A Fresh Look at Brain-Based Education

It has been more than 20 years since it was first suggested that there could be connections between brain function and educational practice. In the face of all the evidence that has now accumulated to support this notion, Mr. Jensen advocates that educators take full advantage of the relevant knowledge from a variety of scientific disciplines.

By Eric P. Jensen

TEN YEARS ago John Bruer, executive administrator of the James S. McDonnell Foundation, began a series of articles critical of brain-based education. They included "Education and the Brain: A Bridge Too Far" (1997), "In Search of . . . Brain-Based Education" (1999), and, most recently, "On the Implications of Neuroscience Research for Science Teaching and Learning: Are There Any?" (2006).[1] Bruer argued that educators should ignore neuroscience and focus on what psychologists and cognitive scientists have already discovered about teaching and learning. His message to educators was "hands off the brain research," and he predicted it would be 25 years before we would see practical classroom applications of the new brain research. Bruer linked brain-based education with tabloid mythology by announcing that, if brain-based education is true, then "the pyramids were built by aliens -- to house Elvis."[2]

Because of Bruer's and others' critiques, many educators decided that they were simply not capable of understanding how our brain works. Other educators may have decided that neuroscience has nothing to offer and that the prudent path would be simply to ignore the brain research for now and follow the yellow brick road to No Child Left Behind. Maybe some went so far as to say, "What's the brain got to do with learning?" But brain-based education has withstood the test of time, and an accumulating body of empirical and experiential evidence confirms the validity of the new model.

Many educationally significant, even profound, brain-based discoveries have occurred in recent years, such as that of neurogenesis, the production of new neurons in the human brain. It is highly likely that these discoveries would have been ignored if the education profession hadn't been primed, alerted, and actively monitoring cognitive neuroscience research and contemplating its implications and applications. Here, I wish to discuss how understanding the brain and the complementary research can have practical educational applications. I will make a case that narrowing the discussion to only neurobiology (and excluding other brain-related sciences) diminishes the opportunity for all of us to learn about how we learn and about better ways to teach. In addition, I will show how the synergy of biology, cognitive science, and education can support better education with direct application to schools.

In 1983 a new model was introduced that established connections between brain function and educational practice. In a groundbreaking book, *Human Brain, Human Learning*, Leslie Hart argued, among other things, that cognitive processes were significantly impaired by classroom threat.[3] While not an earthshaking conclusion, the gauntlet was thrown down, as if to say, "If we ignore how the student brain works, we will risk student success." Many have tied brain function to new models either of thinking or of classroom pedagogy.[4] A field has emerged known as "brain-based" education, and it has now been well over 20 years since this "connect the dots" approach began. In a nutshell, brain-based education says, "Everything we do uses our brain; let's learn more about it and apply that knowledge."

A discussion of this topic could fill books, but the focus here will be on two key issues. First, how can we define the terms, scope, and role of brain research in education? That is, what are the disciplines and relevant issues that should concern educators? These issues are multidisciplinary. Evidence will show that "brain-based" is not a loner's fantasy or narrow-field model; it's a significant educational paradigm of the 21st century. Second, what is the evidence, if any, that brain research can actually help educators do our job better? Is there now credibility to this burgeoning field? What issues have critics raised? Can the brain-based advocates respond to the critics in an empirical way?

Defining Brain-Based Education

Let's start this discussion with a simple but essential premise: the brain is intimately involved in and connected with everything educators and students do at school. Any disconnect is a recipe for frustration and potential disaster. Brain-based education is best understood in three words: engagement, strategies, and principles. Brain-based education is the "engagement of strategies based on principles derived from an understanding of the brain." Notice this definition does not say, "based on strategies given to us by neuroscientists." That's not appropriate. Notice it does not say, "based on strategies exclusively from neuroscience and no other discipline." The question is, Are the approaches and strategies based on solid research from brain-related disciplines, or are they based on myths, a well-meaning mentor teacher, or "junk science"? We would expect an educator to be able to support the use of a particular classroom strategy with scientific reasoning or studies.

Each educator ought to be professional enough to say, "Here's *why* I do what I do." I would ask: Is the person actually *engaged in using* what he or she knows, or does he or she simply have knowledge about it without actually using it? Are teachers using strategies based on the science of how our brain works? Brain-based education is about the professionalism of knowing why one strategy is used instead of another. The science is based on what we know about how our brain works. It's the professionalism to be research-based in one's practices. Keep in mind that if you don't know why you do what you do, it's less purposeful and less professional. It is probably your collected, refined wisdom. Nothing wrong with that, but some "collected, refined wisdom" has led to some bad teaching, too.

