

Can Neuroscience Help Us Do a Better Job of Teaching Music?

By: [Donald A. Hodges](#)

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Abstract:

We are just at the beginning stages of applying neuroscientific findings to music teaching. A simple model of the learning cycle based on neuroscience is Sense → Integrate → Act (sometimes modified as Act → Sense → Integrate). Additional components can be added to the model, including such concepts as active rather than passive learning, learning activates reward centers, all learning is emotionally colored, plasticity, neural pruning, nature and nurture, critical and optimal periods, the pattern-detecting brain, imitation and the social learning brain, group learning, empathy and social emotions, learning is multisensory, and learning requires memory. When this model and the components are applied to music teaching, they confirm best practices. Innovation pedagogical strategies will be forthcoming when there is a better understanding of the brain and music learning.

Keywords: neuroscience, learning cycle, music teaching

Article:

Neuroscientists have made enormous strides in music brain research in recent years. Understandably, music educators have been eager to utilize this new research in their teaching. For quite awhile, I was in the “we’re-not-quite-ready-to-make-applications-yet” camp because of premature movements such as “music is in the right side of the brain,” the “Mozart effect,” and “music makes you smarter.” However, recently, I have been edging into the “perhaps-we’re-ready-to-begin-making-tentative-applications-to-music-teaching” camp. Although we have a long road ahead of us, there are signs that it may be time to be more direct in applying neuroscientific findings to the music teaching–learning process.

There are many thousands of neuroscience articles in the literature, and this number is growing at a very rapid rate. Many hundreds of neuromusic research articles have also been published (Edwards & Hodges, 2007), and abstracts for 473 of these are available on a fully searchable, online database (Edwards, 2009). In spite of these large numbers, only a relatively few have made applications to the teaching–learning process. For example, the relevance of one book is found in its title: *The Art of Changing the Brain: Enriching the Practice of Teaching by Exploring the Biology of Learning* (Zull, 2002). In this book, the author provides a model of learning based on current understanding of the brain. In “Foundations for a New Science of Learning” (Meltzoff, Kuhl, Movellan, & Sejnowski, 2009), the authors review connections among neuroscience, psychology, education, and learning. The most current and detailed application of neuroscience to music teaching and learning is found in *Neurosciences in Music Pedagogy* (Gruhn & Rauscher, 2007).

The primary business of the human brain is to learn. Stated more simply, the brain is a learning machine. Learning is what it does. This article is about learning, and thus of necessity, it is about the brain. More specifically, it is about music learning *and* music teaching. The purpose of the article is to provide as clear and concise an answer as possible to the question posed in the title. It is not intended to be an overly scholarly article filled with a blizzard of citations and complicated explanations. Rather, the attempt is to present ideas in a more user-friendly fashion for practitioners. The structure of the article is in A-B-A fashion. First, I present a brief overview of a brain-based teaching–learning cycle. Then, I provide more detail on a number of specific

components of the cycle. Finally, I return to the cycle to review it in more detail. I provide musical applications throughout.

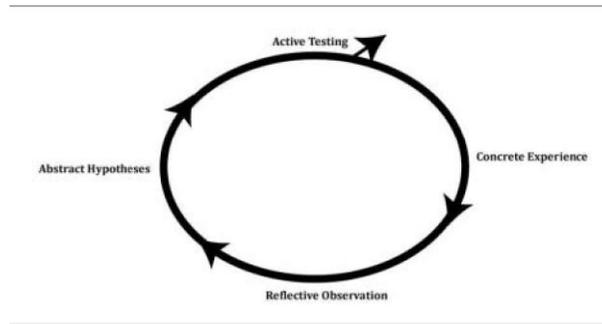


Figure 1. Diagram of the learning cycle.

A Simplified Learning Cycle

Zull (2002) wrote a very concise explanation of learning based on recent advances in neuroscience. The simplest presentation of the learning cycle is Sense → Integrate → Act (p. 15). *Sense* refers to information coming into the brain from the outside through the sensory organs. When we engage in music activities, the raw auditory, visual, and tactile sensory information comes to us in bits and pieces and has little or no meaning. To derive meaning, we must *integrate* the sensory information into a meaningful whole. In turn, our brains transform these meaningful wholes into plans for *action*. In other words, if we hear and see a marching band, the brain organizes incoming sensory information into a meaningful musical experience to which we might respond by tapping our feet or nodding our heads.

Sometimes, however, we learn in this way: Act → Sense → Integrate. As infants, we learned that moving our limbs in certain ways, looking at certain things, or listening to certain sounds created patterns that we could then repeat. Eventually, for example, we learned to reach out and grasp an object. Action, in these cases, initiated learning. Thus, one might ask a group of students to tap on hand drums, and in doing so, the students might discover concepts such as steady beat and accent through their own actions.

