenge, because remaining at a level already mastered does not activate the necessary expectation of dopamine and its pleasure.

Much of what makes video games so compelling is the way they continuously give players evidence of the efficacy of their practice and continued efforts—essential ingredients for development of a growth mindset. The academic learning model can follow suit. When learners have opportunities to engage in learning tasks at their individualized, achievable levels of challenge and believe that their effort can achieve the goal, they are more likely to persist. When incremental progress is valued, they are more likely to recognize that specific feedback will help them improve toward goal achievement, rather than seeing the feedback as criticism or evidence of failure.

The video game model gets at the essence of building growth mindsets fueled by the belief that performance and achievement can improve by using feedback and exerting effort. Students build the self-confidence and experience the intrinsic satisfaction needed to persevere and confront successive challenges.

In subsequent chapters, we will explore the use of the UbD framework for planning curriculum, assessment, and instruction that support how the brain learns best.

Chapter Understandings

- The past two decades of brain research have provided insights that have profoundly extended our understanding of how to maximize the brain's development of the neural networks known as executive functions, the foundation for building skills. This research can be applied to optimize learning success.

- Because it is impossible for the brain to consciously sort through all the sensory information available every second, the brain has an attention filter that prioritizes what information gets in.
- The amygdalae are switching stations that direct communication between the lower brain and the upper brain.
- The brain seeks patterns. Pattern recognition enables predictions. Pattern linking builds short-term memory, and activation of prior knowledge promotes this memory linkage.
- Durable long-term memory and enduring understanding are promoted by active mental manipulations, construction of new ideas, and opportunities to apply newly acquired knowledge and skills in different ways than they were originally learned.
- Dopamine is a neurotransmitter that is released when a learner makes a successful prediction, reaches a goal, or makes progress toward a goal. When dopamine is released in the brain, it promotes feelings of pleasure, a deep satisfaction, and a drive to continue or repeat the actions that triggered the pleasurable response.
- Learners with a fixed mindset do not believe that their effort can lead to achievement and are unlikely to put forth effort when challenged to learn something new. Learners with a growth mindset attribute success to effort, perseverance, and strategy use.
- The video game model contains replicable elements—goal buy-in, achievable challenge, frequent assessment with specific feedback, and acknowledgment of progress—that can be applied in the classroom to promote engaged attention, sustained effort, and perseverance.
- Every class, assignment, and experience reshapes each student's brain through neuroplasticity. Understanding how the brain processes information and changes in response to experiences provides keys to best strategies and interventions for guiding learners to sound understanding and durable, transferrable, long-term memory.

Questions and Answers

Does using the video game model in the classroom mean that students should be playing video games to learn content?

Although there may be some value in having learning games matched to students' skill levels (e.g., for developing basic math skills or learning vocabulary in a new language), that is not our point. Instead, we propose that particular components of video game design can be emulated in the classroom (without actual video games). When these components are incorporated into an instruction and assessment system, they compel students to learn and sustain effort through challenge and setbacks, and they promote motivated effort and learning.

Is dopamine always a good thing? Can students get too much dopamine from learning experiences designed to promote the dopamine-reward response?

In some addictions and types of mental illness such as schizophrenia, an excess release of dopamine has a negative impact. However, in the amounts released by the dopamine boosters we suggest to promote learning and sustain effort, dopamine will not be elevated to the levels where the effects are negative.

3

Goals: The Drivers of Everything

The brain learns most efficiently and effectively when it is motivated by worthy and desirable goals. In this chapter, we'll consider learning goals from two perspectives: (1) goals to guide schools and teachers, and (2) goals that focus and motivate students. We'll examine each of these perspectives and offer specific examples and practical techniques to address them.

Learning Goals for the Modern World

Today's students will need to navigate vastly different sources, varieties, and quantities of information to meet the more complex demands of our new information and economic landscapes. Consider how many jobs from the past decades do not exist today (e.g., one-hour photo developing, pumping gas, repairing cassette and videotape machines, reading utility meters). Similarly, think about how many of today's jobs did not exist 20 years ago (e.g., manufacturing and installation of solar panels and wind turbines, developing apps for smartphones and tablets, online customer service and support, programming robots for manufacturing). This trend of new—and unpredictable—career opportunities is likely to continue and accelerate, while the skill sets required by many of these jobs will become increasingly sophisticated.

The National Association of Colleges and Employers (NACE) conducts an annual survey of employers to gather data about what they look for when hiring new college graduates. (See www.naceweb.org/s11182015/employers-look-for-in-new-hires.aspx.) Here are the summarized results of its 2016 Job Outlook survey, showing a rank ordering of the desired job qualities and skills as reported by employers (NACE, 2016).

Leadership	80.1%
Ability to work in a team	78.9%
Communication skills (written)	70.2%
Problem-solving skills	70.2%
Communication skills (verbal)	68.9%
Strong work ethic	68.9%
Initiative	65.8%
Analytical/quantitative skills	62.7%
Flexibility/adaptability	60.9%
Technical skills	59.6%
Interpersonal skills (relates well to others)	58.4%
Computer skills	55.3%
Detail oriented	52.8%
Organizational ability	48.4%
Friendly/outgoing personality	35.4%
Strategic planning skills	26.7%
Creativity	23.6%
Tactfulness	20.5%
Entrepreneurial skills/risk-taker	18.6%

Notice that most of these qualities and skills require executive functions!

In acknowledging the nature of the skill sets needed in the modern workplace, Linda Darling-Hammond, a professor at Stanford University and an authority on international assessments, suggests implications for education:

> As educators, we know that today's students will enter a workforce in which they will have to not only acquire information, but also analyze, synthesize, and apply it to address new problems, design solutions, collaborate effectively, and communicate persuasively. Few, if any, previous generations have been asked to become such nimble thinkers. (Darling-Hammond & Adamson, 2013, p. 1)

To summarize, if students leave school without the executive function skill sets that develop during the critical years when the brain's prefrontal cortex is maturing, their preparation for the world's challenges and opportunities will be substantially inadequate.