While I have, for years, advocated "brain-based" education, I never have promoted it as the "exclusive" discipline for schools to consider. That's narrow-minded. On the other hand, the brain is involved in everything we do at school. To ignore it would be irresponsible. Thus an appropriate question is, Where exactly is this research coming from?

The Broader Scope of Brain-Based Education

Brain-based education has evolved over the years. Initially it seemed focused on establishing a vocabulary with which to understand the new knowledge. As a result, many of us heard for the first time about axons, dendrites, serotonin, dopamine, the hippocampus, and the amygdala. That was the "first generation" of brain basics, the generation that introduced a working platform for today's generation. There was no harm in doing that, but knowing a few words from a neuroscience textbook certainly doesn't make anyone a better teacher. Times have changed. The brain-based movement has moved on from its infancy of new words and pretty brain scans.

Today's knowledge base comes from a rapidly emerging set of brain-related disciplines. It isn't published in just highly regarded journals such as *Nature*, *Science*, and the *Journal of Neuroscience*. Every people-related discipline takes account of the brain. As an example, psychiatry is now guided by the journal *Biological Psychiatry*, and nutrition is better understood by reading the journal *Nutritional Neuroscience*. Sociology is guided by the journal *Social Neuroscience*. Some critics assert that sociology, physical fitness, psychiatry, nutrition, psychology, and cognitive science are not "brain-based." That's absurd, because if you remove the brain's role from any of those disciplines, there would be no discipline. There is no separation of brain, mind, body, feelings, social contacts, or their respective environments. That assertion is old-school, "turf-based," and outdated. If the research involves the brain in any way, it is "brain-based." The brain is involved in everything we do.

The current model of brain-based education is highly interdisciplinary. Antonio Damasio, the Van Allen Distinguished Professor and head of the department of neurology at the University of Iowa Medical Center and an adjunct professor at the Salk Institute in La Jolla, California, says, "The relation between brain systems and complex cognition and behavior, can only be explained satisfactorily by *a comprehensive blend of theories* and facts related to *all the levels of organization* of the nervous system, from molecules, and cells and circuits, to large-scale systems and physical and social environments. . . . We must beware of explanations that rely on data from one single level, whatever the level may be."[5] Any single discipline, even cognitive neuroscience, should be buttressed by other disciplines. While earlier writings did not reflect it, today we know that brain-based learning cannot be founded on neuroscience; we have learned that it requires a multidisciplinary approach.

The Brain Is Our Common Denominator

Today, many of the school- and learning-related disciplines are looking to the brain for answers. There's no separating the role of the brain and the influence of classroom groupings, lunchroom foods, school architecture, mandated curricula, and state assessments. Each of them affects the brain, and our brain affects each of them. Schools, assessment, environments, and instruction are not bound by one discipline, such as cognitive science, but by multiple disciplines. In short, schools work to the degree that the brains in the schools are working well. When there's a mismatch between the brain and the environment, something at a school will suffer.

Schools present countless opportunities to affect students' brains. Such issues as stress, exercise, nutrition, and social conditions are all relevant, brain-based issues that affect cognition, attention, classroom discipline, attendance, and memory. Our new understanding is that every school day changes the student's brain in some way. Once we make those connections, we can make choices in how we prioritize policies and strategies. Here are some of the powerful connections for educators to make.

1. The human brain can and does grow new neurons. Many survive and become functional. We now know that new neurons are highly correlated with memory, mood, and learning. Of interest to educators is that this process can be regulated by our everyday behaviors. Specifically, it can be enhanced by exercise, lower levels of stress, and good nutrition. Schools can and should influence these variables. This discovery came straight from neuroscientists Gerd Kempermann and Fred Gage.[6]

2. Social conditions influence our brain in ways we didn't know before. The discovery of mirror neurons by Giacomo Rizzolatti and his colleagues at the University of Parma in Italy suggests a vehicle for an imitative reciprocity in our brain.[7] This emerging discipline is explored in *Social Neuroscience*, a new academic journal exploring how social conditions affect the brain. School behaviors are highly social experiences, which become encoded through our sense of reward, acceptance, pain, pleasure, coherence, affinity, and stress. This understanding suggests that we be more active in managing the social environment of students, because students are more affected by it than we thought. It may unlock clues to those with autism, since their mirror neurons are inactive. This discovery suggests that schools should not rely on random social grouping and should work to strengthen prosocial conditions.

3. The ability of the brain to rewire and remap itself by means of neuroplasticity is profound. The new *Journal of Neuroplasticity* explores these and related issues. Schools can influence this process through skill-building, reading, meditation, the arts, career and technical education, and thinking skills that build student success. Neuroscientists Michael Merzenich and Paula Tallal verified that when the correct skill-building protocol is used, educators can make positive and significant changes in our brains in a short time.[8] Without understanding the "rules for how our brain changes," educators can waste time and money, and students will fall through the cracks.

