Promoting Brain-Science Literacy in the K-12 Classroom

By Michaela Labriole

Courtesy of the University of California, Davis, Center for Neuroscience

Editor's note: There are many simple ways to incorporate neuroscience into the K-12 classroom, even when the subject is not explicitly part of the curriculum. Here, Michaela Labriole, a science instructor at the New York Hall of Science, provides tangible examples of how teachers can encourage brain-science literacy in students at a time when growing knowledge of the brain is shaping our understanding of how to best foster learning.

Article available online at http://dana.org/news/cerebrum/detail.aspx?id=28896

A complementary article, "The Brain in Science Education: What Should Everyone Learn?" is available online at http://dana.org/news/cerebrum/detail.aspx?id=28900

The fields of neuroscience and education can benefit from one another, in terms of both how we learn and what we teach. A better understanding of the brain and how it functions can improve study skills, promote improvements in neurological health, and encourage brain-based teaching strategies while at the same time boosting general science literacy. Partnerships involving brain science and education have become increasingly strong as the focus on the field of neuroeducation has increased. For example, this year Johns Hopkins University hosted its second neuroeducation summit, and universities and colleges across the country have begun to include elements of neuroscience in their education degree programs.

Despite these strong connections, many K-12 educators find integrating brain science topics into their curriculum a challenge. Often, science standards do not specifically focus on the brain or neuroscience, and many educators find neuroscience content intimidating and do not feel that they have the resources they need to properly teach brain-related content.

Brain-science literacy may seem like a lofty goal, but by using simple tools and hands-on strategies, teachers can develop students who are familiar with basic brain functioning and health, are comfortable with standard neuroscience terminology, and have some understanding of how scientists learn about the brain. By utilizing new technologies and resources and by making connections to other subject areas, such as writing and the arts, educators can promote neuroscience understanding in the classroom, improve student learning, and create brain-science literate students.

Connecting the Brain to Other Subjects

Educators can readily integrate brain-related topics into subjects where standards may not explicitly include neuroscience content. In many states, the elementary school curriculum includes the five senses. An exploration of how sensory organs, such as the eyes and ears, work with the brain serves as an excellent jumping-off point for further discussion of brain science, especially for young learners who enter the classroom with some awareness of how the senses help them relate to the world around them.

One very easy way of bringing the brain into a lesson on the senses involves optical illusions. Students find classic illusions, such as the Old Woman or the Young Woman, and activities like thaumatropes enthralling. When we look at an object, we see it as a single item, but

our brain processes visual information based on submodalities like shape, size, color, and movement. This processing occurs in parallel, and involves billions of neurons. Certain cells respond to specific stimuli such as color or orientation, and all of the information comes together to form the bigger picture of what we see. If the human brain had to process all of the sensory stimuli a person encounters, the information would become overwhelming, so the brain uses shortcuts. In the Old Woman or the Young Woman illusion, the shortcut involves making the stimuli into a face, because that is what the stimuli most closely resemble, although the image is ambiguous. Based on our individual past experiences, it is easier for the brain to see either a young woman or an old woman.

Given the complexity of this system, it is no surprise that scientists are still learning about sensory processing. Examples like illusions provide an opportunity to make the simple point that visual processing is never complete and the brain works hard to make sense of perceptual information. Visual and auditory illusions help scientists learn about normal sensory processing; just mentioning that the brain is involved in the use of our senses helps open students' eyes to how the brain works.

In much the same way that the brain processes visual or auditory information, it must also process scent, or olfactory, information. Generally speaking, odorants activate specific sensory receptors. Based on the pattern of activation, the brain can identify the substances and provide information about where we might have encountered similar odorants in the past. This strong connection between memory and the senses can be used in language-arts classrooms. For instance, a teacher might ask students to smell an object that evokes a strong emotional memory, and then write down this memory in the form of a poem. The teacher would briefly explain the link between the amygdala, memory, and our sense of smell while encouraging creativity and writing skills. Research has demonstrated that the amygdala, a structure found in the temporal lobe, plays a significant role in emotion and it is also thought to be involved with some types of memory. Interestingly, the amygdala has many synaptic connections with the structures responsible for processing olfactory information. This explains why when some of us smell apple pie, for instance, we not only remember Thanksgiving with our families, but also actually feel calm and happy. With younger children, using words like amygdala or visual processing may not be suitable, but by using neuroscience-related activities and explaining them at a level

appropriate for the age group, educators can lay the groundwork for future neuroscience learning.

