Cognitive neuroscience in relation to education: A path into the literature

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The aim of this document is to give you some pointers to the best and current relevant research-based literature about cognitive neuroscience and education. Then, you can decide for yourself about the current value of cognitive neuroscience in relation to the kinds of problems that one typically encounters in the classroom.

As is often the case in educational research, nothing is simple or black/white in this field of investigation. Some will see half-full glasses, others will see half-empty ones.

Perhaps as a first goal, one should simply try to get an impression of the 'state of the art', without necessarily having to come to a definitive view about the 'state of the glass.' That is, you might first want to assess the current state of knowledge about the relations between neuroscience and classroom learning, rather than assume that there is already a set of well-defined facts and principles. In that connection, I have tried to give you some of the texts that are most positive about the prospects of using neuroscience in relation to education, but I also have tried to point out some places in the commentaries that indicate how little we actually know about the relation between brain and education.

My own estimation about the current state is that neuroscience is unlikely to give significant insight into educational issues — at least for next 50 years. It may be able to indicate some possible reasons for specific difficulties (e.g., it has claimed some success for identifying possible reasons for some kinds of dyslexia), but it is unlikely to give much insight about what to do instructionally (even for dyslexia).

Please start with

1. Goswami, U. (2004). Neuroscience and education. *British Journal of Educational Psychology, 74*, 1-14.

Here are a couple of links to this article. Otherwise, you should know how to use the U. of Bath library resources to find this journal.

http://www.ingentaconnect.com/content/bpsoc/bjep/2004/00000074/00000001/art00001
or http://dx.doi.org/10.1348/000709904322848798

The article gives a quick introduction/overview to neuroscience and brain development, some examples of promising applications, and most importantly, even if you do not read the rest of the article, it is worth looking at the three neuromyths (pp. 10-11), which

[1] In general, all journal references are available electronically through the U. of Bath library. Suggestions for other articles/texts to include in this guide are received with interest.

summarizes a report from the OECD. Here is a link for a newer version of that report, where you can download the first chapter and get links to other relevant information.

http://www.oecd.org/document/60/0,3343,en_2649_201185_38811388_1_1_1_1,00.html

2. Goswami, U. (2006). Neuroscience and education: From research to practice? *Nature Reviews Neuroscience, 7*, 406-411.

http://www.psychology.heacademy.ac.uk/plat2006/assets/presentations/Goswami/GoswamiNRN2006.pdf or http://www.nature.com/nrn/journal/v7/n5/pdf/nrn1907.pdf

Usha Goswami is the Director of the Centre for Neuroscience in Education.
Her training is in psychology and her main research focus is on dyslexia.

http://www.educ.cam.ac.uk/people/staff/goswami/

She has recently published a revised edition of her textbook, which has been praised for its integration of neural and traditional psychological approaches.

Goswami, U. (2008). *Cognitive development: The learning brain.* Hove: Psychology Press.

Then you might continue with:

3. Byrnes, J., & Fox, N. (1998). The educational relevance of research in cognitive neuroscience. *Educational Psychology Review, 10*, 297-342.

http://dx.doi.org/10.1023/A:1022145812276

This article gives a much more detailed discussion of the research methods that are used in cognitive neuroscience, an overview of 'properties' formulated with these methods. They conclude with describing four camps of researchers in relation to neuroscience and education, and then their arguments about the way forward.
(For what it is worth, I would not place myself within any of those camps).

The issue of the journal in which this article is published has two commentaries (1998, Vol. 10, No. 3) about the article, and the next issue (1998, Vol. 10, No. 4) has six additional commentaries about this article, together with Byrnes and Fox's response.

If you want a technical discussion of the historical development of measuring techniques that lead to the development of cognitive neuroscience, then try:

Raichle, M. E. (2009). A brief history of human brain mapping. *Trends in Neurosciences, 32,* 118-126.

http://www.sciencedirect.com/science/article/B6T0V-4V7D5RM-1/2/9e80ff9851f9efb6748c066ce621a54e

4. Ansari, D., & Coch, D. (2006). Bridges over troubled waters: Education and cognitive neuroscience. *Trends in Cognitive Sciences, 10*, 146-151.

http://www.sciencedirect.com/science/article/B6VH9-4JFGFNF-2/1/a84b59620b638cd1f0b88e69b091a5a5

The authors work at Center for Cognitive and Educational Neuroscience (CCEN) at Dartmouth College. The main purpose of this short article is to give an overview about the perspective for cognitive neuroscience. The main reason I mention this article is that if you open the URL for the article, then you will get a HTML version. At the end, the reference list has many links to full-text versions of the references. This gives a quick-and-dirty method to look at a lot of articles quickly.