4. Chronic stress is a very real issue at schools for both staff and students. Homeostasis is no longer a guaranteed "set point." The discovery championed by neuroscientist Bruce McEwen is that a revised metabolic state called "allostasis" is an adjusted new baseline for stress that is evident in the brains of those with anxiety and stress disorders.[9] These pathogenic allostatic stress loads are becoming increasingly common and have serious health, learning, and behavior risks. This issue affects attendance, memory, social skills, and cognition. Acute and chronic stress is explored in *The International Journal of Stress Management*, *The Journal of Anxiety*, *The Journal of Traumatic Stress*, and *Stress*.

5. The old-school view was that either environment or genes decided the outcomes for a student. We now know that there's a third option: gene expression. This is the capacity of our genes to respond to chronic or acute environmental input. This new understanding highlights a new vehicle for change in our students. Neuroscientists Bruce Lipton and Ernest Rossi have written about how our everyday behaviors can influence gene expression.[10] New journals called *Gene Expression*, *Gene Expression Patterns*, and *Nature Genetics* explore the mechanisms for epigenetic (outside of genes) changes. Evidence suggests that gene expression can be regulated by what we do at schools and that this can enhance or harm long-term change prospects.

6. Good nutrition is about far more than avoiding obesity. The journals *Nutritional Neuroscience* and the *European Journal of Clinical Nutrition* explore the effects on our

brain of what we eat. The effects on cognition, memory, attention, stress, and even intelligence are now emerging. Schools that pay attention to nutrition and cognition (not just obesity) will probably support better student achievement.

7. The role of the arts in schools continues to come under great scrutiny. Five neuroscience departments and universities (University of Oregon, Harvard University, University of Michigan, Dartmouth College, and Stanford University) currently have projects studying the impact of the arts on the brain. *Arts and Neuroscience* is a new journal that tracks the connections being made by researchers. This is a serious topic for neuroscience, and it should be for educators also. Issues being explored are whether the arts have transfer value and the possibility of developmentally sensitive periods for the arts.

8. The current high-stakes testing environment means some educators are eliminating recess, play, or physical education from the daily agendas. The value of exercise to the brain was highlighted in a recent cover story in *Newsweek*. More important, there are many studies examining this connection in *The Journal of Exercise*, *Pediatric Exercise Science*, and *The Journal of Exercise Physiology Online*. The weight of the evidence is that exercise is strongly correlated with increased brain mass, better cognition, mood regulation, and new cell production. This information was unknown a generation ago.

9. Stunning strides have been made in the rehabilitation of brain-based disorders, including fetal alcohol syndrome, autism, retardation, strokes, and spinal cord injury. It is now clear that aggressive behavioral therapies, new drugs, and stem cell implantation can be used to influence, regulate, and repair brain-based disorders. *The Journal of Rehabilitation* and *The International Journal of Rehabilitation Research* showcase innovations suggesting that special education students may be able to improve far more than we once thought.

10. The discovery that environments alter our brains is profound. This research goes back decades to the early work of the first trailblazing biological psychologists: Mark Rosenzweig at the University of California, Berkeley, and Bill Greenough at the University of Illinois, Urbana-Champaign. In fact, a new collaboration has emerged between neuroscientists and architects. "The mission of the Academy of Neuroscience for Architecture" according to the group's website, "is to promote and advance knowledge that links neuroscience research to a growing understanding of human responses to the built environment." This is highly relevant for administrators and policy makers who are responsible for school building designs.

Since our brain is involved in everything we do, the next question is, Is our brain fixed, or is it malleable? Is our brain shaped by experience? An overwhelming body of evidence shows our brain is altered by everyday experiences, such as learning to read, learning vocabulary, studying for tests, or learning to play a musical instrument.[11] Studies confirm the success of software programs that use the rules of brain plasticity to retrain the visual and auditory systems to improve attention, hearing, and reading.[12] Therefore, it stands to reason that altering our experiences will alter our brain. This is a simple but profound syllogism: our brain is involved in all we do, our brain changes from experience, therefore our experiences at school will change our brain in some way. Instead of narrowing the discussion about brain research in education to dendrites and axons, a contemporary discussion would include a wider array of topics. Brain-based education says that we use evidence from all disciplines to enhance the brains of our students. The brain is involved with everything we do at school, and educators who understand take this fact into consideration in the decision-making process.