Many famous neuroscientists have focused their work on subjects such as how the brain interprets artistic material like music or literature. For instance, in *Musicophilia*, renowned neurologist Oliver Sacks explores the power of music through the lens of neuroscience. Books and articles that blend science with literature illustrate the connection between the brain and other areas of study, and teachers can also use them as assigned readings in the classroom. Books like Sacks' *The Man Who Mistook His Wife for a Hat: And Other Clinical Tales* or V.S. Ramachandran and Sandra Blakeslee's *Phantoms in the Brain: Probing the Mysteries of the Human Mind* include chapters that can be tailored to different subject areas and are short enough to maintain student interest. Most educational content areas include literacy as a major component, and utilizing books like these, either as homework or as in-class readings, ensures that the standards are being met while at the same time engaging student interest and highlighting neuroscience content. Instead of assigning reading on the history of music or the biography of a famous musician, for instance, educators can ask students to read a chapter on how the brain understands music.

Many of the famous writers, artists, and musicians included in classroom curricula suffered from mental illnesses. Students are drawn to these personal struggles, and by addressing them in depth, educators can create a discussion of different types of mental illnesses, how scientists treat these illnesses, and why mental illness and creativity seem to have some sort of connection.[1]

Teachers can utilize the strong connection between neuroscience and other subject areas to boost scientific literacy. Some students find certain topics in neuroscience, such as neurotransmitters, very abstract. By tying in other subject areas, especially through hands-on techniques, educators can improve student understanding. They can easily turn neurons into an art project by using pipe cleaners and other materials to model different structures, or into an exercise in physical education by asking students to use their arms as axons and dendrites to pass a ball that serves as a neurotransmitter.

Making connections to popular activities like sports and films can also spark a student's interest in neuroscience. Students often ask, "When am I ever going to use this?" Using

examples relevant to students' lives makes the integration of neuroscience content more meaningful. An educator could ask students what parts of the brain allow them to kick a soccer ball, or with the increase in popularity of 3D movies, could have students research how the brain allows us to see in three dimensions.

Students routinely learn that they must wear bicycle helmets, stay away from drugs, and eat properly, but they are not always taught how helmets, drugs, and nutrition can affect brain function. By making clearer connections to material already being taught, educators can increase students' understanding of the brain. For older students, presenting brain scans from people who have used drugs or suffered brain trauma make the brain-health connection more evident. For younger students, creating brain hats can help illustrate both the importance of protecting the brain and fundamental ideas such as cortical localization of function. This basic concept states that while some structures may have roles that overlap, and some structures may do multiple jobs, in general there is a division of labor in the brain. Understanding this basic idea primes students for deeper exploration of neuroanatomy. There are many brain-hat templates available on the Internet; educators can create paper hats that students label with the various parts or functions of the brain. For young learners, one could simply put a picture of an eye in the back of the brain hat rather than use words like occipital lobe or visual-processing center. By having students label the hats this way and then wear them, an educator can ask students to consider what would happen if they fell off their bikes and hit their heads in different areas.

The Brain and Technology

In addition to creating connections with other subject areas and making use of topics of interest to students, educators can use technology to bring neuroscience into the classroom. Many outstanding Web sites and software programs bring neuroanatomy into the classroom without the use of scalpels or probes. For example, Genes to Cognition Online[2] allows students to explore topics in neuroscience in a dynamic and self-directed way, while links on the Dana Foundation's Brainy Kids[3] site let students observe dissections or digitally probe a brain. There are also programs and Web sites that allow students to hear the firing of actual action potentials or manipulate brain scans (see sidebar). Rather than lecturing, educators can use these tools to allow for hands-on exploration of the brain using active teaching techniques.