Drawing on the work of Kolb (1984), who borrowed heavily from John Dewey, Kurt Lewin, and Jean Piaget, Zull (2002) presented a simplified version of the learning cycle, as shown in Figure 1. From this view, learning begins in concrete experiences. Experiential learning is followed by reflection, formulation of abstract hypotheses, and active testing of these hypotheses. A key contribution of Zull is the recognition that this learning cycle emerges naturally from the way the brain is built. Concrete experiences involve the sensory cortex, reflective observation occurs in the back integrative cortex of the temporal lobes, abstract hypotheses form in the front integrative cortex in the frontal lobes, and active testing engages the motor cortex.

To put this in a musical context, imagine that 6-year-old Mary is attending her first piano recital. This is a concrete experience in which the sensory cortices in Mary's brain register direct auditory and visual information from the outside world. There are also tactile sensations of sitting in an auditorium seat and wearing her best dress-up clothes. Sitting next to her mother, she can smell her mother's familiar perfume, and so on. (In time, she could also generate a musical experience internally from memory.)

Upon reflection, Mary remembers related experiences. Perhaps she has seen someone play the piano on television. Even if she has not heard a piano before, she can relate the sounds to other music that she has heard. The back integrative cortex fashions all the incoming sensory data into a coherent whole. This area of her brain is forming memories, developing relationships and associations, and identifying images, sounds, and so on. Mary connects the sounds she just heard with the fact that her parents told her this was a piano, and she linked the word *piano* and its sounds with her prior experiences of singing and moving to music.

From her reflections, Mary generated abstract hypotheses, such as *that looks like fun* or *I would really like to do that*. The front integrative cortex is responsible for short-term memory, critical thinking, evaluating, and

planning. By manipulating sensory images and using language, Mary formed new mental constructs, made choices, and created plans for future actions.

To test our new ideas, we need to do something and that requires action. Mary talked excitedly to her parents after the piano recital. She went up on stage and tentatively touched the piano keys. She waited in line to speak to the pianist. The motor systems of her brain coordinated and implemented these action plans. Acting upon Mary's abstract hypotheses required walking, talking, pressing the keys, and likely, while waiting in line, squirming, fidgeting, and hopping.

Let us now add the critical role of emotion to the learning cycle. Although I will have more to say in a subsequent section, for now it is important to recognize the essential place emotion has in all learning. In the foregoing vignette, I characterized Mary's reactions to the piano recital as positive. But, what if she were bored? What if she were afraid— afraid that her parents might make her take piano lessons, afraid that it would be too difficult to learn, afraid that she might fail, afraid that she might disappoint her parents, and on and on? Clearly, Mary's emotional reactions would color what she learned from attending the piano recital.

Additional Components

In the following sections, I present a number of additional components that elaborate on the simplistic learning cycle already presented. Sprinkled throughout, you will see teaching suggestions. Many, if not all, of these are old ideas. In fact, experienced and effective teachers are already doing them. So, why are they included? Precisely because we are now better able to confirm the efficacy of these practices through peer-reviewed scientific research. In moving from an opinion-based profession to an evidence-based one, a critical first step is confirming best practices.

Active Rather Than Passive Learning

We learn by doing. An infant exploring her surroundings— reaching, grasping, tasting—demonstrates learning in action. We know she has learned something when we observe her intentionally repeating an action. Later, abstract thinking involves mental movement. We can rotate a figure in our minds, silently recite a poem or hear a song, or imagine moving in space. Brain-imaging studies of musicians in action show activations in motor systems, even in the absence of overt behaviors.

Two types of neuronal connections have implications for music and active learning. First, there are audiomotor networks. This explains why it is so natural to move to music, whether playing or listening. Furthermore, brain systems that link perceptual and motor areas help the two mechanisms to reinforce each other. Looking at images or listening to sounds characteristic of action activates motor systems (Binkofski & Buccino, 2006; Nishitani & Hari, 2002). Second, motor networks link to pleasure centers in the brain. It feels good to move, and it feels good to move to music. The physical activity of making music brings deep pleasure. Listening to music also stimulates movement, both real and imagined. In the first half of the 20th century, jazz groups were called dance bands because the audience was on the floor dancing to the music. In modern jazz concerts, the audience may not be dancing physically, but they are moving mentally. We experience vicarious, mental dancing in many musical experiences.