Brain-Based Education in Action

An essential understanding about brain-based education is that most neuroscientists don't teach and most teachers don't do research. It's unrealistic to expect neuroscientists to reveal which classroom strategies will work best. That's not appropriate for neuroscientists, and most don't do that. Many critics could cite this as a weakness, but it's not. Neuroscience and many related disciplines (e.g., genetics, chemistry, endocrinology) are what we refer to as basic science. The work is done in labs, and the science is more likely to provide general guidelines or to suggest future directions for research. Of all the neuroscience studies published each month, only a small fraction have potential relevance for education.

Clinical and cognitive research are mid-level research domains. In clinical and cognitive studies, humans are more likely (but not always) to be subjects in controlled conditions. Finally, applied research is typically done "in context," such as in a school. Each domain has different advantages and disadvantages. Critics of using neuroscience for educational decision making assert that the leap is too great from basic science to the classroom. I agree with that assertion; education must be multidisciplinary. I never have proposed, and never will, that schools be run solely based on neuroscience. But to ignore the research is equally irresponsible. Let's use a typical example that is "pushed" by the brain-based advocates, such as myself.

Physical Education Is Supported by Brain Research

While many schools are reducing physical activity because of time constraints created by the No Child Left Behind Act, a large group of studies has linked physical activity with cognition. The researchers have come at the topic from a wide range of disciplines. Some are cognitive scientists or exercise physiologists. Other advocates are educational psychologists, neurobiologists, or physical educators. The applied research, which compares academic achievement between schools where kids have physical activity and those where they don't, also supports the hypothesis.[13] Like six blind men describing different parts of an elephant, they are all addressing the same issue but from different viewpoints. They are all correct in revealing how physical experience affects the brain. Each of their viewpoints is valid, yet incomplete by itself.

Now let's add the neuroscience perspective. It reveals information that other disciplines cannot reveal. For example, we know that exercise is highly correlated with neurogenesis, the production of new brain cells.[14] We know exercise upregulates a critical compound called brain-derived neurotrophic factor.[15] We also know that neurogenesis is correlated with improved learning and memory.[16] In addition, neurogenesis appears to be inversely correlated with depression.[17] While careless policy makers reduce physical activity, many administrators are unaware of the inverse correlations with adolescent depression. It's scary, but each year one in six teens makes plans for suicide, and roughly one in 12 teens attempts suicide.[18] Yet there is considerable evidence that running can serve as an antidepressant.[19] These data would suggest that educators might want to foster neurogenesis with physical education. But educators and policy makers can't see the new brain cells being produced. That's one reason to know the science, to show everyday, easy-to-influence school factors that regulate neurogenesis and, subsequently, cognition, memory, and mood. Those are the kinds of connections that should be made. They are not careless; there's little downside risk and much to gain.

To verify this hypothesis, we check the applied research to find out what happens to student achievement in schools where physical activity is either added or strengthened. The research in this arena is mixed because there are no broadly established protocols. For example, there are questions about when and how much physical activity is needed, what kind, and whether it should be voluntary. These are not trivial issues; our brains respond better to meaningful activities with appropriate duration and intensity over enough time to make changes. Voluntary activity is important, too. If the activity is forced, it is likely to generate distress, not cognitive or health benefits. But when the studies are well designed, there is support for physical activity in schools. So the interdisciplinary promotion of physical activity as a "brain-compatible" activity is well founded. Again, we see the brain involved in everything we do at school.

Thus a brain-based perspective strengthens the case for maintaining or enhancing physical activities in school. Was all of the research from the realm of neuroscience? No, it was from a wide range of sources. But every source still comes back to our brain. Is our brain enhanced or impaired by physical activity? The answer is clear: brains benefit from physical activity in many ways. The brain is involved in everything we do at school. How you measure it (basic science, cognitive science, psychology, applied research, sports research, neurochemistry, etc.) will still require the brain. While critics are trying to narrow the discussion of brain-based education to a "turf war" over where the science comes from, the bigger picture is simple: the brain is involved in everything we do at school. To ignore it is irresponsible.

Is There Evidence That Brain Research Can Help Educators?

This question is highly relevant for all educators. To repeat our definition, brain-based teaching is the active engagement of practical strategies based on principles derived from brain-related sciences. All teachers use strategies; the difference here is that you're using strategies based on real science, not rumor or mythology. But the strategies ought to be generated by verifiable, established principles. An example of a principle would be "Brains change based on experience." The science tells us how they change in response to experience. For example, we know that behaviorally relevant repetition is a smart strategy for learning skills. We know that intensity and duration matter. Did anyone 20 years ago know the optimal protocols for skill-building to maximize brain change? Yes, some knew them through trial and error. But at issue is not whether any educator has learned a revolutionary new strategy from the brain research. Teachers are highly resourceful and creative; literally thousands of strategies have been tried in the classrooms around the world.

