Neuroscience and Education: An Ideal Partnership for Producing Evidence-Based Solutions to Guide 21st Century Learning

Thomas J. Carew[1,*] and Susan H. Magsamen[2,*]
[1]Department of Neurobiology and Behavior, Center for the Neurobiology of Learning and Memory, Department of Education, University of California, Irvine, Irvine, CA 92697, USA
[2]Johns Hopkins University School of Education, Baltimore, MD 21030, USA
*Correspondence: tcarew@uci.edu (T.J.C.), smagsamen@mac.com (S.H.M.)
DOI 10.1016/j.neuron.2010.08.028

Neuro-Education is a nascent discipline that seeks to blend the collective fields of neuroscience, psychology, cognitive science, and education to create a better understanding of how we learn and how this information can be used to create more effective teaching methods, curricula, and educational policy. Though still in its infancy as a research discipline, this initiative is already opening critical new dialogs between teachers, administrators, parents, and brain scientists.

There is no question that learning—and teaching—are intricately intertwined with brain function. Yet for many years, researchers in both education and neuroscience have worked far apart in silos—often within sight of each other across a university campus, but worlds away in forming hypotheses about how people learn, investigating those learning processes, and finally, translating findings into practice. Thankfully, that is changing. There are now exciting new opportunities for informing the practice of teaching and learning within the broad discipline of neuroscience. This is good news, because more than ever, we need to figure out how to teach our children how to learn.

An International Concern

The U.S. Secretary of Education, Arne Duncan, called the state of education in America a national public health crisis. American children are not excelling. Test grades show it. Innovation and creative thinking are not being taught, practiced, or nurtured in children's lives. Industry and business are concerned that we are not producing engineers, mathematicians, scientists, and physicists. Something must be done to prepare our children for a 21st century future, and here we propose that Neuro-Education may provide one critical element toward a solution.

And this is not simply a national problem: it is global. Comparable challenges in education exist around the world, and exciting programs have been developed in a number of countries to address this critical issue. The International Mind, Brain, and Education Society has fostered a growing number of global initiatives that have brought together many interested countries. In addition, since 1999, the Organization for Economic Co-operation and Development has had a Neuroscience and Education program that brokered a variety of productive collaborations. In the United Kingdom, Cambridge University has founded an educational neuroscience program, and under the guidance of Hirokazu Tanaka, Japan is currently building a strong Mind, Brain, and Education research program. Likewise, in Shanghai, East Normal University has recently founded a neuroeducation effort. Finally, a European organization on learning research (EARLI) held its first meeting in Zurich in 2010, focusing on learning and the brain. Thus, a global initiative is on the march, which promises extraordinary opportunities for international collaboration.

How Can Neuroscience Help?

What can neuroscientists do about any of this? After all, research is about well-defined problems, not big societal issues. Well—not really. It is not news that neuroscience and related fields have done an extraordinary job of creating vast amounts of knowledge. Every day more and more useful information, data, and perspectives on important learning topics are being generated by new research, exploration, and inquiry. While much of this knowledge is shared through academic circles, for the most part it has not been widely shared and used outside of disciplines to inform larger issues. In fact, the "translational" potential of this work is often not discovered, explored, or further evaluated.

The field of neuroscience is ripe for expanding its translational reach. "Neuro-Education" is still a relatively new and developing area. Last summer, one of us (T.J.C.) created a presidential initiative, a Neuroscience Research in Education Summit (Society for Neuroscience, 2009), for his year as president of the Society for Neuroscience. This gave rise to a working group that has formed into a Neuro-Education Leadership Coalition that is working together to further the development and strategic integration of this nascent field. It seeks to blend the collective fields of neuroscience, psychology, cognitive science, and education to create more effective teaching methods and curricula and, ultimately, to inform and transform educational policy. Though still in its infancy as a research discipline, this initiative is already opening critical new dialogs between its primary partners—teachers, parents, and brain researchers—through the development of a common language. While this will take time and is a complex task, the more each discipline approaches its work with common terminology, new traditions, and learning outcomes in mind, the faster and stronger a new community and field will be formed.