5. Blakemore, S-J., & Frith, U. (2005). *The learning brain: Lessons for education.* Oxford: Blackwell.

Blakemore's research has focused primarily on brain development. Much of Frith's research has been focused on autism. In other words, they are experimental psychologists, not educators.

A summary of their book can be found in:

6. Blakemore, S.-J., & Frith, U. (2005). The learning brain: Lessons for education: A précis. *Developmental Science, 8*, 459-465.

http://www.blackwell-synergy.com/doi/abs/10.1111/j.1467-7687.2005.00434.x

Their précis in the journal is followed by three commentaries. One of them is:

7. Goswami, U. (2005). The brain in the classroom? The state of the art. *Developmental Science, 8*, 467-469.

Here are a few words from her commentary:

> "This delightful book provides the best introduction to neuroscience for educators that I have come across. It presents clear information about the developing brain in an accessible and lively manner, and demystifies neuroscience as a discipline. In terms of providing a comprehensive introduction to 'the learning brain', it does its job admirably. But does it really contain many lessons for education? (pp. 467-468)
>
> ... [summary of book's contents] ...
>
> So – lessons for education? Not so many. But a fantastic collection of interesting facts about the brain, and many engaging descriptions of neuroscientific studies that will help the lay reader to understand how the brain works." (p. 469)

Current developments

Howard-Jones, P. (2007). *Neuroscience and education: Issues and opportunities: A commentary by the Teaching and Learning Research Programme.* London: TLRP.

Gives a balanced and critical evaluation of the 'state-of-the-art.'

http://www.tlrp.org/pub/documents/Neuroscience%20Commentary%20FINAL.pdf

Mind, Brain, and Education is a journal that started in 2007. Full-text is available through U. of Bath library.

http://www.blackwell-synergy.com/loi/mbe

It might be worth reading the short editorial in Vol. 1, No. 1 that explains why the journal is being started.

Fischer, K. W., Daniel, D. B., Immordino-Yang, M. H., Stern, E., Battro, A., & Koizumi, H. (2007). Why mind, brain, and education? Why now? *Mind, Brain, and Education, 1*, 1-2.

http://www.blackwell-synergy.com/links/doi/10.1111/j.1751-228X.2007.00006.x

Many who publish in that journal also have a chapter in this recent book. Most of these researchers are experimental psychologists.

Battro, A. M., Fischer, K. W., & Léna, P. J. (Eds.) (2008). *The educated brain: Essays in neuroeducation*. Cambridge: Cambridge University Press.

> *From the publisher*:
>
> The emerging field of neuroeducation, concerned with the interaction between mind, brain and education, has proved revolutionary in educational research, introducing concepts, methods and technologies into many advanced institutions around the world. *The Educated Brain* presents a broad overview of the major topics in this new discipline:
> - *part I* examines the historical and epistemological issues related to the mind/brain problem and the scope of neuroeducation;
> - *part II* provides a view of basic brain research in education and use of imaging techniques, and the study of brain and cognitive development;
> - *part III* is dedicated to the neural foundations of language and reading in different cultures and the acquisition of basic mathematical concepts. With contributions from leading researchers in the field, this book features the most recent and advanced research in cognitive neurosciences.

http://www.cambridge.org/9780521876735

The debate continues...

Articles continue to appear discussing the possibilities, problems, and challenges for using neuroscience in relation to education. Here is a recent article from *Educational Researcher.* This journal is usually very selective about what it will publish, because it is the main general interest journal for the American Educational Research Association. The article systematically takes challenges or criticisms of using neuroscience in relation to education, and then tries to argue against them. If you are interested in observing the fine (almost philosophical) details of debate in this area, then this article is the one for you.

Varma, S., McCandliss, B. D., & Schwartz, D. L. (2008). Scientific and pragmatic challenges for bridging education and neuroscience. *Educational Researcher, 37,* 140-152.

http://www.aera.net/uploadedFiles/Publications/Journals/Educational_Researcher/3703/04EDR08_140-152.pdf

The journal *Phi Delta Kappan* (Feb 2008, Vol. 89, Issue 6) has a 'target article,' which is very positive (or optimistic) about the possibilities of using neuroscience in education.

Jensen, Eric P. (2008). A fresh look at brain-based education. *Phi Delta Kappan, 89*, 408-417.

Several researchers then wrote responses to this article, including:

Willingham, D. T. (2008). When and how neuroscience applies to education. *Phi Delta Kappan, 89*, 421-423.