The issue is, Can we make *better*-informed decisions about teaching based on what we have learned about the brain? Brain-based education suggests that we not wait 20 years until each of these correlations is proven beyond any possible doubt. Many theories might never be proven beyond reasonable doubt. It's possible that the sheer quantity of school, home, and genetic factors will render any generalizable principle impossible to prove as 100% accurate. As educators, we must live in the world of "likely" and "unlikely" as opposed to the world of "certainty." Yet, in the example above, the data from neuroscience are highly suggestive that gross motor voluntary exercise enhances neurogenesis and that neurogenesis supports cognition, memory, and mood regulation. The neuroscience merely supports other disciplines, but it's a discipline you can't see with your naked eyes, so it's worth reporting. Brain-based advocates should be pointing out how neuroscience parallels, supports, or leads the related sciences. But neuroscience is not a replacement science. Schools are too complex for that.

The Healthy Role of Critics

Almost 40 years ago, Thomas Kuhn's seminal work, *The Structure of Scientific Revolutions*, described how society responds when there is a significant shift in the prevailing paradigm. Kuhn argued that such a shift is typically met with vehement denial and opposition.[20] Brain-based education has faced all of those reactions, and, a generation later, the paradigm continues to strengthen, not weaken. Over time, as more peer-reviewed research and real-world results accumulate, the novel paradigm gains credibility. The fact is, there will always be critics, regardless of overwhelming, highest-quality evidence. Having critics is a healthy part of society's checks and balances. All paradigm shifts attract critics.

As an example, Harvard's highly respected cognitive scientist Howard Gardner has endured his share of criticism from neuroscientists who were uncomfortable with his brain-based evidence for the theory of multiple intelligences. Yet, while subjected to two decades of criticism, Gardner's work has made and continues to make a profound and positive difference in education worldwide. His ideas are in thousands of schools, and teachers are asking, "How are my students smart?" Some critics were fearful of a new paradigm; others were more territorial, protecting their turf and crying foul at any change in the benchmarks for intelligence. And still others will attack and attack again, offering only negatives. What is unhealthy is when critics resort to sarcasm and sink to linking brain-based education to Elvis, pyramids, and aliens.[21] That displays an embarrassing lack of scholarship and is disrespectful to those who work hard to improve education.

Critics often do have valid criticisms. For example, they mock policies (as they have every right to) that claim that a district is "brain-based" if every kid has a water bottle on his or her desk. No responsible advocate for brain-based education would argue that making water available is based on cutting-edge revelations about the brain. John Bruer argued that "we can only be thankful that members of the medical profession are more careful in applying biological research to their professional practice than some educators are in applying brain research to theirs."[22] This would be humorous except for the fact that, according to a study published in the *Journal of the American Medical Association*, the third leading cause of death in the United States (over 100,000 deaths per year) is medical incompetence and malpractice.[23] Is this the model of research and application that educators should be following? I think not. Give educators some credit. Much better to err on the side of enthusiasm and interdisciplinary research than to be part of the "head in the sand club."

Critics also commonly attempt to marginalize the discussion about brain-based education by using highly selective research (versus that from the prevailing majority of neuroscientists) to dispute scientific points. Examples of artificially "controversial" issues include whether "sensitive developmental periods," "gender differences," or "left-right brain differences" exist or can guide instructional practices.[24] Turning these kinds of mainstream understandings into myths is akin to the current Administration's spin on global warming. For years, conservative Presidents have referred to global warming as the "Global Warming Debate," as if scientists are split 50-50 on the subject. The reality is that there is a nearly universal scientific consensus on both the effects of global warming and who is responsible for it.

The same can be said for the topics mentioned above. There is little controversy over whether sensitive periods, gender differences, or hemispheric specificity exist. There is no controversy over the value of developmentally appropriate instruction or removing gender biases from curriculum and instruction. There is no reputable debate over the significance of hemisphericity, either. Neuroscience giants like Michael Gazzaniga have invested careers exploring this field. Any critic who asserts that there is no significant difference between the instructional implications of our left and right hemispheres should answer the question, If each hemisphere has little functional difference, would you voluntarily undergo a hemispherectomy? That's a ridiculous question and, of course, everyone's answer would be no!

John Bruer says that he is "notorious" for his "skepticism about what neuroscience can currently offer to education."[25] He argues that cognitive psychology, not neuroscience, is the strongest current candidate for a basic science of teaching. I happen to agree with that statement. I do believe that cognitive neuroscience has provided a great deal for educators and will continue to do so. The field has generated countless relevant insights. My own bias is toward psychology because I am currently a Ph.D. student in psychology. But even the term "psychology" is morphing into "cognitive neuroscience" because "psychology" implies a behaviorist orientation and "cognitive neuroscience" suggests a biological underpinning. For me, it's all about the interdisciplinary nature of understanding the brain, the mind, and education.