Teaching suggestion. Engage your students in active learning as much as possible. Talking about African drumming or watching a video about African drumming is not as effective as having students play African drumming patterns. Asking students to sing louder and softer or to demonstrate dynamic contrasts through movement is a more effective teaching strategy than talking about dynamics or asking students to listen for dynamic contrasts in a music-listening lesson. This certainly does not mean that there is no room for talking in a music lesson or for listening lessons. The second component of the learning cycle, reflective observation, does in fact call for students to reflect on their observations.

Learning Activates Reward Centers

We feel good when we learn. That is because the brain has reward centers (see Figure 2).

When we engage in pleasurable and successful learning activities, the brain rewards itself through the release of hormones such as serotonin and dopamine, which are associated with feelings of satisfaction and pleasure (Braun & Bock, 2007). Learning activates areas that mediate rewards and that monitor autonomic and cognitive processes. One explanation for the seemingly insatiable need to learn that children have arises because of an “addiction to learning.” In essence, we give ourselves a drug boost when we learn something successfully. Involvement in musical activities changes levels of serotonin (Evers & Suhr, 2000) and dopamine (Menon & Levitin, 2005) and activates areas on both sides of the brain known to be involved in emotion, reward, and motivation (Blood & Zatorre, 2001; Blood, Zatorre, Bermudez, & Evans, 1999; S. Brown, Martinez, & Parsons, 2004).

Teaching suggestion. Have fun! Unfortunately, *having fun* in school has a bad rap and connotes less-than-serious activity. However, learning in every subject in the curriculum should be fun—fun, that is, in the sense of deep-seated pleasure. Infants learn constantly, and most of it looks like fun, doesn’t it? Somehow, we have created the notion that school learning is serious business, which of course it is in a certain way. The discussion in the next section elaborates on the notion that learning should be fun.

All Learning Is Emotionally Colored

Emotion strongly affects learning. To learn something successfully is to have emotional success. Of course, one can learn through fear or intimidation, but in those circumstances, negative emotions color the learning. Learning that occurs in a positive, affirming environment links the learned material with pleasant feelings so that recall of the information also brings back the positive affect. Music presents possibilities for both positive and negative learning. When students enjoy their musical interactions, they develop positive associations that may persist for life. Likewise, those music-learning situations in which the prevailing feeling is one of stress, fear, or failure may set up lifelong negative associations with music. Likely, most teachers have spoken with parents who, long after their active music making has ceased, radiate with joy or project discomfort when reflecting on their school music experiences.

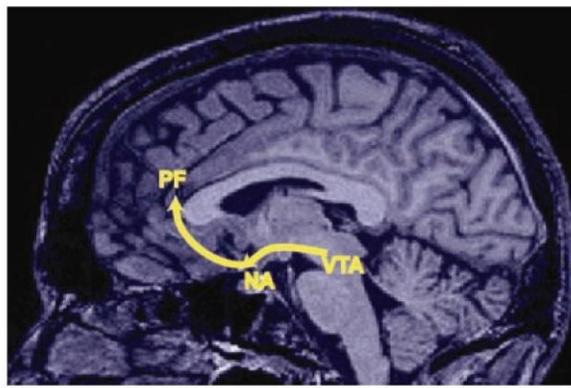


Figure 2. One of the major reward system pathways. Information travels from the ventral tegmental area (VTA) to the nucleus accumbens (NA) to the prefrontal cortex (PF). This is one of several pathways activated by a rewarding stimulus such as learning.

A great model for connecting active learning with positive feelings is found in Csikszentmihalyi’s (1990) concept of flow. Flow occurs when a person is totally engaged in a task and where the level of challenge matches the person’s level of competence. A person so engaged is likely to feel energized, deeply satisfied, fulfilled, and happy. If a task is too difficult, the person feels frustrated; if it is too simple, the person is bored. This may help explain why infants learn so happily. They are intensely absorbed in a challenge that matches their skill level.

Learning information that is personally meaningful to the learner is also critical. Students may not automatically understand why it is important to learn a particular fact or skill. Teachers can facilitate learning by connecting new learning challenges to students’ personal interests. Why should a seventh-grade general music student learn

what a *rondo* is? Creative and successful teachers find ways to connect such a seemingly archaic and irrelevant term to the adolescent's life.

Teaching suggestions. Perhaps the most important concept of this article comes from the combination of active involvement, positive emotions, flow, and meaningful learning. Students are most likely to have powerful learning experiences when they intensely focus on meaningful tasks that match their skill levels. Fortunately, with intentional forethought, music teachers can accomplish this easily. Use a positive teaching approach. You can do this by showing enthusiasm for teaching and pleasure in working with your students. You can also take a genuine interest in what your students think and in the music they spend time with outside class.