Why Does It Matter?

The stakes are high and the rewards worthwhile. Imagine being able to share what we know about multisensory learning to new mothers. What could be said about the effects of an enriched environment on brain development? Imagine explaining to a high school teacher what executive function is and how it might influence judgment as they create meaningful lessons in ethics. Imagine being able to use what we know about the rules of learning to design a classroom that actually made kids smarter. Imagine using our knowledge about brain function to help prevent, reverse, or stop damage to the brain through neglect, abuse, or even malnutrition with at-risk children. Or imagine a school day that incorporated our understanding of the biological factors of stress and sleep on children's ability to learn and remember. We could continue to imagine a million things that are all possible when fueled by evidence-based rigorous neuroscience research that can be translated to practical application and tested for their efficacy through the creation of research schools, informal learning testing, and other measures. These game-changers for education and learning are within our reach.

Advances in techniques, relentless inquiry, and innovative practitioners, curious about how the mind and brain work, are creating significant findings and new knowledge about the brain, from memory and learning to executive function, emotions, autism, literacy, language motor skills, and more. And we know that educators, parents, and child service providers are reading everything they can get their hands on about this work. Why? Because the problems and issues our children face today are like no other generation before them. And those of us enlisted in the nurturing and developmental support of our most precious national resource, our children, need information, ideas, conversation, and useable knowledge.

Gaining Traction

Research findings in many disciplines, from psychology and genetics to neuroscience and engineering, are already converging to inform curricula and policy. For example, neuroscientists know a great deal about attention, stress, memory, exercise, sleep, and music—and all are well-studied topics that can readily translate to the classroom. Some educators are beginning to capitalize on these and other findings, with promising results. For example, The Johns Hopkins University School of Education has developed the Neuro-Education Initiative, which emphasizes the importance of professional development, research, communications, and outreach (http://education.jhu.edu/nei).

In addition, institutions are creating innovative new Neuro-Education partnerships. Kurt Fischer at the Harvard Graduate School of Education promotes "usable knowledge" to bridge the gap between research and practice. He aims to educate a cadre of researchers with a novel skill set, combining the study of biological and cognitive sciences with educational pedagogy. His department offers master's and doctoral degrees in "brain, mind, and education." Interdisciplinary graduate degrees such as this open up intriguing new career paths for young educators—and for young neuroscientists (Harvard Graduate School of Education, "Mind, Brain and Education" [http://www.gse.harvard.edu/academics/masters/mbe/]).

Mary Brabeck, Dean of New York University's Steinhardt School of Culture, Education, and Human Development, believes that, in this growing new field, a parity relationship between educators and researchers is integral to make gains in educational outcomes (Brabeck, 2008). Educators must pull research findings out of the lab and put them to use in the classroom, and researchers need to distill their results for teachers' purposes. Effective changes in teaching practices must then be communicated back to scientists. Consistent and quantitative feedback, both for what works and what doesn't, is crucial for improvement, Brabeck believes. In her efforts to promote "translational research" from the lab to the classroom, Brabeck likens this gap to that between health researchers and physicians. She says that in education, like medicine, vital knowledge too often remains with researchers and is inaccessible to people who are in positions to help our children—that is, teachers and parents (Brabeck, 2008).

There Are Some Barriers Too

The neuroscience community, educators, and parents also have to confront false preconceptions about brain-based pedagogy. These "neuromyths"—for example, that children are either "right-brain" or "left-brain" learners—exist in the classroom and thrive under the misnomer of "brain-based teaching" (Society for Neuroscience, 2009). But this is just the beginning. Journalists, educators, and parents all need to communicate with one another about topics that relate learning and the brain to better understand what is and is not accurate.