By making these employment-related points, we are not implying that the sole purpose of an education is job preparation. Certainly, outcomes such as responsible citizenship and lifelong wellness are desirable goals of schooling. However, as parents of millennials, we are mindful of the need for young people to develop the skills needed for gainful and satisfying employment as one dimension of a fulfilling life. No one is happy when 20-somethings are stuck living in their parents' basements because they are unqualified for available jobs!

Establishing Curricular Goals

Just as individual brains are goal directed, educators need learning goals to help direct and focus their efforts. Research has confirmed that teacher clarity about what they want their students to learn is one of the most significant factors related to student achievement (Hattie, 2008; Marzano, 1998). In his book *Clarity in the Classroom*, New Zealand educator Michael Absolum (2006) highlights the importance of task clarity and summarizes the benefits:

> For students to truly be able to take responsibility for their learning, both teachers and students need to be very clear about what is being learned, and how they should go about it. When learning and the path toward it are clear, research shows that there are a number of important shifts for students. Their motivation improves, they stay on task, their behavior improves and they are able to take more responsibility for their learning. (p. 76)

From a curriculum design perspective, goal clarity is the critical starting point of UbD because everything, including learning experiences, instructional resources, assessments, and schedule, should be planned *backward* from the targeted goals. One dimension of goal clarity is the recognition that there are different kinds of learning goals. The differences matter, in terms of both how teachers teach for different goals and how each is most appropriately assessed. The following sections describe different types of goals.

Goals Related to Knowledge

Knowledge goals specify what students should know. This category focuses on declarative knowledge of factual information (e.g., multiplication tables, state capitals), vocabulary terms, and basic concepts (e.g., *interdependence*, *adaptation*). From an instructional standpoint, teachers can impart factual knowledge through a lecture or by having learners read informational texts. (In Chapter 5, we'll explore a number of brain-friendly techniques for enhancing memory storage and retrieval of factual knowledge.) As for assessment, teachers can gauge the attainment of knowledge goals through questioning and by using objective test and quiz items.

Goals Related to Skills and Processes

Goals for skills and processes are procedural in nature; they state what students should be able to *do*. Some skills involve relatively simple behaviors, such as tying a knot or adding numbers. Others, such as writing an essay or conducting a scientific investigation, are actually more complex processes involving a number of specific skills working together. Skill proficiency is best developed through an instructional process involving modeling, guided practice, and feedback. Teachers assess student proficiency in a skill or process through direct observation of a performance, as might occur in physical education; or by examining a product, such as a piece of writing. Unlike assessment of knowledge, which usually looks for a single "correct" answer, the assessment of skills and processes can best be conceived as a continuum of proficiency levels from novice to expert—similar to the different colored belts used in karate.

Goals Related to Understanding

Goals for understanding refer to the *big ideas* that we want students to comprehend at a deep level. Such ideas are inherently conceptual and abstract. They may be in the form of concepts (e.g., *migration*), principles (e.g., *F=MA*), themes (e.g., *friendship*), or processes (e.g., *problem solving*). In UbD, desired understandings are stated as full-sentence generalizations (e.g., *A muscle that contracts through its full range of motion will generate more force*).

Teaching for understanding requires more than simple didactic presentation and rote learning. Teachers must facilitate *meaning making* by the learner, using instructional methods such as Socratic questioning, concept attainment, inquiry, and problem-based learning. It is precisely this way of teaching that yields a dual benefit: (1) deepening of subject matter understanding and (2) strengthening the brain's neural networks associated with its executive functions.

The most appropriate assessments of understanding are not multiple-choice or fill-in-the-blank test items. Understanding is evident when students can effectively do two things: (1) *apply* their learning to a new situation—that is, transfer; and (2) *explain* their thinking to justify their conclusion or answer. Thus we recommend using performance-based assessments and rubrics to gauge the degree of a student's understanding. (We will explore assessing understanding and transfer in more detail in Chapter 4.)

We have found it helpful to frame desired understandings through *essential questions*, and you can think of understandings and essential questions as two sides of a coin. Although essential questions are not goals, per se, they can help to clarify desired understandings, spark student inquiry, and engage higher-order thinking. Figure 3.1 shows examples of related understandings and essential questions for academic subject areas.

Goals Related to Transfer

A fourth goal type involves transfer. Transfer refers to students' capacity to apply what they have learned to a new situation, beyond the context in which it was learned. Transfer goals specify what we want students to *be able to do with their learning* in the long run when confronted by new opportunities and challenges. In a world in which people can access much of the world's knowledge on a smartphone, it is no longer enough for educators to simply prepare learners to give back existing knowledge. A modern education should equip learners to use executive functions to apply their learning to address new—even unpredictable—opportunities and challenges, within and outside school. In other words, school must develop *know-how*, not just knowledge.

In *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*, the National Research Council (2012) characterizes transfer goals as the essence of 21st century learning:

> We define "deeper learning" as the process through which an individual becomes capable of taking what was learned in one situation and applying it to new situations (i.e., transfer). Through deeper learning (which often involves shared learning

> and interactions with others in a community), the individual develops expertise in a particular domain of knowledge and/or performance. . . . The product of deeper learning is transferable knowledge, including content knowledge in a domain and knowledge of how, why, and when to apply this knowledge to answer questions and solve problems. We refer to this blend of both knowledge and skills as "21st century competencies." (p. 6)

Figure 3.1 Sample Understandings and Essential Questions for Academic Subjects

Understandings	Essential Questions
Effective readers actively monitor their comprehension to ensure they understand what they are reading.	• *What do good readers do?* • *How will I know that I understand what I am reading?*
A muscle that contracts through its full range of motion will generate more force.	• *How can I hit* [e.g., a golf ball, tennis ball, or baseball] *with greater power without losing control?*
Visual artists choose to follow or break established conventions in pursuit of expressive goals.	• *Why and when should an artist depart from established conventions?*
Statistical analysis and data display can reveal patterns that may not be obvious. Pattern recognition enables prediction.	• *Is there a pattern here?* • *What will/might happen next?*
Language is embedded within a cultural context, and acquisition requires much more than word-for-word translation.	• *Why isn't a dictionary enough (when learning to speak a new language)?*
Scientific claims must be verified by independent investigations and replications.	• *How do I know what to believe about a scientific claim?* • *When and how do scientific conjectures become facts?*
Measure twice, cut once.	• *How can I avoid costly errors?*
Audience and purpose influence a writer's choice of organizational pattern, language, and literary techniques to elicit an intended response from the reader.	• *Why am I writing? What is my purpose?* • *Who is my audience? What will work best for my audience?*

The Latin origin of the term *curriculum* translates roughly as "the course to be run," and it is useful to think of a curriculum as the course or pathway to a destination. Our contention is that long-term transfer goals—both within and across academic disciplines—reflect *the* destination of a contemporary K–12 education. Accordingly, we should plan the curriculum backward from these important outcomes.