Create flow in your students by matching the tasks you give them with their skill levels. This may mean stratifying a group task into multiple levels of difficulty and matching different students to their appropriate levels. This requires that you diagnose what your students already know and are able to do. Engage students in learning situations that are meaningful to them personally. As before, knowing about your students' lives outside of school and how they engage with music will be very helpful.

Plasticity

One of the most influential understandings about the brain that has arisen from recent research is the concept of plasticity. This means that the brain is constantly changing and reorganizing itself (Doidge, 2007). Genetic instructions and life experiences constantly shape the brain. If disease or injury harms the brain, healthy areas may take over for damaged parts via neural rewiring. Similar rewiring takes place in the healthy brain during learning. Anything that is learned results in a physical change in the brain: *Neurons that fire together, wire together*, and *neurons that fire apart, wire apart*. To build on concepts from the previous paragraphs, Zull (2002) recognizes that plasticity depends more on internal signals from the brain indicating importance and emotional satisfaction than from direct sensory signals.

Musicians are wonderful examples of brain plasticity (Münste, Altenmüller, & Jäncke, 2002). There is considerable evidence to support the contention that musicians' brains, because of their training and experiences, are shaped differently from those of people without musical training. Adult musicians typically have enlarged areas in the auditory cortex (primary seat of hearing), corpus callosum (the bundle of fibers that connects the two hemispheres), cerebellum (a part of the brain involved in motor learning, cognitive functioning, and sensory integration), sensorimotor cortex (monitors sensory input and motor output), multisensory integration zones (areas where sensory information from ears, eyes, and so on are integrated into a coherent whole), and increased gray and white matter (gray matter is found in the cortex, and white matter contains connecting pathways within the hemispheres).

Teaching suggestion. Enable students to build on what they can already do. Discovering the natural strengths and weaknesses of each individual student and proceeding from there is difficult and time consuming. In fact, in some situations it may seem impossible. However, to the extent possible, the most efficient way to teach someone is to start with his or her natural gifts and proclivities. The more familiar you are with your students, the better you will be able to accomplish this. Some ways of familiarizing yourself with students are formal, as in diagnostic testing, and others are more informal as you visit with them and provide them with opportunities to share information about themselves and their music.

Neural Pruning

A primary mechanism of plasticity is neural pruning. Early in life we produce many more neural connections than are needed (Berk, 2004). Different parts of the brain grow at different rates and at different times. When neural connections, called synapses, are not utilized, they gradually wither and die; they are pruned away. Synapses reinforced through constant usage grow stronger and become more efficient. Thus, our learning experiences shape the brain. The brain changes found in adult musicians, described in the previous paragraph, are more substantial in those who began intensive musical studies before the age of 7.

At birth, we have the biological capability of learning any language or any musical system from any place on the globe (Meltzoff et al., 2009). However, the more a child learns about his own culture's language, music, and other perceptual inputs, the less sensitive he is to the nuances of other cultures (Pons, Lewkowicz, Soto-Faraco, & Sebastián-Gallés, 2009). In other words, there is a narrowing of perceptual sensitivity as one acquires skills and knowledge embedded in the native culture. Microtonings and poly-rhythms found in non-Western music are often difficult for those who have been exposed to Western music only (Patel, Meltzoff, & Kuhl, 2004). In one experiment, 6-month-old American infants perceived rhythmic alterations that violated the original metrical structure in both Western and non-Western music, but adults did not respond to the non-Western musical violations (Hannon & Trehub, 2005).

Teaching suggestion. In some respects, the two ideas just presented are in conflict. On the one hand, repetition and reinforcement are critical in strengthening the neural connections necessary for successful musicianship. For example, youngsters should perceive and sing the diatonic intervals correctly (i.e., with good posture, proper breath control, good intonation, etc.) numerous times until they become habitual. Yet, the stronger these connections become, the less sensitive the learner becomes to music that follows different rules. One way to think about this dilemma is to think of children who grow up in bilingual homes. Presented with two equally viable languages, each with its own grammatical, syntactic, and prosodic elements, the child simply learns both. The same is true of bimusical homes. Thus, when teachers present children with varied multicultural musical experiences from an early age, they are helping them to develop sensitivities to Western and non-Western musical styles better than if non-Western styles are presented only after Western styles are well ingrained.

Nature and Nurture

Both genetic instructions and learning experiences are important in shaping the brain. Genes prepare us to learn the music of any culture, and although it is not precisely clear what genetic advantages may be conferred on precocious musicians (e.g., Mozart) as compared to those who struggle musically, it is obvious that some individuals are more adept and acquire musical skills more quickly than others. It is equally obvious that no one is simply born an accomplished musician. In fact, it takes approximately 10,000 hours of deliberate practice over at least a decade to develop high-level musical performance skills (Ericsson, Krampe, & Tesch-Römer, 1993).