Several similarities exist between the brain and a computer, and an increasing number of technology teachers use brain/computer comparisons to liven up their curricula. Nerves can be compared to wires since, to some extent, both carry information in the form of electrical impulses. Our sensory receptor cells share certain similarities with the sensors in computers, but unlike a computer, the brain communicates in part by using chemical neurotransmitters. By prompting students to find similarities and differences between technology and the brain, educators can give students the opportunity to learn more about both topics. Videos of classic neuroscience studies are available online and lend themselves to use in the classroom. By accessing and watching the videos, children not only practice computer skills and gain a better understanding of how a computer functions, but they also learn about the brain and how we study it.

While most students think brain-science research can only take place in a lab using brain-imaging technology, neuroscientists recruit participants and carry out valid research using Web sites that classrooms can access. Students can take part in brain-science studies and get a better understanding of what exactly a neuroscientist does. One example of a site like this is Test My Brain. Students can participate in actual experiments related to topics such as facial recognition or spatial memory.[4] Experimental design is part of middle- and high-school curricula, and real brain-science studies naturally lend themselves to a discussion of how scientists create experiments. This participation can spark students' interest in neuroscience and encourage them to learn more.

All of these resources make it easier than ever before to help educators become comfortable with brain-related content. They allow users to access real research and ask questions of the researchers. Often, a separation between scientists and the lay public makes it difficult to implement strategies based on research. In a recent article on neuroeducation, Hardiman and Denckla assert, "One source of this apparent disconnect is the human tendency to view research findings through the lens of a specific discipline."[5] Now, however, there are sites that interpret research into lay terms. By making these resources available online, educators can become more comfortable with content and stay up-to-date with breakthroughs in brain science. In turn, educators can convey to researchers their needs and interests.

The Brain and Learning

Educators can make stronger connections between neuroscience and learning in terms of study skills and classroom practices. Many educators use techniques based on neuroscience research without even knowing it. These techniques include strategies for remembering content, such as devising mnemonics or chunking items. Chunking aids in memory because our brains organize items into networks for more efficient storage and retrieval. Our memory is limited, and by chunking items, or grouping them, the brain is essentially creating a smaller number of items that contain more information. When reciting a phone number, for example, we usually speak the numbers in groups, saying 555-555-5555, not 5555555555. In effect, our brains store three multiple-digit numbers as opposed to ten single-digit numbers. This grouping leads to easier storage and retrieval. By making clear how these techniques help us remember, teachers can use everyday classroom occurrences to create brain-science-literate students. Additionally, students can become more aware of their study habits and can adjust accordingly.

School administrators and others encourage educators to create lesson plans that include creative, hands-on activities that present content in many different modalities and make use of the brain's plasticity to create connections. Students' brains can change and adapt based on experiences and stimuli the students encounter in their environments. The brain continually reorganizes neural pathways, and repeated experiences, such as practice, can increase or create synaptic connections. Additionally, some brains respond to different types of stimuli better than they do to other types. By using different modalities and reinforcing information, educators can create learning environments that take advantage of the brain's amazing changeability as well as the differences in student brains. The educator can explain to the class why he or she uses both hands-on learning and visual or auditory repetition of the subject, and again use normal classroom practices as teachable moments.

Attention is always a subject of interest in the classroom. In a study available from the Visual Cognition Lab at the University of Illinois, researchers instructed participants to count the number of times a ball got passed among a group of players.[6] Many times, the participants focused so intently on the ball that they did not notice a person in a gorilla suit pass through the group. By using an example like this, educators can introduce students to a classic neuroscience

study while making the class more aware of the idea that attention takes work, and we often miss things right in front of us.

Discussing common signs of mental fatigue can help students learn when to take breaks, which ultimately results in more studying. The tip-of-the-tongue phenomenon provides one example of the importance of taking breaks. When the phenomenon occurs, we struggle to find a word but have the overwhelming feeling that we will retrieve it at any second. In reality, if we stop trying to think of the word and let our conscious brains rest, we have a better chance of retrieving the thought. Even though we are not actively trying to remember the word, the brain is able to keep working on the problem. Rather than taking a break, however, most people struggle to think of the word or phrase immediately. By using relevant examples like this universal phenomenon, educators can take the opportunity to explain basic neuroscience principles, such as brain fatigue, to further student awareness of brain function and at the same time improve study habits.