Willingham did his dissertation research at Harvard University, where he worked on the psychology of motor skill learning and development, from a cognitive neuroscientific perspective. In recent years, he has been writing actively about neuroscience and education, as well as education in general. Most recently:

Willingham, D. T. (2009). Three problems in the marriage of neuroscience and education. *Cortex, 45*, 544-545.

He also has a column entitled 'Ask the Cognitive Scientist' in the journal *American Educator*, where he sometimes writes about neuroscience and education.

For example:

Willingham, D. T. (2006). "Brain-based" learning: More fiction than fact. *American Educator,* 30-37.

There is still much to learn about brain function and its relation to human psychological functions

The biological or physiological details of brain function are not a 'solved' problem. The 'classic' model of brain function (based on communication between neurons via synapses) is not necessarily the 'final' model.

Since the 1990s, several laboratories have produced evidence for the role of astrocytes (a kind of glial cell) in controlling synaptic communication between neurons. Here is a recent article that summarizes the current state of affairs.

Perea, G., Navarrete, M., & Araque, A. (2009). Tripartite synapses: Astrocytes process and control synaptic information. *Trends in Neurosciences, 32*, 421-431.

At this point there is no strong analysis of the relation between astrocytes and behaviour, plus the current understanding is that astrocytes are not involved in all neuronal activity. On the other hand, it does appear to be relevant in many different brain structures, which perhaps inspires these authors to refer to the 'glia revolution' (p. 429). I bring this example forward to illustrate that the scientific understanding of the physiology of brain function is still developing and changing. While one can certainly try to draw conclusions and implications about psychological processes based on our current understanding of cellular function in the brain, we must also remember that it is possible that we have not yet arrived at a sufficiently adequate model of brain function for the uses to which we want to put it.

And there continue to articles that raise new or different perspectives for thinking about brain function.

Raichle, M. E. (2010). Two views of brain function. *Trends in Cognitive Sciences, 14*, 180-190.

> Traditionally studies of brain function have focused on task-evoked responses. By their very nature, such experiments tacitly encourage a reflexive view of brain function. Although such an approach has been remarkably productive, it ignores the alternative possibility that brain functions are mainly intrinsic, involving information processing for interpreting, responding to and predicting environmental demands. Here I argue that the latter view best captures the essence of brain function, a position that accords well with the allocation of the brain's energy resources. Recognizing the importance of intrinsic activity will require integrating knowledge from cognitive and systems neuroscience with cellular and molecular neuroscience where ion channels, receptors, components of signal transduction and metabolic pathways are all in a constant state of flux.

Bressler, S. L., & Menon, V. (2010). Large-scale brain networks in cognition: Emerging methods and principles. *Trends in Cognitive Sciences, 14*, 277-290.

An understanding of how the human brain produces cognition ultimately depends on knowledge of large-scale brain organization. Although it has long been assumed that cognitive functions are attributable to the isolated operations of single brain areas, we demonstrate that the weight of evidence has now shifted in support of the view that cognition results from the dynamic interactions of distributed brain areas operating in large-scale networks. We review current research on structural and functional brain organization, and argue that the emerging science of large-scale brain networks provides a coherent framework for understanding of cognition. Critically, this framework allows a principled exploration of how cognitive functions emerge from, and are constrained by, core structural and functional networks of the brain.

There is still much to learn about how to conceptualise brain function in relation to human action

The general idea that there is a connection between brain activity and psychological performance and experience seems to be generally accepted. Thereafter, it is difficult to describe or explain specific connections. There are conceptual problems about how to relate these physiological details to phenomena that are interesting from an educational point of view (e.g, learning, thinking, problem solving, reading, etc.). Here is a recent article, which reflects a line of argument being developed by a number of different researchers, that one cannot understand (or reduce) psychological phenomena from brain processes alone.

van Dijk, J., Kerkhofs, R., van Rooij, I., & Haselager, P. (2008). Can there be such a thing as embodied embedded cognitive neuroscience? *Theory & Psychology, 18*, 297-316.

A few extracts from their abstract:

> Since the 1990s, philosophers and cognitive scientists have started to question this position [that cognizing is something that the brain does], arguing that the brain constitutes only one of several contributing factors to cognition, the other factors being the body and the world. … We put forth a new guiding metaphor of the role of the brain in cognitive behavior to replace the current cognitivist metaphor of the brain as an information-processing device.
>
> http://tap.sagepub.com/cgi/reprint/18/3/297

or take a look at this short article by one of the pioneers of cognitive neuroscience

Gazzaniga, M. S. (2010). Neuroscience and the correct level of explanation for understanding mind: An extraterrestrial roams through some neuroscience laboratories and concludes earthlings are not grasping how best to understand the mind-brain interface. *Trends in Cognitive Sciences, 14*, 291-292.