Teaching suggestion. Working with large numbers of students makes individualization difficult, but to the extent possible, teachers should pay attention to individual differences. Discover what the child can do and build on that. Approaches such as Orff Schulwerk are designed to maximize each student's ability to contribute to the ensemble regardless of specific level of musical ability.

Critical and Optimal Periods

In early childhood, the brain is changing rapidly, and appropriate stimulation is necessary during critical periods of growth. Enriched environments are essential to healthy brain growth, and those children raised in impoverished environments may suffer lifelong physical, emotional, and social deficits (Carey, 2008). Furthermore, appropriate experiences at the right time have a cascading effect leading to long-term benefits (Meltzoff et al., 2009). In terms of learning, the window of opportunity never closes, so it may be more appropriate to speak of optimal or sensitive periods. From a musical standpoint, we learn most efficiently at a younger age. However, it is never too late to gain some measure of musical competence, and adult beginners find much pleasure and gain many benefits from studying music, such as learning to express feelings both alone and in a group.

Teaching suggestion. Early childhood music-learning experiences are important. Children surrounded by a variety of rich, musical experiences throughout childhood develop extensive neural networks that build on inborn music-processing mechanisms. This is not the article to provide a detailed overview of musical development (see Hodges, 2006), but introducing children to the right concepts at the right time makes learning more efficient.

The Pattern-Detecting Brain

The brain is extremely good at pattern detecting. In fact, we have an inborn desire to discover patterns in the environment. Reflection, from the model in Figure 1, is a search for connections and for unity. It is also pleasurable to find patterns embedded in seemingly unstructured sensory information. Consider the extent to which many people find pleasure in puzzles, mazes, word games, Sudoku, Where's Waldo?, and the like. Similar to the concept of flow described previously, very simple puzzles are boring, and exceedingly difficult puzzles are frustrating.

In the brain, neurons form networks and fire in patterns. Music learning, like any other form of learning, creates neural networks, and these can develop very rapidly. In one experiment, adults who had never played the piano showed changes in brain activation patterns within 20 minutes of practicing the piano for the first time (Bangert, 2006). Thus, there are both discoverable patterns in sensory information and developing patterns in neural networks.

In computational learning, children use statistical patterns to determine which perceptual units belong to the culture (Meltzoff et al., 2009). Infants typically hear an enormous amount of music in mother's lullabies, television, radio, and so on. Each time they hear the "Barney Song," they are using frequency distributions to learn that these patterns belong to their native culture. Unconsciously, they learn the rules of melody, harmony, and rhythm that form the patterns of the music they hear. Likewise, as they begin to coo and make their own vocal sounds, they learn which patterns receive affirmation from their caretakers. In time, they will start to sing simple melodies like "Twinkle, Twinkle," and the melodic contours they produce will gradually approximate the correct ones.

Teaching suggestion. Help students find and identify patterns. This can be the recognition of a motive in a listening lesson or recurring finger patterns in a recorder piece. Often, what seems so obvious to us as teachers is not so obvious to young students. Once students begin to recognize musical patterns, things will make more sense to them.

Imitation and the Social Learning Brain

Statistical learning does not occur in isolation. People learn a great deal from their social interactions. In particular, we are avid mimics, beginning as newborns (Meltzoff & Moore, 1989) and extending throughout the life span. We observe and copy the actions of others in our immediate families, peer groups, or social networks. Mirror neurons in the brain fire when we observe or hear someone performing an action; these neurons also fire when we perform the action ourselves (Schlaug, 2006). Thus, the brain has built-in mechanisms that help us learn by imitation.

Learning by imitation speeds up the learning process because the learner does not have to start from scratch. Furthermore, we learn what others have discovered or what the culture has learned over a long period. Finally, we can learn from experts. It is hard for a novice to imagine a finished product unless presented with a model. If the only model a beginning violinist had was her own out-of-tune scratching, she could never move toward the sound and look of an accomplished artist.

Teaching suggestion. Teachers should model the behaviors they want students to emulate. Although this is one of those self-evident statements—don't all teachers model the correct way to hold Orff instrument mallets?—the idea here is a higher standard. It is not enough to model specific behaviors from time to time; rather, teachers should constantly model appropriate behaviors. Students are always observing teachers. It should never be the case of "Do as I say, not as I do"; it should always be "Do as I do."

