Title

Brain Science and Education: Is it Still a Bridge Too Far?

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Brain Science and Education: Is it Still a Bridge Too Far?

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Abstract

Does neuroscience have the potential to inform education? In this debate, three participants will describe emerging results in neuroscience with translatable links to learning and memory. Experts in learning sciences will discuss connections as well as limits in the ways that neuroscience can inform education at the individual and classroom levels. Although significant progress has been made in our understanding of how the brain learns and remembers, the question for this symposium is whether this progress does or can provide a *direct* bridge from brain science to education.

Keywords: neuroscience; brain science; translational research; education; brain-based education; educational neuroscience

Can our knowledge of brain structure and function be used to improve education? Twenty years ago, in "Education and the Brain: A Bridge Too Far" (1997), John Bruer warned that "we should be wary of the claim that neuroscience has much to tell us about education." His was a common position (e.g., Chipman, 1986). However, even at that time, many educational researchers (e.g., Mayer, 1986, Mayer et al., 1998; Brynes & Fox, 1998) disagreed with this view and argued that ignoring how the brain is structured and functions is a mistake and short sighted. Ten years later, the battle still raged with some researchers (e.g., Giedd & Rapport, 2010) arguing in favor of the potential impact of brain science on education, and others (e.g., Hirsh-Pasek & Bruer, 2007) maintaining the argument against, and further, that the perceived benefit of brain science to early childhood education was, in part, based on the misconception of critical periods for learning.

We have three goals for this symposium. First: to provide an assessment of the advances in cognitive neuroscience that are most relevant to the question of educational application. Second: to provide a forum for discussing translational research (i.e., the nature of the bridge) from the neuroscience to education. Third: to provide specific examples of promising brain science to education (e.g., reading, STEM).

The symposium features an introduction by John Bruer, four talks by eminent researchers in brain and cognitive science, a brief discussion by Ray Perez, and a 20 min Q&A among panel members and the audience. *John Bruer* will summarize the major issues in the debate. Presentations, by *Gary Lynch*, *Marcel Just*, and *Terrence Sejnowski*, will summarize the latest results from brain science at three different levels of analysis. Gary Lynch will describe current understandings of the neurobiology and neurophysiology of memory. Marcel Just and Robert Mason will describe their research at the cognitive neuroscience level, in particular the use of machine learning on fMRI data to chart neural signatures of concept formation. Terrence Sejnowski will provide a description of cortical models (modeling of network communication) of spatial and unsupervised learning of brain function and structure that could serve as a framework to integrate results of brain science across various levels of analysis.

Danielle S. McNamara raises questions on the potential impact of neuroscience on reading and literacy and how this research can influence neuroscience. *Richard Mayer*, more broadly, raises questions of how brain research can help educational psychologists better understand the nature of cognitive processing during learning (including markers of heavy or light cognitive load, or deep or shallow processing).

Discussant, *Ray Perez*, will briefly summarize both sides of the arguments followed by recommendations as to what could be the nature of translation research.

Symposium Presentations

Introduction: Revisiting The Bridge Too Far

John T. Bruer

John T. Bruer served as President of the James S. McDonnell Foundation from 1986 through 2015, initiating both *Cognitive Studies for Educational Practice* and the Foundation's program to support the development of cognitive neuroscience. More recently, Bruer helped to organize and fund the *Latin American School in the Neural, Cognitive and Educational Sciences*. His 1996 article, A Bridge Too Far, continues to be a lightning rod for debate about the promise and pitfalls of educational neuroscience. The paper's negative argument was that developmental synaptogenesis, critical periods, and enriched environments did not inform educational practice. Its positive argument, that links between neuroscience and education are most likely to be mediated by psychology, is still being debated. John Bruer will open up this discussion with a summary of the major issues in the debate and principle considerations, including the importance of identifying and prioritizing educational problems and ascertaining the levels of scientific analysis most likely to generate solutions in the near to intermediate future (see e.g., Bruer, 2016).

Brain Substrates for Complex Learning

Gary Lynch, University of California Irvine

Decades of work have led neuroscientists to a detailed, behaviorally predictive model describing the synaptic plasticity required for encoding memory. Substantial progress has also been made in defining forebrain networks related to fundamental aspects of cognition; combined, these developments describe realistic bridges between brain science and education. For example, recent studies on the synaptic model uncovered a physiological/biochemical analogue of *distributed practice effects* in learning: neurobiological timing rules successfully predict optimal training regimens. Other work has linked episodic memory to specific nodes and types of plasticity in hippocampal networks; individuals need to engage this form of memory when learning how to deal with complexities of real world circumstances. Advances in this area are expected to suggest mechanism-based strategies for optimization and enhancement of teaching.

Using Brain Reading to Understand Concept Learning in Educational Contexts

Marcel Adam Just and Robert Mason
Carnegie Mellon University

Advances in identifying neural signatures of a concept renders it possible to determine the neural basis of the learning of scientific and technical knowledge. Just and Mason present findings observing (a) a high degree of commonality across people in representations of concepts, including abstract scientific concepts; (b) the neural emergence of individual newly learned concepts can be observed, with the ability to predict each concept's brain locations and its neural similarity to other concepts; and (c) a set of concepts in a specific domain can be characterized in terms of a few key underlying neurosemantic dimensions of representation. Such findings (including classroom research) enable the beginning of a neurally informed understanding of how individual scientific concepts are learned, and can potentially lead to enhanced instruction.

Cortical Models of Brain Function

Terrence Sejnowski, UC San Diego and The Salk Institute

From a computational neuroscience perspective, Sejnowski describes research towards understanding the principles that link brain to behavior. Drawing upon studies that use multi-imaging techniques, such as, EEG, TMS, PET, MEG, and behavioral measures, his laboratory uses both experimental and modeling techniques to study the biophysical properties of synapses and neurons and the population dynamics of large networks of neurons. He has developed new computational models and new analytical tools to better understand how the brain represents the world and how new representations are formed through learning algorithms for changing the synaptic strengths of connections between neurons.

Bridges from Brain Science to Reading: Some Key Ingredients of a Direct Translation

Danielle S. McNamara, Arizona State University

Dr. McNamara, an expert in reading comprehension and reading interventions, will discuss potential links between brain science and reading, including neural correlates of strategic reading. She will discuss potentially promising results as well as inherent limitations of neural correlates in informing educational practice, and in particular, the necessity to inform interventions for individuals at various stages of development.

How Can Brain Research Inform Academic Learning and Instruction?

Richard E. Mayer, UC Santa Barbara

Renowned for his work in applying the science of learning to education, Mayer will discuss ways that brain research may help educational psychologists understand the nature of cognitive processing during learning. From the standpoint of educational psychology, he will describe work connecting brain signatures (including markers of heavy or light cognitive load, or deep or shallow processing) and (including markers for meaningful or rote learning) and what brain research can tell us about individual differences in learning strategies and the effectiveness of instructional manipulations.

Discussant: Ray S. Perez, senior scientist and Program Officer at the Office of Naval Research, is responsible for managing ONR's Cognitive Science of Learning Program, with three major multidisciplinary and highly intertwined thrusts. Specifically, (1) training/education research and their core technologies, (2) individual differences research, and (3) neuro-biology of learning research.

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