A critical component of this endeavor is that tangible financial resources must materialize for progress to be made, from the local university level all the way up to the federal government. Less than one-half of one percent of the federal education budget is spent on research, compared with about 20% of the federal health budget (U.S. Department of Education, *Fiscal Year 2008–FY 2010 State Tables for the U.S. Department of Education*: http://www2.ed.gov/about/overview/budget/statetables/). Increased private funding will also play a critical role.

Informed Solutions to Practical Problems Are Essential

Teachers and parents have much to gain from this comprehensive effort. Greater exposure to scientists and high-quality research will help educators become more informed and critical consumers of science and make it easier for them to avoid non-research-based fads. The translational value of some cognitive studies is obvious. For example, creative work from Henry Roediger's laboratory showed that testing not only measures knowledge, but actually strengthens it (Karpicke and Roediger, 2010). The take-home message: retrieval is not a passive process, but rather is a critical means of fortifying memory. This result has the potential to alter a fundamental structure of classroom learning. Moreover, since memory retrieval and the consolidation of learning are basic components of education *and* are deeply explored topics in neuroscience, what a great place to start building bridges to span the two disciplines.

Another example of how our knowledge can enhance learning derives from our understanding of the cognitive benefits of music. Nina Kraus and colleagues have shown that musical experience significantly limits the negative effects of competing background noise (Kraus et al., 2007), and Gottfried Schlaug and collaborators have found that people who regularly practiced a musical instrument when young display better sound recognition as well as enhanced levels of memory and attention compared to nonmusicians (Forgeard et al., 2008). Educators, parents, and the public-at-large should know that musical training is likely to enhance both verbal skills and nonverbal abilities, and how this is possible (Hyde et al., 2009).

Neuro-Education reaches down to even the most basic human functions, such as sleep. The role of sleep and its impact on memory is a richly explored topic among neuroscientists; a good night's sleep is not just restful, it triggers brain changes that help improve memory. Animal studies show that memory is greater after sleep than after wakefulness and that the brain works to consolidate memory during its rest period (Gilestro et al., 2009). And studies in humans reinforce the same basic point. For example, Elizabeth Kensinger and her colleagues have found that sleep preferentially enhances memory for emotional components of visual scenes (Payne et al., 2008). This knowledge clearly makes an impact on children and their ability to learn. Lack of sleep can lead to developmental, attentional, and emotional problems, all of which are reflected in classroom performance. These findings could ultimately impact the time children start their school day or the number of hours of sleep parents recommend for their child.

What about exercise? Both human and animal studies on exercise and the brain show that physical exertion promotes mental health (Kramer et al., 2006). Exercise protects certain types of brain cells and improves motor function, adding to a growing body of research that reveals its benefit for young brains. Moreover, Michael Zigmond and colleagues have shown that physical activity can aid in recovery after neural damage (Zigmond et al., 2009). With dance classes, recess, and outdoor playtime slashed along with school budgets, these kinds of findings can hopefully inform education and policy leaders as they prioritize the most critical components for learning.

Finally, stress, particularly chronic stress, undermines learning by impairing students' ability to concentrate. Students functioning in a more relaxed environment, who feel less overwhelmed, have better brain function (Dias-Ferreira et al., 2009). An important study by Conor Liston, Bruce McEwen, and B.J. Casey (Liston et al., 2009) compared how highly stressed and relatively nonstressed medical students performed on tasks that required that they shift their attention from one visual stimulus to another. Their results showed that the extremely stressed students scored lower on tests and had reduced processing in certain brain regions, implying that chronic stress disrupts the brain's ability to shift attention, a function certainly necessary for classroom learning.

If Not Now, What Price Will We Pay In 10 Years?

International test-score comparisons, intractable achievement gaps, and static U.S. graduation rates clearly indicate that now is the time to act. To maintain (and expand) any technologically advanced society, cultivating generations of science, technology, engineering, and math disciples is required. Much has been written about slumps in science "literacy"; American students clearly require a new approach to spark or reenergize their sense of curiosity, passion, and competition. And the same is true for students around the globe.