Group Learning

Another important aspect of social learning is group learning. That is, when children work together on the same project, the group reinforces the individual. Neurologically, we are wired with shared attention mechanisms. Infants, for example, learn to look in the direction of an adult's head turn. At 1 year of age, infants are sensitive

not only to the direction of the head turn but also to the direction and state of adult eye movements (Meltzoff et al., 2009). Eventually, we learn to interpret the behavior and intent of others by using ourselves as a model; we can project our own experience onto others.

Teaching suggestion. Structuring group-learning projects into the curriculum is an effective way to improve learning efficiency. Students learn a lot from each other, and Green (2008) describes two ways this happened in a group-learning project. “One occurred during music-making itself, through listening to each other’s handling of sonic materials and their relationships, watching and imitating each other, without any discussion. The other occurred in between music-making, through group discussion, exchanging ideas, planning, organizing and negotiating” (p. 123). A model for general music group activities might be a professional string quartet. The close-knit feeling of tight ensemble comes from heightened sensitivities to each other’s actions and reactions, and this increased awareness comes from both verbal and nonverbal communication.

Empathy and Social Emotions

Empathy is another important aspect of social learning. As social creatures, we spend a great deal of time in the company of others. Without the wherewithal to understand how others are feeling, cooperative ventures would be exceedingly difficult. Recent brain-imaging work (e.g., Hein & Singer, 2008) reveals specialized neural networks for empathizing with another person; for example, we empathize with another’s pain when we see that that person is hurt. Thus, as we work together, we learn to regulate our emotions.

Music-learning situations are an obvious place to look for the effects of empathy on learning. When children sing, play, or move together, they are sharing a common emotional experience beyond the content of the lesson. This does not mean that every child is feeling the same thing. Rather, the music provides a common emotional core that centers the group. The conductor, soloists, chorus, and orchestra performing Mozart’s requiem share in the expression of that which is embodied in the work, even while undergoing their private experiences. In similar fashion, children can learn to become aware of the feelings of others while engaged in a group effort.

Teaching suggestion. Teachers can facilitate awareness of social emotions when students work both in small groups and in the class as a whole. Teaching children to be musically sensitive and sensitive to the feelings of others go hand-in-hand. Providing a safe and nurturing environment where children are not afraid to express both themselves and the music, and in some cases themselves in and through the music, is a vitally important contribution our profession can make.

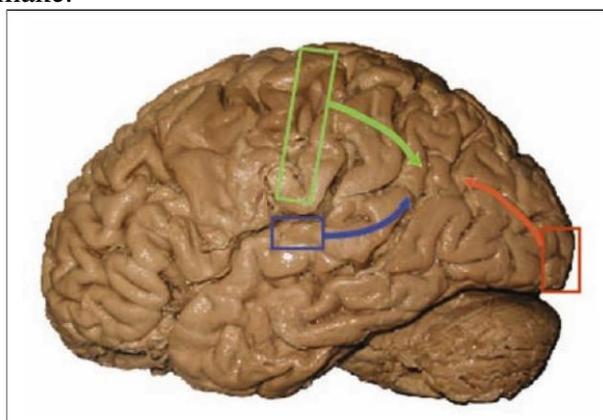


Figure 3. Information from the primary sensory areas of touch (green), hearing (blue), and sight (red) travels to convergence zones in the parietal lobes, where it is integrated into a coherent whole.

Learning is Multisensory

Each sensory organ has a primary zone: For vision it is in the occipital region at the back of the brain, and for hearing it is in the temporal lobes on each side. There are also convergence zones with multisensory inputs. These multimodal integration areas are where information from the different senses are integrated into a

coherent whole. Most, if not all, learning experiences are multisensory, and approaching a new concept from multiple angles strengthens the overall understanding.

In one study, my colleagues and I (Hodges, Hairston, & Burdette, 2005) found that trained conductors were much more accurate and much faster in making minute pitch discriminations than were untrained participants. In addition, conductors were much faster and more accurate in locating tones in space; they were most efficient when auditory information and visual information were combined. The untrained controls did not receive a benefit from multisensory input, and subsequent brain images confirmed that the conductors had increased activity in multisensory convergence zones, whereas the controls did not.

Teaching suggestion. Approach each learning experience from as many different sensory experiences as you can. Children can hear a rhythm, see a rhythm, feel a rhythm tactilely, and move to a rhythm. Not only do multiple inputs strengthen the concept, but they make it easier to access later, as one can retrieve the newly learned material from any of the sensory modes individually.