And what about ideology….

For some reason, there seems to be a tendency to more readily or more easily accept brain-based arguments as having more (scientific?) validity. Why?

The (everyday) effects of that tendency can be seen in the following experiment with university undergraduates.

McCabe, D. P., & Castel, A. D. (2008). Seeing is believing: The effect of brain images on judgments of scientific reasoning. *Cognition, 107*, 343-352.

> Brain images are believed to have a particularly persuasive influence on the public perception of research on cognition. Three experiments are reported showing that presenting brain images with articles summarizing cognitive neuroscience research resulted in higher ratings of scientific reasoning for arguments made in those articles, as compared to articles accompanied by bar graphs, a topographical map of brain activation, or no image. These data lend support to the notion that part of the fascination, and the credibility, of brain imaging research lies in the persuasive power of the actual brain images themselves. We argue that brain images are influential because they provide a physical basis for abstract cognitive processes, appealing to people's affinity for reductionistic explanations of cognitive phenomena.

The article is fairly short, well-written, and the abstract does not reveal its sophisticated experimental design. In principle, these results may not generalise to people with research training, but it certainly lends support to the idea that there is an uncritical, popular bias to arguments that are accompanied with brain images.

And here is another paper, from the same journal, by a British biologist and a British sociologist. Perhaps its analysis gives some hypotheses about the (possibly unintended) assumptions that lie behind a preference for neurobiological explanations.

Rose, S. P. R., & Rose, H. (1973). 'Do not adjust your mind, there is a fault in reality' – Ideology in neurobiology. *Cognition, 2*, 479-502.

> The paper considers the relationship between scientific knowledge and the social context within which science is done. Because of the relationship of science and scientists to the state, scientific paradigms may be ideological, and much that is done in the name of science may itself be ideologically saturated. The dominant ideology in neurobiology is that of reductionism, and indeed reductionism is argued by its proponents to constitute the scientific method, with ethical overtones, whilst opponents of science cite reductionism as exemplifying the inevitably oppressive nature of science. Within neurobiology, several types of reductionism are considered. Molecular reductionism seeks biological causes for socially observed events, for instance, schizophrenia and depression. Its consequences, in relationship to 'minimal brain dysfunction' and psychosurgery, are considered. Genetic determinism in relation, e.g., to intelligence (IQ), is another form of this type of reductionism. Evolutionary reductionism attempts to explain human behavior in terms of that of primates and other non-human

> animals, hence seeking to justify the existing social order as dependent on a biological base. Category reductionism includes behaviorism and machine reductionism; in this latter, attempts are made to reduce the brain to the interactions of simply modellable logical neuronal networks. Against reductionism, autonomism as a separate type of paradigm is briefly discussed and rejected. A non-ideological, and hence scientific and non-oppressive paradigm, would be a version of interactionism, dialectical materialism; such a science cannot be fully realized except in a transformed society.

Finally, the following may be interesting.

Bennett, M. R., & Hacker, P. M. S. (2008). *History of cognitive neuroscience*. Chichester: Wiley-Blackwell.

I have not seen this book, but here is a snippet from a review:

> Do brains see, attend, remember, think, understand, translate, and emote? More to the point, do synaptic networks possess psychological attributes? In a provocative century-plus spanning history of empirical work in cognitive neuroscience, Maxwell Bennett and Peter Hacker answer a resounding no.
>
> This book continues the collaboration of neuroscientist Bennett and philosopher Hacker that began with the publication of *Philosophical Foundations of Neuroscience* (2003). That book was the first systematic examination of neuroscience's conceptual structure. In *History of Cognitive Neuroscience*, the authors advance their analysis by examining major threads of empirical investigation, outlining what investigators believed they discovered and the conclusions they drew, and then subjecting these investigative accounts to critical scrutiny. (Wight, 2010, p. 329)

Wight, R. D. (2010). M. R. Bennett and P. M. S. Hacker. *History of Cognitive Neuroscience* [review]. *Journal of the History of the Behavioral Sciences, 46*, 329–331.

Conclusion?

It is understandable that some are optimistic about the potential of cognitive neuroscience in relation to education — but we should not mistake potential for accomplishment! It may be interesting to look at current cognitive neuroscience, but you must apply your critical reading skills, and you must evaluate whether existing results are a sufficient basis for action in relation to educational issues.