Having said that, the critics do have one thing right: brain-based education must move from being a "field" to becoming more of a "domain." An academic field is merely an aggregate or collection of forces within that territory. Brain-based education is merely a "field" right now. It is composed of scholars, consultants, publishers, staff developers, neuroscientists, conferences, and school programs. That's far from concise and replicable, yet it is typical for the start of a new movement. For brain-based education to mature, it must become a "domain." Domains have all of the same "players" as "fields," but there's an important distinction. Domains have accumulated a clear set of values, qualities, and even criteria for acceptance and validity. As brain-based education matures, it will become a "domain." From that more credible perspective, it will be easier to say if an instructional or assessment principle is "brain-based" because, right now, we can't say that. Brain-based education has grown past the "terrible twos" and the tween years. The bottom line is that before it can become accepted as a mature adult, it must forge its way out of the tumultuous teens and emerge with an accepted body of core structures that define its identity with more than a pretty picture of a brain scan. That maturing process is well under way.

Validation of Brain-Based Education

Today, as a result of years of work by brain-based educators, educators are a far more informed profession. They are more professional, they look more at research, and they are increasingly more capable of understanding and incorporating new cognitive neuroscience discoveries than they were 10 years ago. More schools of education are incorporating knowledge from the brain sciences than would have done so if we had followed the critics' advice and crawled into an intellectual cave for 25 years. Many forward thinkers have stayed tuned to such sources as Bob Sylwester's monthly column in *Brain Connection*, Scientific Learning's Internet journal that's regularly read by thousands of educators and parents. Sylwester, formerly a professor at the University of Oregon and a widely published authority on brain-based education, has been "connecting the dots" for educators for a decade.

One of the better-publicized examples of "science to the classroom" is the phonological processing software program Fast ForWord, based on the work of many neuroscientists.[26] Again, the critics assert that a long history of psychological research on reading and an even longer one of clinical neurological studies of dyslexia trump the fact that the resulting product was produced by neuroscientists for educators. They don't get it; it's all about being interdisciplinary. Another breakthrough is the new face-recognition software for learning social skills called "Let's Face It." It was developed by Jim Tanaka and his research team, who were interested in solutions for autism. It's likely critics will say that the product comes from a long history of human face recognition; ergo, it's not really a breakthrough. Other neuroscientists have recently penned "translational" books showing a "science to the classroom" connection. They include the luminary Michael Posner on attention, Sally Shaywitz on dyslexia, and Helen Nevills and Pat Wolfe on reading.[27]

Two major conference organizations, PIRI and the Learning Brain EXPO (the author's company), have produced "science to the classroom" events for 10 years. These biannual events have engaged more than 100 highly reputable, often award-winning, neuroscientists to speak in translational terms to educators. The list of speakers has been a veritable "who's who" in cutting-edge, interdisciplinary neuroscience. This has come about only as a result of the collaboration of educators and scientists linking the research directly to those in the schools. Whether the presenter was a biological psychologist, neuroscientist, or cognitive scientist is irrelevant; they've all spoken on science to the classroom.

How reputable is brain-based education? Harvard University now has both master's and doctoral degrees in it. Every year, Harvard's Mind, Brain, and Education (MBE) program produces about 40 graduates with master's degrees and two to four doctors of education, who go on to interdisciplinary positions in research and practice. "Our mission is to build a movement in which cognitive science and neuroscience are integrated with education so that we train people to make that integration both in research and in practice," says Prof. Kurt Fischer, director of the program.[28] This intersection of biology and cognitive science with pedagogy has become a new focus in education. Interest in the program is high in Canada, Japan, Australia, South Korea, England, South Africa, New Zealand, Argentina, and other countries. There's also a peer-reviewed scientific journal on brain-based education. The journal, which is published quarterly by the reputable Blackwell publishers and the International Mind, Brain, and Education Society (IMBES), features research, conceptual papers, reviews, debates, and dialogue.

Conclusion

Today, 10 years after the mudslinging criticism of brain-based education, it's appropriate to say, "We were right." In fact, because of the efforts of the brain-based community to inform educators, thousands are currently using this knowledge appropriately to enhance education policy and practice. There are degree programs in it, scientific journals, and conferences; and peer-reviewed brain-related research now supports the discipline. There are countless neuroscientists who support the movement, and they demonstrate their support by writing and speaking at educational conferences.