Learning Requires Memory

Anything learned has to be stored in memory. There are many different ways to talk about memory, but for our purposes, we can identify declarative (knowing *that*) and procedural (knowing *how*) memory. Declarative memory has to do with learning factual information, such as how many beats a quarter note gets in common time. Procedural memory is when we learn a new skill, such as which hand goes on top when you play the recorder. There are at least three stages of memory: acquisition, storage, and retrieval. Acquisition occurs during short-term memory, sometimes referred to as *working memory* (J. Brown, 2004). When we look up an unfamiliar phone number, it cycles around in the electrical circuits of the brain long enough for us to dial the phone and then is promptly forgotten. Information that is important to us is stored permanently in the brain as long-term memory (Deutsch, 2004). Long-term memories are chemically encoded in the brain and are essentially permanent. Sometimes we might have trouble retrieving memories, but the brain is a very powerful storage-retrieval device; it has been estimated that the brain can sort through 50,000 images per second during retrieval (Zull, 2002). As an example of how rapidly the brain can sort through musical memories, my colleagues and I (Wagoner, Hodges, Teachout, & Mace, 2009) asked 347 trained and untrained music listeners to identify the genre of classical, jazz, country, metal, and rap/hip-hop excerpts that were one, one-half, one-fourth, and one-eighth second long. Overall, participants identified 76% of the genres correctly.

Teaching suggestions. There are at least four strategies that cognitive neuroscientists have identified as being useful to committing information to memory:

- Repeat, repeat, repeat: Repetition is critical to move information from short-term to long-term memory.
- Help students make a personal connection. Information that is personally meaningful to the learner is easier to remember.
- Avoid disruptions during short-term rehearsal. Sometimes teachers add too many instructions during too short a time for students to grasp it all. Focus on one thing at a time. Give students some private time to rehearse physically or mentally.
- Help students see patterns and organize information into manageable chunks. Just as we organize long strings of numbers (e.g., phone numbers, social security numbers) into chunks, so should other kinds of information be organized into smaller units. Finding and identifying patterns, such as a repeating melodic motive, helps students commit material to memory.

A Structure for Learning

Many years ago, Bloom and colleagues developed a framework for learning. They talked about the cognitive (what one knows), psychomotor (what one can do), and affective (how one feels) domains (Bloom, 1956;

Krathwohl, Bloom, & Masia, 1964; Simpson, 1966). For example, Tony *knows* the fingering for B on the recorder, he can *play* a B on the recorder, and he *feels* good when he does so. The modern concept of the brain is one of modularity. That is, there are neural networks for cognition, motor behavior, and affect, and parsing learning activities into one of the three domains can be an effective strategy. However, even though the brain is modular, the baseline or default position is one of coherency and integration. The brain desires unity.

Sensory information is delivered via neuronal pathways that are myelinated. This means that they are coated with a fatty sheath that allows for message transmission 100 times faster than unmyelinated pathways (Zull, 2002). Myelination plays a role in cognition (Webb, Monk, & Nelson, 2001), but most of the pathways in the parts of the brain devoted to integration are not myelinated. Thus, the input of data is rapid, but the integration of information into a coherent whole is much slower. We need time to link different pieces of information together and to understand relationships. What we know, what we can do, and how we feel about it can become fragmented unless we take time to create a unified whole.

Teaching suggestion. It may be that students fail to learn successfully sometimes because the rapid influx of information is not counterbalanced by an adequate amount of time for reflection. Teachers can facilitate the search for unity by inserting pauses or creating spaces so that students can take a moment to reflect on what has just transpired. Teachers can guide these momentary respites through careful questioning, they can allow students to talk to one another about what they have just experienced, they can ask students to write in a journal, or they can allow students to introspect in relative privacy. To avoid the chaos of 30 sixth graders sitting in unstructured, free time, these reflective moments could be as brief as 30 seconds, or they could involve overnight contemplation.

Putting It All Together

Let us now return to the learning cycle presented at the outset. In Figure 4, we see the learning cycle overlaid on the brain. Beginning with *concrete experience*, experiences register in the sensory and postsensory part of the brain (parietal lobe), where raw information from the primary sensory zones is integrated into a coherent whole. *Reflective observation* occurs in the back integrative cortex (temporal lobes), where memory formation occurs, language is understood, and objects are identified. *Abstract hypotheses* are developed in the front integrative cortex (frontal lobes), as problems are solved and action plans are created. Finally, *active testing* is carried out by the motor cortex when our hypotheses are put into action.

Although the discussion of the learning cycle began with concrete experiences, notice how in Figure 4 the loop has an added arrow and is continuous, so that motor actions lead to sensory input (i.e., concrete experiences) and so on.