Practically speaking, we are *not* suggesting that every teacher should come up with her own list of transfer goals for every unit she teaches. Instead, we propose that district- and school-level curriculum teams identify a set of transfer goals as long-term exit outcomes—goals to be attained by the end of a K–12 education. Such goals bring specificity to the phrase "college- and career-ready." We further recommend that there be only a small number of truly long-term transfer goals for each discipline and a small number that cut across the disciplines. For example, a long-term transfer goal in history is for students to reference the lessons of the past when they consider contemporary issues, whereas a transfer goal in mathematics is for students to be able to use sound mathematical reasoning and strategies to tackle real-world problems. Cross-disciplinary transfer goals include those requiring the brain's executive functions, such as *critical thinking, collaboration,* and *creativity*. Figure 3.2 presents examples of long-term transfer goals within academic disciplines.

Cross-Disciplinary Transfer Goals for Executive Functions

Another category of transfer goals cuts across the disciplines and is associated with the executive functions of the brain. We contend that teachers can enhance academic learning while *concurrently* developing these mental processes. This means that educators should specify what they want students to come to understand about their brain and its controls, pose essential questions to help develop those understandings, and remind students to invoke them when needed. Figure 3.3 presents examples of understandings about various executive functions and associated essential questions that may be used to develop these lifelong capacities.

Clarity about long-term transfer goals, within and across the disciplines, helps teachers and students truly keep the "end in mind." These goals help teachers prioritize and focus their teaching and avoid getting lost in the weeds of trying to "cover" long lists of discrete facts and skills. For students, transfer goals speak to relevance because they identify ways to apply learning to real-life situations.

Teaching for transfer means equipping learners to apply their learning to a *new* and specific setting in which sensitivity to context matters. We hope it is evident that the development of long-term transfer capacities requires use of the brain's executive functions. Rote learning from lectures can never prepare students for such outcomes (Wiggins & McTighe, 2011).

Figure 3.2 Examples of Long-Term Transfer Goals Within Academic Disciplines

Students will be able to independently use their learning to . . .

Economics
Make economically sound and ethical financial decisions.

History
Use knowledge of patterns of history to help understand the present and prepare for the future.

Health and Physical Education
Make healthful choices and decisions throughout their lives.

Mathematics
Apply sound mathematical reasoning and strategies to tackle real-world problems.

Reading
Comprehend texts in various genres (literature, nonfiction, technical) for various purposes (e.g., for entertainment, to be informed, to perform a task).

Research
Locate pertinent information from varied sources (print, online; primary, secondary).

Science
Conduct a sound investigation to answer an empirical question.

World Language
Effectively communicate with varied audiences and for varied purposes while displaying appropriate cultural understanding.

Writing
Write in various genres for various purposes and audiences.

Goals in the UbD Template

When using the UbD framework for curriculum planning and design, educators should "unpack" standards- and mission-related

Figure 3.3 Sample Understandings and Essential Questions for the Brain's Executive Functions

Understandings	Essential Questions
Attention Focus Optimal learning requires the ability to selectively focus the brain's attention to prioritize the most important sensory data/information while blocking distracting/irrelevant input.	• *What should I focus on?* • *What strategies can I use to focus my attention and resist distractions?*
Goal Setting Effective learners set specific, measurable goals and make plans to achieve them, monitor their progress toward goal achievement, and make needed adjustments in response to feedback or new information. Goal-oriented people resist immediate gratification in order to work toward future goals.	• *What is my goal or desired outcome?* • *What steps are needed to achieve this goal?* • *What obstacle(s) might impede my progress?* • *How can I obtain helpful feedback?* • *What can I learn from setbacks or mistakes?* • *What adjustments are needed?* • *How might I delay my desire for immediate gratification in order to achieve a long-term goal?*
Prioritizing Prioritizing involves determining hierarchies of importance and managing time and resources effectively in order to achieve the most important goals.	• *What is most important here?* • *What should I do first? Second?* • *What action will be most effective? Least effective?* • *What is the best use of my time and resources?*
Critical Thinking Critical thinkers do not simply believe whatever they read, hear, or view. They remain skeptical, ask critical questions, and seek alternative points of view before reaching decisions or taking actions.	• *How do I know what to believe in what I read, hear, and view? Just what is true?* • *What other perspectives should I consider?*
Decision Making One's choices and actions have consequences. Effective decision making requires judgment regarding possible choices/actions and associated outcomes, risks, and consequences. Specific criteria are needed to evaluate options and guide decisions.	• *How should I decide?* • *By what criteria will I evaluate options and guide decisions?* • *What are possible consequences of my choices or actions?*
Cognitive Flexibility An intellectually mature person looks for varied ways of defining problems, considers different points of view, tries alternative strategies/approaches, and explores new solutions and possibilities.	• *In what other ways might I define this problem?* • *Are there other ways of viewing this situation?* • *What can I do when my approach is not working?* • *What are other possibilities and solutions?* • *When should I "shift gears" and try a new approach?*

Understandings	Essential Questions
Delaying Gratification Resisting a smaller but more immediate reward can enable one to achieve a larger or more enduring reward later. Instead of acting or responding immediately to temptations, effective people exert self-control and consider the short- and long-term impacts of their actions.	• *Why can't I just have what I want when I want it?* • *How can I avoid temptations that may distract me from my long-term goal(s)?* • *How can I control myself?*
Metacognitive Self-management Capacity for metacognitive self-management includes active and ongoing monitoring of one's cognitive and emotional states and making needed adjustments based on insights in response to feedback and new information. Effective learners reflect on their experiences and learn from them.	• *How am I doing?* • *How can I monitor my cognitive and emotional states?* • *What are my strengths and weaknesses?* • *How can I obtain helpful feedback?* • *What adjustments are needed?* • *What did I learn from this experience?*

outcomes by considering each of these goal types—knowledge, skills, understandings, and transfer. Figure 3.4 presents the UbD Unit Design Template for Stage 1, with its associated planning questions shown under Transfer (for transfer goals), Meaning (for goals related to understandings), and Acquisition (for goals related to knowledge and skills).