As an author in the brain-based movement, I have reminded educators that they should never say, "Brain research proves . . ." because it does not prove anything. It may, however, suggest or strengthen the value of a particular pathway. What educators should say is, "These studies suggest that XYZ may be true about the brain. Given that insight, it probably makes sense for us, under these conditions, to use the following strategies in schools." This approach, which is a cautionary one, sticks with the truth. When one is careful about making causal claims, the connections are there for those with an open mind.

The science may come from a wide range of disciplines. Brain-based education is not a panacea or magic bullet to solve all of education's problems. Anyone who claims that is misleading people. It is not yet a program, a model, or a package for schools to follow. The discussion of how to improve student learning must widen from axons and dendrites to the bigger picture. That bigger picture is that our brain is involved with everything we do at school. The brain is the most relevant feature to explore, because it affects every strategy, action, behavior, and policy at your school. New journals explore such essential topics as social conditions, exercise, neurogenesis, arts, stress, and nutrition. A school cannot remove arts, career education, and physical education and at the same time claim to be doing what's best for the brains of its students. These are the issues we must be exploring, not whether someone can prove whether a teacher's strategy was used before or after a neuroscience study provided peer-reviewed support for that strategy.

Today, there is still criticism, but the voices are no longer a chorus; they're a diminishing whine. For the critic, it's still "my way or the highway." That's an old, tired theme among critics; the tactic of dismissing another's research by narrowing the discussion to irrelevant issues, such as whether the research is cognitive science, neurobiology, or psychology. They're all about the mind and brain. The real issues that we should be talking about are what environmental, instructional, and social conditions can help us enrich students' lives. To answer that, it's obvious that everything that our brain does is relevant and that's what should now be on the table for discussion. Yes, we are in the infancy of brain research -- there's so much more to learn. But dismissing it is not only shortsighted, it's also dead wrong. At this early stage, that would be like calling the Wright Brothers' first flight at Kitty Hawk a failure because it only went a few hundred yards. And let's remember, the Wright Brothers had no credibility either; they were actually bicycle mechanics, not aviators. The future belongs not to the turf protectors, but to those with vision who can grasp interdisciplinary trends as well as the big picture. Nothing is more relevant to educators than the brains of their students, parents, or staff. Brain-based education is here to stay.

1. John T. Bruer, "Education and the Brain: A Bridge Too Far," *Educational Researcher*, November 1997, pp. 1-13; idem, "In Search of . . . Brain-Based Education," *Phi Delta Kappan*, May 1999, pp. 648-57; and idem, "Points of View: On the Implications of Neuroscience Research for Science Teaching and Learning: Are There Any?," *CBE Life Science Education*, vol. 5, 2006, pp. 445-61.

2. Bruer, "In Search of," p. 655.

3. Leslie A. Hart, *Human Brain, Human Learning* (New York: Longman, 1983).

4. Howard Gardner, *Frames of Mind: The Theory of Multiple Intelligences* (New York: Basic Books, 1983); Renata N. Caine and Geoffrey Caine, *Making Connections: Teaching and the Human Brain* (Alexandria, Va.: Association for Supervision and Curriculum Development, 1991); David A. Sousa, *How the Brain Learns*, 3rd ed. (Thousand Oaks, Calif.: Corwin, 2005); and Eric Jensen, T*eaching with the Brain in Mind*, 2nd ed. (Alexandria, Va.: Association for Supervision and Curriculum Development, 2005).

5. Conor Liston, "An Interview with Antonio R. Damasio," *The Harvard Brain*, Spring 2001, p. 2, emphasis added.

6. Gerd Kempermann, Laurenz Wiskott, and Fred Gage, "Functional Significance of Adult Neurogenesis," *Current Opinion in Neurobiology*, April 2004, pp. 186-91.

7. Marco Iacoboni et al., "Grasping the Intentions of Others with One's Own Mirror Neuron System," *PLoS Biology*, 22 February 2005, available at http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0030079.

8. Michael Kilgard and Michael Merzenich, "Cortical Map Reorganization Enabled by Nucleus Basalis Activity," *Science*, vol. 279, 1998, pp. 1714-18; Henry W. Mahncke et al., "Memory Enhancement in Healthy Older Adults Using a Brain Plasticity-Based Training Program: A Randomized, Controlled Study," *Proceedings of the National Academy of Sciences*, 15 August 2006, pp. 12523-28; and Elise Temple et al., "Neural Deficits in Children with Dyslexia Ameliorated by Behavioral Remediation: Evidence from Functional MRI," *Proceedings of the National Academy of Sciences*, 4 March 2003, pp. 2860-65.

9. Bruce McEwen and John Wingfield, "The Concept of Allostasis in Biology and Biomedicine," *Hormone Behavior*, January 2003, pp. 2-15.