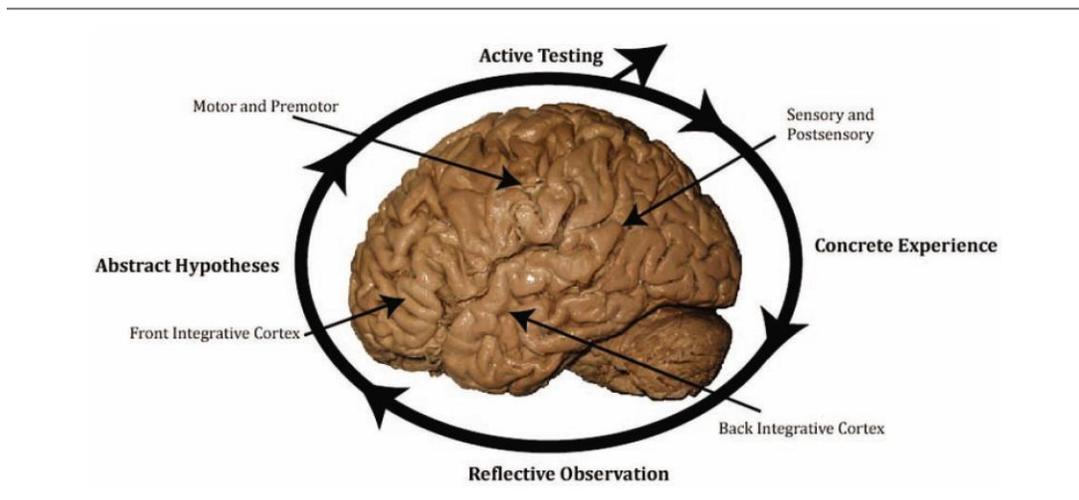


Figure 4. Learning cycle overlaid on the brain showing how the learning cycle matches the structure of the brain.

Table 1. Detail of the Learning Cycle

Learning cycle: Concrete experience

Brain region: Sensory cortex. Primary sensory areas feed into convergence zones located in the parietal lobes.

Activity: Integration of information from hearing, seeing, touching, tasting, and smelling into coherent whole.

Musical example: Students observe their music teacher as she sings an unfamiliar song to them.

Learning cycle: Reflective observation

Brain region: Back integrative cortex; temporal lobes.

Activity: Memory formation, understanding language, identification of objects, faces, and motion.

Musical example: As the teacher repeats the song, students begin to commit portions of the melody and rhythm to memory. They understand the words of the song and the people and events reflected in the lyrics.

Learning cycle: Abstract hypothesis

Brain region: Front integrative cortex; frontal lobes.

Activity: Short-term memory, problem solving, creating plans for action, making judgments and evaluations.

Musical example: As musical phrases resonate in short-term memory, students internally rehearse the music and the words. They begin to prepare themselves to sing the song.

Learning cycle: Active testing

Brain Region: Motor cortex.

Activity: Carries out action plans formulated by the front integrative cortex.

Musical example: Students sing the song, repeating phrases after the teacher's model. After each repetition, their performance more nearly approximates the correct version.

As in the example at the outset, of an infant learning through action (Act → Sense → Integrate), this possibility exists for all learners. The four steps of the learning cycle, along with a musical example, are outlined in Table 1.

To the simple diagram in Figure 4, we must now add the additional components discussed in the article's middle section:

- active rather than passive learning
- learning activates reward centers
- all learning is emotionally colored
- plasticity
- neural pruning
- nature and nurture
- critical and optimal periods
- the pattern-detecting brain
- imitation and the social learning brain
- group learning
- empathy and social emotions
- learning is multisensory learning requires memory
- a structure for learning

Although the learning cycle presented in Figure 4 is fairly simple, keeping all these additional components in mind is much more complicated. Even with this complexity, the teaching suggestions made in this article are

not particularly new or different from what most excellent teachers are already doing. However, our current state of knowledge concerning music learning in the brain is too limited to allow for revolutionary changes in our pedagogy.

Think of our understanding of the teaching–learning process in three stages. In Stage 1, good teachers developed effective strategies without knowledge of what was going on in the brains of their students. Perhaps they used intuition, trial and error, or even behavioral research. This article reflects the beginnings of Stage 2; we can now confirm best practices through neuroscientific research. Stage 3 will come some day when we have a more thorough understanding of how the brain works. Perhaps at that time there will be some innovative strategies that will significantly improve our teaching. In the meantime, for those teachers who are already doing all of the things mentioned in this article—congratulations; your teaching is supported by solid, neuroscientific research. For those who have discovered something different in these pages, perhaps these evidence-based suggestions will be of use to you in the classroom. Finally, all of us should stay abreast of new neuroscientific developments that are being made at an ever-increasing pace. Undoubtedly, many exciting findings will enrich our teaching in years to come.

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