Goal Setting for and by Students

We now consider learning goals from the viewpoint of the learner. The brain learns with maximum efficiency when it is motivated by desirable goals, and students will be more likely to focus their efforts and persist in learning when

- The learning goals are clear.
- They see the goals as having personal relevance and value.
- They know how their achievement will be recognized (e.g., via known tasks and success criteria).
- They believe that the goals are attainable and they can see their progress toward achieving the goals.

Let's consider each of these factors, along with practical techniques for addressing them.

Figure 3.4 UbD Unit Design Template for Stage 1

Stage 1—Desired Results		
Established Goals What content standards and program- or mission-related goal(s) will this unit address? What habits of mind and cross-disciplinary goal(s)—for example, 21st century skills, core competencies—will this unit address?	**Transfer**	
	Students will be able to independently use their learning to . . . What kinds of long-term independent accomplishments are desired?	
	Meaning	
	UNDERSTANDINGS *Students will understand that . . .* What specifically do you want students to understand? What inferences should they make?	ESSENTIAL QUESTIONS *Students will keep considering . . .* What thought-provoking questions will foster inquiry, meaning-making, and transfer?
	Acquisition	
	Students will know . . . What facts and basic concepts should students know and be able to recall?	*Students will be skilled at . . .* What discrete skills and processes should students be able to use?

Source: From *The Understanding by Design Guide to Creating High-Quality Units* (p. 16), by G. Wiggins and J. McTighe (2011), Alexandria, VA: ASCD. Copyright © 2011 by Grant Wiggins and Jay McTighe. Adapted with permission.

Goal Clarity

Learners are more likely to focus their efforts when the learning goal is clear and they see it as worthwhile. Clarity in goal planning is needed to prime the pleasure-seeking brain to invest the effort to achieve a clear goal. It is therefore essential to be clear from the start as to what the goals of the learning will be and to communicate these goals early to students. Neuroscience studies confirm that goal clarity positively affects students' motivation and their capacity to organize and focus their efforts, leading to enhanced academic performance. The process begins with clear teaching goals and is enhanced when students participate in setting their own goals (Morisano et al., 2010; Prabhakar et al., 2016). Conversely, when the goal is unclear or irrelevant to students, it is unlikely that they will maintain attention, try their best, or persist when learning becomes challenging.

If curriculum planners have done well in their Stage 1 efforts, the various learning goals they want learners to attain (transfer, understandings, knowledge, and skills) should be crystal clear. The next step is to bring that clarity to the learners. Teachers can take a number of practical actions in this regard, including the following:

- Directly state the desired goals/outcomes at the beginning of a new unit. Then, connect daily lesson goals to the longer-term unit goals.
- Post and discuss the essential questions at the start of the unit and refer to them throughout.
- Invite student questions about the unit topic and allow students to explore them. Using KWL charts at the beginning of a unit can increase students' goal ownership because they can pose questions and identify those aspects of a subject about which they are curious and ***W***ant to learn. (Note: The KWL strategy also activates students' prior knowledge by asking them what they already ***K***now. Additionally, if students create their own individual KWL charts, they can incorporate their own goals—things they particularly want to know that are relevant to the coming unit of study. They will see their progress toward their personal goal as the unit continues, and they can fill in the chart sections about what they have ***L***earned and make corrections to any errors in the K column.)

- Present the ways in which students can demonstrate their learning—the assessments—and discuss the associated success criteria. For example, in addition to traditional tests, students may be asked to plan a lesson for kids in a lower grade. Knowing in advance they will teach a concept to younger children motivates students to put more effort into learning a concept fully and keeps their minds focused when they practice.
- Share samples of work from previous years' students that illustrate the desired learning. Tangible examples make the goals and assessment criteria come to life.

Goal Relevance and Value

Goal clarity is necessary but insufficient on its own. Brains are goal-driven, but only if the goal is seen as personally relevant and having some value. As adults, how many of us will put forth maximum effort to learn something new that we do not care about or that we think we will never use? Accepting a goal as relevant and valuable, or worthwhile, is especially important to school-age learners who may not always see inherent value in what they are being asked to learn. Indeed, it is not uncommon to encounter questions such as "Why are we learning this?" or "Whoever uses this stuff?" from skeptical students. Without believable answers, how can we expect learners to commit a whole-hearted effort to learning? Accordingly, teachers need to plan assiduously to help students see relevance in, and make personal connections to, targeted learning goals. Here are several practical techniques for promoting student acceptance of goals:

- Demonstrate or discuss the "so what?" factor. Identify people and places beyond the classroom where the knowledge and skills are applied.
- Watch a relevant video to help students see real-world value in what they are being asked to learn. Two good sources are PBS Learning Media (www.pbslearningmedia.org) and the Futures Channel (www.thefutureschannel.com).
- Describe how students will be able to use their new learning during or after achieving the goals, such as through a project or performance task, teaching younger students, or presenting to an authentic audience. Using authentic performance tasks can make

learning more relevant and memorable while supporting conceptual understanding and the construction of enduring memory circuits.