Neuro-Education may help prevent counterproductive actions in tough times. Dwindling school budgets have led to anemic arts programs, which have reduced children's access to dance, music, theater, creative writing, and the visual arts (see Lehrer, 2009). These programs are far from superfluous; current research supports the view that they are conduits for problem-solving, motivation, collaboration, and innovative thinking. In his seminal book, Michael Posner describes studies revealing that attention-focusing art forms significantly improve listening skills and concentration (Posner, 2004). Neuro-Education initiatives can help frame issues and make the case for far-sighted education policies that make evidence-based sense for children's development.

The bottom line is everyone wins. As psychologists, cognitive scientists, neuroscientists, educators and parents continue to overcome challenges, children must remain the clear motivation for action and should form the basis for a compelling drive to sustain and grow this movement. For each young mind served by Neuro-Education knowledge, all societies have the opportunity to regain lost ground—and build the potential for better academic achievements and opportunities for both young people and society at large. Moreover, if successful, it also highlights that science can collaborate best with society when we bring to the table what we *do* know—our scientific expertise—and a dose of humility about what we *don't* know—in this case, what works best in a classroom, at home, and in the community.

In the end, Neuro-Education provides a paradigm for how science can inform broader social policies by being inclusive and collaborative with other established disciplines. And when the collaboration bears fruit, we will have children who can learn better, which in turn yields a society better equipped for the future.

ACKNOWLEDGMENTS

We thank Nicholas Spitzer for his thoughtful comments on an earlier draft of the manuscript. This work was supported in part by NIH Grants R01 MH14-10183 and MH 081151, and NSF Grant IOB-0444762 (T.J.C.), and a grant from the Johns Hopkins Medicine Brain Science Institute (S.H.M.).

REFERENCES

Brabeck, M. (2008). Putting Clinical Findings to Work in the Classroom (Bethesda, MD: Education Week).

Dias-Ferreira, E., Sousa, J.C., Melo, I., Morgado, P., Mesquita, A.R., Cerqueira, J.J., Costa, R.M., and Sousa, N. (2009). Science *325*, 621–625.

Forgeard, M., Winner, E., Norton, A., and Schlaug, G. (2008). PLoS ONE *3*, e3566.

Gilestro, G.F., Tononi, G., and Cirelli, C. (2009). Science *324*, 109–112.

Hyde, K.L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A.C., and Schlaug, G. (2009). J. Neurosci. *29*, 3019–3025.

Karpicke, J.D., and Roediger, H.L. (2010). Mem. Cognit. *38*, 116–124.

Kramer, A.F., Erickson, K.I., and Colcombe, S.J. (2006). J. Appl. Physiol. *101*, 1237–1242.

Kraus, N., Skoe, E., Sams, M., and Musacchia, G. (2007). Proc. Natl. Acad. Sci. USA *104*, 15894–15898.

Lehrer, J. (2009). Recession's Effects Batter New York School District (http://www.pbs.org/newshour/bb/education/jan-june09/peekskill_02-09.html).

Liston, C., McEwen, B.S., and Casey, B.J. (2009). Proc. Natl. Acad. Sci. USA *106*, 912–917.

Payne, J.D., Stickgold, R., Swanberg, K., and Kensinger, E.A. (2008). Psychol. Sci. *19*, 781–788.

Posner, M.I., ed. (2004). Cognitive Neuroscience of Attention (New York: Guilford).

Society for Neuroscience. (2009). Neuroscience Research in Education Summit: The Promise of Interdisciplinary Partnerships Between Brain Sciences and Education (http://www.sfn.org/siteobjects/published/0000BDF20016F63800FD712C30FA42DD/D0E7F2B692E1853CC31DDB5D80E4AE69/file/Education Summit Report.pdf).

Zigmond, M.J., Cameron, J.L., Leak, R.K., Mirnics, K., Russell, V.A., Smeyne, R.J., and Smith, A.D. (2009). Parkinsonism Relat. Disord. *15* (*Suppl 3*), S42–S45.