Neuroscience and Education

Report following sabbatical

Simon Lamb

May 2009

Acknowledgements

I start by acknowledging the Ministry of Education for the opportunity to take a sabbatical in Term 2, 2009. It has been a wonderful opportunity to pursue an interest, the study of neuroscience and a belief that developments here should be informing education. This report serves to investigate the dynamics and the developments of this issue, rather than the specifics learned along the way.

I thank John Poulter for organizing school visits to two Tower Hamlet Schools. I hope to return the favour one day. These visits did much to establish my perceptions of East London students and the lives they live. I was astounded by their enthusiasm, curiousity and gregariousness. I learned much in my discussions with them and the staff at these schools. I also thank Brian Butterworth, University College of London and Anne Cook, University of Bristol, for their support and time in assisting me with great information and references.

Introductions

In 1990 "Decade of the Brain" was launched in the USA. It promoted left versus right brain and brain gym activities and learning styles a pattern tending to draw more from psychology (Brues 1999) than neuroscience. There is a strong feeling that Brain Gym and other learning brain based models were not tested scientifically nor educationally and tend to use pseudo-scientific explanations. Twelve years later a group of neuroscientists began to suggest that education would benefit from a greater awareness of the functions of the brain

Most notably Uta Frith and Sarah Jayne Blakemore were commissioned by the Teaching and Learning Research Programme (Blakemore and Frith, 2000). This research attacked a number of myths and highlighted other issues such as the role of sleep in learning. The review highlighted neuroscience questions that might be of interest to educators, the first step in collaborative research. This started in 2001 by writing to 233 science institutions and 193 educational institutions. Only 14 educational organizations responded!

In 1999 a supranational OECD project on "Learning Sciences and Brain Research" was being launched by the OECD centre for Educational Research and Innovation. It came in two phases.

Phase 1: 1999-2002 brought together international researchers to look at potential implications of findings in policy making.

Phase 2: 2002 – 2006 channeled the focus on three main issues:
Literacy
Numeracy
Lifelong learning lead by Sackler Institute USA; INSERM – France; RIKEN Brain science institute – Japan

By 2005 a number of key events took place. The University of Cambridge opened up Centre for Neuroscience and Education at the faculty of Education. A major seminar series took off “Collaborative Framework in Neuroscience and Education” Japan and Germany lead with their own innovations concurrently.

The OECD also published a summary of their interim findings too. Both highlight similar areas of interdisciplinary interest such as plasticity, emotion and understanding the developmental disorders such as dyslexia. This contrasts with the emphasis found in the previous brain based programmes of the 1990s.

Approaches to learning under the heading of Accelerated Learning are more eclectic mixture of popular reported neuroscience and psychology. Neuroscience and psychology are often used to promote and explain learning mechanisms. Accelerated learning often embraces Multiple Intelligences (Gardner’s Theory) is plastic intelligence rather than one fixed intelligence.

As well as learning style references educators and scientists are again paying attention to the notion that education can be improved with insights from neuroscience and a new interdisciplinary research agenda is underway.

Central to the success is the need to support teachers in their understanding of neuroscience. However in addition to the issues mentioned above there was much debate about the role of neuroscience in education. The first is the perception of “learning” in science versus education. In science learning is studied in context. For example a study of young aboriginals in Australia will highlight the modeling that occurs as a young ones learn off patterns modeled by their elders. Learning, in an educational sense, occurs without reference to context and often in an abstract situation.

There is also the perception of teachers in terms of importance neuroscience in the classroom. Perceptions of neuroscience and its role can be compelling if not based on accurate research. The London taxi drivers and the enlarged hippocampus did clasp some accuracy. Those not so accurate were more inclined to draw on psychology rather than neuroscience.

If such programmes are effective we do not truly understand why as yet. The science can be over interpreted and misapplied, especially in the context of students containing a certain learning style. What is clear is the importance of neuroscientists and teachers working together (see www.innovation-unit.co.uk)

In the investigation to the role of neuroscience in education evidence was collected in two stages:

1

Questionnaire to identify key issues in educators perceptions of the role of neuroscience and education. The questionnaire was developed in 2007

2

Semi structured interviews with teachers

Initial investigation of key issues carried out in two conferences held in June and July 2005. The first organized by a group of headteachers from Macclesfield.