- Use a "hook" question to engage learners in seeing the worthiness and relevance of a goal. For example, a 7th grade health teacher begins a unit on nutrition with the question "How can what you eat help prevent zits?" to help her students recognize the personal benefits of learning the designated content.
- Spark acceptance by "selling" the parts of the unit that you know will be particularly engaging. For example, as part of a mathematics unit involving percent and decimals, describe how the unit will be taught through a simulation of personal banking in which students will have blank checks, a check register, deposit slips, and choices of transactions (e.g., purchases from shopping catalogs or investments) for them to do with the "money" in their accounts.
- Invite students to tell personal stories of how the topic relates to their lives, or ask them to brainstorm how they might be able to apply the new learning both now and in the future.
- Before a lesson or unit, tell an anecdote about the life of the author, scientist, historical figure, or mathematician when that individual was about the age of your students.

When planning sections of units that students may not recognize as intrinsically interesting or clearly linked to personally desirable goals, teachers can use the brain's natural curiosity to boost students' interest and engagement. Neurologically, curiosity and prediction activate the brain's dopamine-reward system to fuel attention and sustained effort.

One way to engage students' curiosity is to emulate certain techniques used by advertisers to gain the attention and interest of their audience. For example, the "coming attractions" at a movie theater are meant to leave the viewer wanting more. The trailers are usually edited to be particularly dramatic and attention grabbing; they provide some indication of what the film is about but leave out most of the details. This technique creates suspense. The viewer, if successfully enticed, wants to see the full-length movie to see how things resolve.

Teachers can similarly "advertise" an upcoming unit to provoke curiosity about what's to come using a variety of low- and high-tech techniques. For example, cut up a picture of a poster, painting, or photograph relating to the content, and every day or so add pieces or clues leading up to a "big-idea understanding" about the topic. For fractions, these clues could include a picture of an x-ray of an arm fracture; sheet music with half, whole, and quarter notes; a carrot cut into quarters; a ball floating in water with part of it submerged; and a photo of an iceberg showing the proportions above and below water.

Here are other time-honored ways of sparking curiosity in the classroom:

- Present "weird facts" or discrepant events. For example, punch a balloon with a wooden skewer and ask students to speculate why the balloon did not burst.
- Show thought-provoking pictures, such as an M. C. Escher drawing, or short video clips, such as the opening scenes of Ken Burns's documentary film *The Civil War*, depicting the horrors and personal impact of war.
- Use humor to open the door to a new topic. For example, show cartoons featuring exaggerated proportions to start a unit on ratio and proportion; tell a humorous anecdote about the misuse of vocabulary in a world language class.

Curiosity may fade, but the brain's permanent wiring dictates the need to find out if a prediction is correct. Recall the dopamine-reward response described in Chapter 1. A correct prediction can trigger this response, leading the brain to correct faulty knowledge from incorrect predictions and to reward successful predictions and responses or choices. Just as curiosity engages attention, prediction sustains attention because the brain *wants* to know if its predictions are correct. (Think of adults who pick a favorite in a horse race and then judiciously watch the race to see if they hold a winning ticket.) Teachers can use the brain's need to validate predictions. After hooking learners with various attention-getters, teachers can sustain their attention by asking them to predict what they think the curiosity-stimulating sight, sound, object, statement, picture, or question might have to do with the lesson.

It is important that all students make predictions, using either low-tech methods, such as "thumbs up, thumbs down" or writing on individual whiteboards or "magic pads," or through high-tech devices, such as student-response clickers or smartphone apps. Because students can change their predictions, their brains sustain buy-in because they want to know what you have to teach!

Recognizing Goal Achievement

When students are aware of the criteria by which educational goals will be assessed, they show better long-term academic development than do their peers who are focused only on a final grade or are motivated by outperforming others. By knowing the criteria in advance, students are provided with clear expectations regarding the quality of their work. There is no mystery as to the desired elements of quality or the basis for evaluation and grading. Students don't have to guess about what is most important or how their achievement will be judged.

Teachers can use a number of practical techniques to help learners understand how their achievement will be recognized. Here are some examples:

- Present success criteria at the start of a new unit.
- Involve students in identifying preliminary evaluation criteria.
- Show models/exemplars for expected products/performances.
- Have students review examples and induce the characteristics of the most effective ones.
- Show and explain scoring rubrics to clarify how students' work will be judged.

Attainability and Awareness of Progress Toward Goals

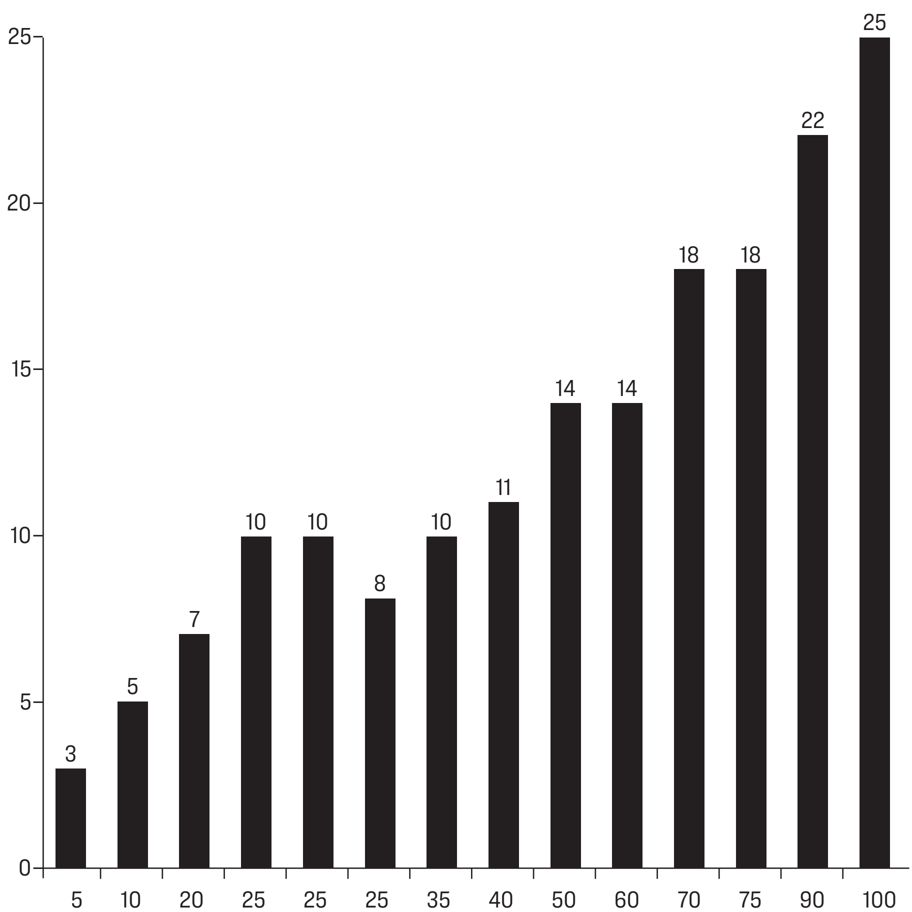
Learners benefit not only from knowing the learning goals and associated success criteria; they are more likely to persist on challenging tasks when they believe that the goals are *attainable* and that they are *making progress* toward those goals. Recall that the prefrontal cortex, where the goal-planning executive functions develop, is the last part of the brain to mature—a process that continues well into the 20s. Although it may seem obvious to adults, young people do not automatically recognize the correlation between their effort and goal attainment. For students to sustain effort on the way to reaching long-term goals, they need explicit feedback about, and affirmation of, their incremental progress. Providing recognition (and celebration) of goal progress can counteract the ingrained tendency for immediate gratification that is characteristic of the developing brains of school-age children and adolescents. As the video game model illustrates, the dopamine-reward response in the brain fuels a player's sustained effort—even through increasing challenges and setbacks.