10. Bruce Lipton, *The Biology of Belief* (Santa Rosa, Calif.: Mountain of Love Publishing, 2005); and Ernest Rossi, *The Psychobiology of Gene Expression* (New York: Norton, 2002).

11. Temple et al. (learning to read); HweeLing Lee et al., "Anatomical Traces of Vocabulary Acquisition in the Adolescent Brain," *Journal of Neuroscience*, 31 January 2007, pp. 1184-89 (learning vocabulary); Bogdon Draganski et al., "Temporal and Spatial Dynamics of Brain Structure Changes During Extensive Learning," *Journal of Neuroscience*, vol. 26, 2006, pp. 6314-17 (studying for tests); and Christien Gaser and

Gottfried Schlaug, "Brain Structures Differ Between Musicians and Non-Musicians," *Journal of Neuroscience*, vol. 23, 2003, pp. 9240-45 (learning to play a musical instrument).

12. Panaqiotis G. Simos et al., "Dyslexia-Specific Brain Activation Profile Becomes Normal Following Successful Remedial Training," *Neurology*, April 2002, pp. 1203-13.

13. Nancy Brener, John O. G. Billy, and William R. Grady, "Assessment of Factors Affecting the Validity of Self-Reported Health-Risk Behavior Among Adolescents: Evidence from the Scientific Literature," *Journal of Adolescent Health*, vol. 33, 2003, pp. 436-57.

14. Henriette van Praag et al., "Running Enhances Neurogenesis, Learning and Long-Term Potentiation in Mice," *Proceedings of the National Academy of Sciences*, vol. 96, 1999, pp. 13427-31; and Ana C. Pereira et al., "An In Vivo Correlate of Exercise-Induced Neurogenesis in the Adult Dentate Gyrus," *Proceedings of the National Academy of Sciences*, vol. 104, 2007, pp. 5638-43.

15. Grace S. Griesbach et al., "Voluntary Exercise Following Traumatic Brain Injury: Brain-Derived Neurotrophic Factor Upregulation and Recovery of Function," *Neuroscience*, vol. 125, 2006, pp. 129-39.

16. Tracey J. Shors et al., "Neurogenesis in the Adult Is Involved in the Formation of Trace Memories," *Nature*, vol. 410, 2001, pp. 372-76; and Yasuji Kitabatake et al., "Adult Neurogenesis and Hippocampal Memory Function: New Cells, More Plasticity, New Memories?," *Neurosurgery Clinics North America*, January 2007, pp. 105-13.

17. L. Sanji Nandam et al., "5-ht(7), Neurogenesis and Antidepressants: A Promising Therapeutic Axis for Treating Depression," *Clinical Experiments in Pharmacology and Physiology*, May-June 2007, pp. 546-51.

18. Gitanjali Saluja et al., "Prevalence of and Risk Factors for Depressive Symptoms Among Young Adolescents," *Archives of Pediatric and Adolescent Medicine*, August 2004, pp. 760-65.

19. Astrid Bjornebekk et al., "The Antidepressant Effect of Running Is Associated with Increased Hippocampal Cell Proliferation," *International Journal of Neuropsychopharmacology*, September 2005, pp. 357-68.

20. Thomas Kuhn, *The Structure of Scientific Revolutions* (Chicago: University of Chicago Press, 1970).

21. Bruer, "In Search of."

22. Ibid., p. 657.

23. Chunliu Zhan and Marlene R. Miller, "Excess Length of Stay, Charges, and Mortality Attributable to Medical Injuries During Hospitalization," *Journal of the American Medical Association*, October 2003, pp. 1868-74.

24. Bruer, "In Search of."

25. Bruer, "Points of View: On the Implications of Neuroscience," p. 104.

26. Temple et al., op. cit.

27. Michael Posner and Mary Klevjord Rothbart, *Educating the Human Brain* (Washington, D.C.: American Psychological Association, 2006); Sally Shaywitz, *Overcoming Dyslexia* (New York: Random House, 2004); and Helen Nevills and Pat Wolfe, *Building the Reading Brain* (Thousand Oaks, Calif.: Corwin, 2005).

28. Julia Hanna, "Mind, Brain, & Education: Linking Biology, Neuroscience, & Educational Practice," *Harvard Graduate School of Education News*, 1 June 2005, available at www.gse.harvard.edu/news/features/mbe06012005.html.

ERIC P. JENSEN is a former middle school teacher and adjunct professor for the University of California, San Diego. He co-founded the Brain Store and the Learning Brain EXPO and has written 21 books on the brain and learning. His most recent book is *Enriching the Brain* (Jossey-Bass, 2006). He currently is a doctoral student in Media Psychology at Fielding Graduate University, Santa Barbara, Calif.