Educators can incorporate readings from scientific publications into their lesson plans to encourage students to think about how they learn. Students have a natural curiosity about the brain and are drawn to articles that discuss both normal and abnormal brain functioning. By taking advantage of this innate interest, educators can introduce students at the high-school level to the skill of reading a scientific paper while at the same time including neuroscience content.

What's Next?

As the field of neuroscience continues to grow, so does the link between brain science and education. Educators may already use or want to use many of the strategies suggested in this article, but find themselves restricted by a lack of resources or brain-related standards in their curricula, or by their unfamiliarity with brain-science content. But by taking small steps and making stronger connections between neuroscience and what they already teach, educators can make great strides in increasing their students' understanding of how we learn and perform. New resources and technologies make accessing and understanding brain-science content easier than ever before, and this ease can translate into classroom practice.

There are now programs that match researchers with educators to disseminate information. As part of a 2009 summer institute, Harvard University's Mind, Brain, and

Education program brought together neuroscience practitioners and classroom educators. Kurt Fischer, the program's director, states, "Educators have a strong desire to make a connection between biology and scientific findings. To build appropriate connections with biology, we educators must make sure that research is conducted responsibly and that we are training people to truly understand the connection between brain science and the world of education."[7] In addition to an increased dialogue among researchers and educators, we may start to see standards that include more brain-science components.

As we learn more about how the brain functions and malfunctions, it will become increasingly important for students to have a mastery of brain science. As our scientific knowledge base increases, brain science will likely take its rightful place alongside the other sciences in the classroom as an essential component of the curriculum. Therefore, educators must take an active role in creating students fluent in the language and practices of neuroscience.

Sidebars

Online Resources

Genes to Cognition Online: Students can explore topics in neuroscience in a dynamic and fluid way.

Brainy Kids: This Dana Foundation Web site provides resources and activities ranging from virtual dissections to interactive games.

Test My Brain: Researchers recruit participants via this Web site, allowing students to participate in and learn about actual neuroscience studies.

University of Illinois Visual Cognition Lab: This site provides videos of classic neuroscience studies on topics like inattentional blindness.

Brain Hat Template: Educators can use this hat to aid students in learning the different parts and functions of the brain.

Neuroscience for Kids: This site has many great resources, including recordings of action potentials.

The Whole Brain Atlas: This site associated with Harvard Medical allows students to manipulate brain scans.

The Scientist and Scientific American: These magazines have interesting articles on current topics in neuroscience for classroom use with older students.

Classroom Activities and Exercises

Language Arts
- Scent poems
- Readings from science magazines and journals

Arts and Music
- Pipe cleaner neurons
- Optical illusions
- Readings connecting the arts and neuroscience

Health, Nutrition, and Fitness
- Brain hats
- Brain food activity
- Kinesthetic models of synaptic transmission
- Brain Dissection

Technology
- Videos of classic neuroscience studies
- Models comparing computers and the brain
- Virtual dissection web-exploration
- Online neuroscience studies

Michaela Labriole has a B.S. in cognitive neuroscience from Brown University, and an M.S. in environmental science from the SUNY College of Environmental Science and Forestry. She is a science instructor in the professional development department at the New York Hall of Science. She received a 2010 SIGOL Online Learning Highly Commended Award from the International Society for Technology in Education (ISTE) for her work on the Dana Brain Science Educator Series hosted by the New York Hall of Science.

References

1. D.I. Simeonova, K.D. Chang, C.Strong, and T.A. Ketter, "Creativity in Familial Bipolar Disorder," *Journal of Psychiatric Research* 39, no. 6 (2005): 623-631.

2. Genes to Cognition Online, http://www.g2conline.org (accessed June 2010).

3. Brainy Kids, http://www.dana.org/kids (accessed June 2010).

4. Test My Brain, http://www.testybrain.org (accessed June 2010).

5. M. Hardiman and M. B. Denckla, "The Science of Education: Informing Teaching and Learning through the Brain Sciences," *Cerebrum* (2009), http://www.dana.org/news/cerebrum/detail.aspx?id=23738.

6. D. J. Simons and C. F. Chabris, "Gorillas in Our Midst: Sustained Inattentional Blindness for Dynamic Events," *Perception* 28 (1999): 1059-1074.

7. K. Fischer, "The Myths and Promises of the Learning Brain," *Ed. Magazine* (Spring 2004).