Teachers can harness this effect by providing ongoing feedback on progress to promote students' persistence and reward sustained effort on important learning tasks. Here are practical techniques for promoting students' awareness of their progress toward worthy goals:

- Guide students in breaking down a long-term goal into a series of simpler goals that will build, step-by-step, toward the final goal. For example, if students are expected to read a 50-page book in two weeks, have them write down the five pages they'll read on each of 10 days and record each accomplishment. If a goal is to learn 25 new vocabulary words, create a "thermometer" graph and mark off progress points achieved along the way to that goal. These simple actions give the brain visual feedback and help learners experience the dopamine pleasure of recognizing tangible progress toward a goal.
- Model self-assessment using the success criteria and developed rubrics. Provide feedback on the accuracy of the students' own self-assessments.
- Guide students in using rubrics to identify where they are and where they need to go next for each trait or performance level.
- Involve students in identifying success criteria and have them develop their own individualized rubrics, using your general rubric.
- Use "effort-to-goal progress graphs" to keep track of incremental progress. These graphs are a type of visual organizer that students can use to keep progress records and create associated bar graphs, such as for time spent on practice, scores on quizzes, or feedback from teachers or peers (see www.onlinecharttool.com). For example, the graph shown in Figure 3.5 was developed by an 11th grade student whose goal was to improve his free-throw shooting in basketball. At each practice session, he took 25 shots and recorded the number of baskets he made. He also recorded the cumulative time he had put into practicing; that is, he added the time spent on each day's practice to the total time he had practiced thus far.

A visual model like that shown in Figure 3.5 allows students to see that their level of success is under their control. The graph provides visible evidence that greater *effort* (in this case, time spent practicing free throws) results in measurable *progress* toward a goal (an increasing percentage of successful free-throw shots). Because the measurements on the graph relate the progress toward a goal, students can savor successes without having to be embarrassed by their specific scores or the point of mastery to which they have progressed. The first designation on each student's graph simply indicates the individual "starting place," and subsequent points on the graph delineate the amounts by which the student increased or improved from that point.

Figure 3.5 Effort-to-Goal Progress Graph



x = cumulative time practicing
y = number of baskets made

Record-keeping methods like this chart enable learners to track their progress and celebrate personal growth toward worthy learning goals. Recall that the brain's response to the awareness that it has achieved success releases a spike in dopamine, a neurochemical producing feelings of deep pleasure and satisfaction. When students recognize the association between progress toward (and achievement of) goals and the brain's reward response, they will be able to use their own internal motivation systems to sustain progress toward a goal.

Guiding Students in Personal Goal Setting

The educational goals referenced in this chapter thus far are identified by national or state standards or specified by teachers. However, educational goal setting can also be personalized. Teachers who guide their students in setting clear, achievable, and personally desirable goals reflect an understanding of how the brain learns best. When learners have some input into (or choices within) the learning process, they are often motivated to put forth greater effort, resulting in enhanced performance on academic tasks. Moreover, by engaging the skill sets involved in goal setting—prioritizing, planning, self-monitoring, seeking feedback, persisting—learners are strengthening the neural networks associated with these executive functions.

There are various options for allowing students to set personal learning goals or to make choices within the framework of established ones. As an example, Figure 3.6 presents a simple frame for allowing student choices based on a "Content, Process, Product" organizer.

Teachers will need to determine when it is appropriate and feasible to give students such options. Although it may not always be possible to open the door for personalization, we do not want to lose sight of the underlying neuroscience principle: whenever learners see a goal as personally meaningful and attainable for them, their brains will be more motivated to pursue it!

Of course, students will need guidance on how to set specific, achievable, and worthwhile learning goals. As with learning any skill, learners need teacher modeling, guided practice, and ongoing feedback in order to build the needed capacities. We have found it valuable to help students become aware of the basic neuroscience behind what makes their brains want to put forth effort to achieve goals. A teacher can explain how a big part of successful goal setting is related to the brain's inborn programming to try things when it believes there is something it wants and can achieve—with planning and effort. For example, a teacher might say, "Your brain is more likely to engage and be more responsive when it knows how you will benefit from any activity. Setting your own goals increases your brain's desire to achieve them. The more specifically you define your goal and acknowledge its value to you, the more effort your brain will put into achieving it."

Figure 3.6 Personal Goal Setting for Content, Process, and Product

Content: Students set personal goals related to the content outcomes.

Examples:

- Students in a history class studying World War II may be allowed to pursue personal interests. For instance, a student interested in aviation learns about various warplanes, whereas another student researches a famous person of the era, such as Anne Frank or Douglas MacArthur.
- Elementary students generate their own "I really want to know" questions related to a new topic. They have time to pursue their personal inquiries with assistance from the school librarian.

Process: Students set goals related to their learning process and make choices about the strategies that will be most effective for them.

Examples:

- A language learner may use podcasts to learn vocabulary, whereas another student chooses to practice with flashcards.
- Students choose personal techniques for note taking and studying, such as a traditional outline, graphic organizers, or summary note cards.

Product: Students set personal goals related to the products by which they will show their learning.

Examples:

- One student creates a visual "concept map" to show her understanding of cell structures and functions; another student writes a simulated textbook section for younger students.
- Middle school students working on an authentic performance task can pick from a list of product options, including a newspaper article, a presentation, a poster, a podcast, a graphic organizer, and a museum display.

Here are other practical actions that teachers can take to support students as they plan and monitor their learning goals.

- Model your own planning processes by thinking aloud about how you identify your own personal goals and how you make a specific plan to attain them.

- Just as you use students' interests, strengths, and talents to engage them in the goals you have developed, encourage them to recognize and use this information to set personalized goals.
- Provide opportunities for students to review weekly charts showing progress toward goal achievement and note which strategies were most effective for them.
- Teach students how to make schedules and manage time when planning long-term projects.
- Provide (or guide the construction of) goal-setting and self-monitoring tools, such as to-do lists, step-by-step guides, personalized rubrics, graphic organizers, and self-assessment prompts.
- Guide students in identifying personalized success criteria for self-assessing their achievement of targeted goals.
- Schedule brief "touch base" conferences with students to check in on their progress toward their goals.

As students become more experienced at setting personal goals based on their interests, strengths, and talents, they build their self-confidence as learners. When they choose learning and self-monitoring strategies that work for them, they develop greater autonomy and capacity for independent learning. With each success, the increased sense of their own competence will encourage them to confidently set and pursue higher goals, while also building the persistence, resilience, and greater tolerance needed to face inevitable setbacks.

Delaying Gratification

One of the brain's most critical executive functions is the ability to delay gratification, especially when working toward goals that are not immediate or tangible. This is a formidable habit of mind that undergirds the perseverance needed to achieve a long-term goal and sustains successful people through challenging times.

We propose that the concept of delayed gratification be introduced to younger students and reinforced throughout the grades. Teachers can explain the related neuroscience in developmentally appropriate ways. For example, help students understand that working toward worthwhile, long-term goals actually goes against their brain's programming. Developing brains are wired to favor immediate gratification, so they need to build the executive function skill sets in order to delay that drive and reap achievement rewards in the future.

Here are practical actions that teachers can take to develop students' capacities for delaying gratification in pursuit of worthy goals:

- Tell students stories that illustrate delayed gratification; cite characters in literature (e.g., *The Little Red Hen*) or real people (e.g., athletes) who have set long-term goals and made sacrifices in the short term to achieve them.
- Provide personal examples of times when you delayed gratification. Reveal how hard it was to resist temptation, explain how you kept at it, and relate the benefits that you realized through persistence.
- Have students share their own stories of successful delay of gratification.
- Use think-alouds to illustrate ways that you defer gratification, such as avoiding a sugary afternoon snack before a nutritious dinner.
- Use and revisit engaging and student-relevant essential questions throughout a unit. Remind students that their understanding will deepen as they consider and reconsider these open-ended questions.
- Teach students specific strategies that they can use to focus on long-term goals—for example, writing down a long-term goal and then creating and posting an image or picture of the desired goal on a bulletin board.
- Model specific strategies students can use to delay immediate gratification, such as keeping progress charts, developing and following a study/practice schedule, and working with a learning buddy or study group.
- Post a list of basic "Delaying Gratification" strategies in the classroom. Add to the list throughout the year.
- Use metacognitive prompts such as these:
  - *What will I be able to do, understand, or create when I have achieved my goal(s)?*
  - *How might I avoid known distractions (e.g., social media, television, games, parties)?*
  - *How can I stay on track (e.g., daily check-in with a partner with a similar goal)?*

- Look for opportunities to highlight and celebrate occasions when students delayed gratification and achieved something in the long run.

As students develop their understanding about the benefits of, and strategies for, delaying gratification, they will become increasingly able to apply effort even when the pleasure of attaining a goal is not instantaneous. As they recognize the value of goal setting, practice, and application of learning, they will become better able to persist in working toward targeted goals—including the "boring" fundamentals and the very challenging topics.

Chapter Understandings

- Even as the prefrontal cortex of the brain develops during the school years, the goal-directed executive functions such as prioritizing, systematic planning, self-monitoring, and deferring gratification do not automatically emerge. Students need ongoing opportunities to develop these critical skills—and the neural networks that underpin them.
- With regular opportunities to set personal goals, learn and apply effective strategies, track their progress, and celebrate achievements, students will become increasingly able to transfer these goal-setting skills to other applications in school and life. Increasing goal-directed executive functions leads to greater persistence and enhanced self-control of attention focus, inhibition of distraction, and self-regulation.
- Given the intrinsic satisfaction of achieving a goal, students will be motivated to take on new challenges and persevere in working to attain them (Karakowsky & Mann, 2008; Prabhakar et al., 2016).
- There are qualitatively different types of educational goals, including Knowledge, Skills, Understandings, and long-term Transfer Goals. The differences are important since each type calls for specific approaches to both teaching and assessment.
- Since young people can now access much of the world's information on a smartphone, modern education should prepare learners for transfer (i.e., to be able to *apply* their learning to new situations). We recommend that educators plan the curriculum

backward from long-term transfer goals—both within and across academic disciplines.

- Developing the brain's executive functions is both a means and an end to enduring learning. When you plan backward from long-term transfer goals while concurrently developing the skill sets needed for goal attainment, (1) learners will develop and deepen the conceptual understandings needed to transfer their learning, and (2) their brain's neural networks associated with executive function skill sets will strengthen, resulting in the lifelong skill of being self-directed learners and goal achievers.

Questions and Answers

What are the executive functions, and how do they develop?

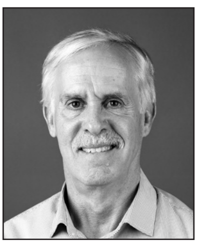
The neural networks that direct executive functions develop in the prefrontal cortex. They begin their extended maturation starting in early childhood and continue to develop at an accelerated rate through the school years. These networks are what give students increasing voluntary control over their attention focus, inhibitory control, delay of gratification, emotional self-awareness and self-management, interpersonal relationships, goal-directed behavior, planning, prioritizing, critical thinking, judgment, reasoning, flexibility of thinking, and adaptability. Through the neuroplastic response, by which using a network makes it stronger, all these executive functions can be strengthened by classroom opportunities that guide them, across the curriculum, in foundational skillsets they then apply to their construction of understanding and transfer of knowledge.

What is the difference between Knowledge and Understanding?

Knowledge refers to the "knowing" of facts, vocabulary, and basic concepts, and it can be thought of as "binary" (i.e., you either know it or you don't). *Understanding* involves comprehension of abstract and transferrable ideas (concepts, principles, and processes) and can be thought of in terms of degrees (i.e., one can have a deep understanding, a surface [incomplete] understanding, and a misunderstanding). A student can know a fact (e.g., the date of the *Brown v. Board of Education of Topeka* Supreme Court ruling) without understanding its meaning.

Another distinction between the terms is realized when we consider assessment. To see if a student "knows" information, teachers can use objective questions with correct answers. However, understanding is best assessed by having students *apply* their learning to a new situation (transfer) and *explain* their reasoning.

About the Authors



Jay McTighe brings a wealth of experience from a rich and varied career in education. He served as director of the Maryland Assessment Consortium, a collaboration of school districts working together to develop and share formative performance assessments. Previously he was involved with school improvement projects at the Maryland State Department of Education, where he helped lead standards-based reforms, including development of performance-based statewide assessments. He directed development of the Instructional Framework, a multimedia database on teaching. Well known for his work with thinking skills, Jay coordinated statewide efforts to develop instructional strategies, curriculum models, and assessment procedures for improving the quality of student thinking. In addition to his work at the state level, Jay has experience at the district level in Prince George's County, Maryland, as a classroom teacher, resource specialist, and program coordinator. He also directed a state residential enrichment program for gifted and talented students.

Jay is an accomplished author, having coauthored 16 books, including the award-winning and best-selling *Understanding by Design* series with Grant Wiggins. His books have been translated into six languages. Jay has also written more than 35 articles and book chapters, and has been published in leading journals, including *Educational Leadership* and *Education Week*.

With an extensive background in professional development, Jay is a regular speaker at national, state, and district conferences and workshops. He has made presentations in 47 states within the United States, in 7 Canadian provinces, and internationally to educators in 37 countries on six continents.

Jay received his undergraduate degree from the College of William and Mary, earned his master's degree from the University of Maryland, and completed postgraduate studies at the Johns Hopkins University. He was selected to participate in the Educational Policy Fellowship Program through the Institute for Educational Leadership in Washington, D.C., and served as a member of the National Assessment Forum, a coalition of education and civil rights organizations advocating reforms in national, state, and local assessment policies and practices. Jay may be reached via e-mail at jay@mctighe-associates.com and on Twitter @jaymctighe. His website is www.jaymactighe.com.

After graduating Phi Beta Kappa as the first woman graduate from Williams College, Judy Willis attended the UCLA School of Medicine, where she was awarded her medical degree. She remained at UCLA and completed a medical residency and neurology residency, including chief residency. She practiced neurology for 15 years before returning to university to obtain her teaching credential and master's of education from the University of California, Santa Barbara. She has taught in elementary and middle school for the past 10 years.

An authority on brain research regarding learning and the brain, Judy writes extensively for professional educational journals and has written a number of books about applying brain and education research to classroom teaching. In 2007 the Association of Educational Publishers honored her as a finalist for the Distinguished Achievement Award for her educational writing.

Judy is a presenter at educational conferences and conducts professional development workshops nationally and internationally about classroom strategies correlated with neuroscience research, and she has been a Distinguished and Featured Presenter at ASCD national conferences. Her books include *Research-Based Strategies to Ignite Student Learning*, *Brain-Friendly Strategies for the Inclusion Classroom*, *Teaching the*

Brain to Read, Inspiring Middle School Minds, How Your Child Learns Best, Learning to Love Math, Unlock Your Teen's Brainpower, and *The Neuroscience of Learning: Principles and Applications for Educators.* Contact Judy through her website at www.RADTeach.com and follow her on Twitter @judywillis.

Related ASCD Resources: Brain and Learning

At the time of publication, the following resources were available (ASCD stock numbers in parentheses). For up-to-date information about ASCD resources, go to www.ascd.org. You can search the complete archives of *Educational Leadership* at www.ascd.org/el.

Print Products

Attack of the Teenage Brain! Understanding and Supporting the Weird and Wonderful Adolescent Learner, by John Medina (#118024)

Engage the Brain: How to Design for Learning That Taps into the Power of Emotion, by Allison Posey (#119015)

Essential Questions: Opening Doors to Student Understanding, by Jay McTighe and Grant Wiggins (#109004)

How to Teach So Students Remember, 2nd ed., by Marilee Sprenger (#118016)

Making the Most of Understanding by Design, by John L. Brown (#103110)

The Power of the Adolescent Brain: Strategies for Teaching Middle and High School Students, by Thomas Armstrong (#116017)

Research-Based Strategies to Ignite Student Learning: Insights from a Neurologist and Classroom Teacher, by Judy Willis (#107006)

Teaching Students to Drive Their Brains: Metacognitive Strategies, Activities, and Lesson Ideas, by Donna Wilson and Marcus Conyers (#117002)

The Understanding by Design Guide to Advanced Concepts in Creating and Reviewing Units by Grant Wiggins and Jay McTighe (#112026)

The Understanding by Design Guide to Creating High-Quality Units, by Grant Wiggins and Jay McTighe (#109107)

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