The interviews with teachers:

Some held at the Education and Brain Research Conference in Cambridge/ others at Bristol

Questionnaires findings
54% teachers (Primary and Secondary) 46% from others in education

Educators understanding of "education" and "neuroscience"

For Education the response was varied
31% learning
19% dev of someone's potential
15% preparation for future life in society
7% lifelong process
17% all the rest

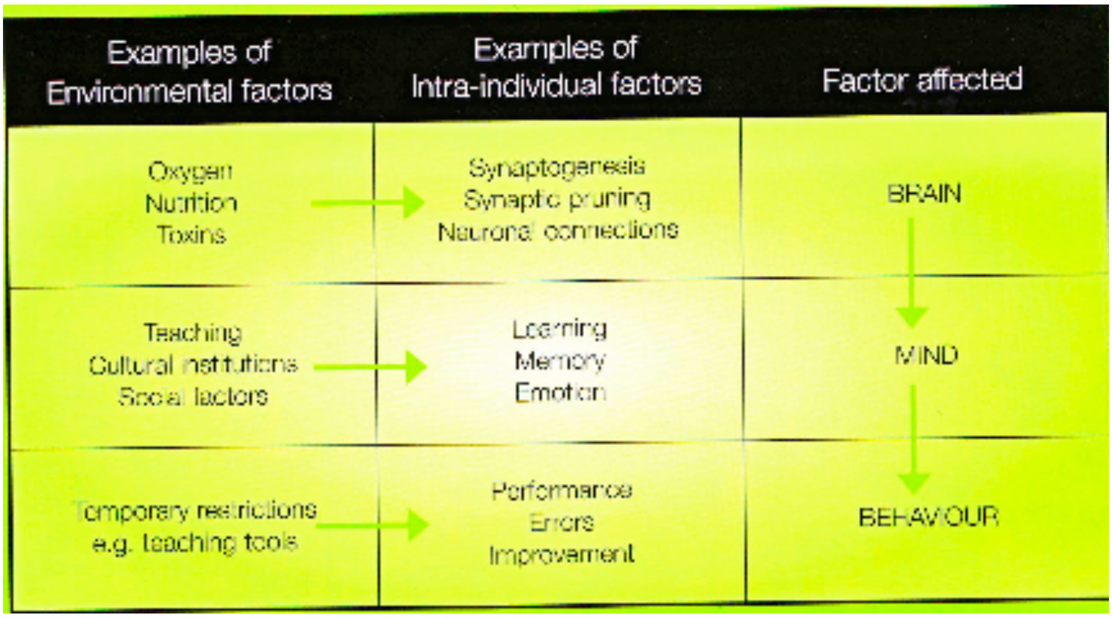
For Neuroscience the response was less varied
60% - "study and science of the brain"
24% learning
13% how brain works

So the role of neuroscience and education is born in an environment where science and education need to define what exactly learning is. From there the investigation can establish itself. In the vacuum, brain based models for learning have been promoted under the guise of neuroscience leading to some misperceptions about what exactly is psychological and what is neuroscience.

Neuroscience and Education

Aside from the debate over the role of neuroscience and education there are some obvious impacts the research within the realm of science could inform education, particularly in respect to strategies for teaching and learning. While the issues remain, the clarity in the connection between the research and education do not appear to have real connections, at least within New Zealand's education system. There is an obvious connection to psychology and the various teaching and learning strategies tenuously linked to neuroscience. There are few examples of such programmes having been evaluated and they often appear to have been developed without neuroscience scrutiny.

Many different experimental techniques are used in brain research. The outcomes of MRI have probably attracted the greatest popular interest. However such images only provide the image of the biological changes within the brain, such as blood flow. They do not allow us to see the thinking or the learning directly. To understand what such an image has to do with learning we need a psychological model to help relate it to our mental processes. When cognitive models and our knowledge of biological processes inform each other then we can be more confident abut both. Cognitive neuroscience is very much concerned with exploring this relationship between the biology of the brain and the cognition of the brain. In this way the cognitive neuroscience is also drawing new attention to the variety of existing psychological concepts relevant to education, and in a very visual manner.



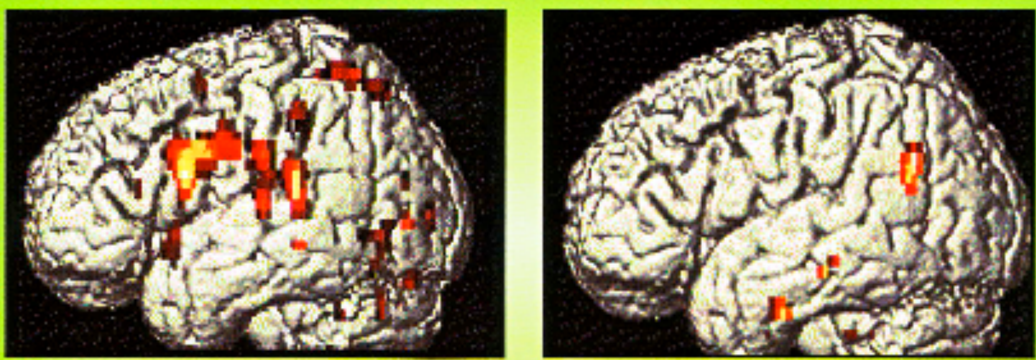
Working memory is one example of how neuroscience is helping conceptualize psychological concepts. Working memory is our capacity to temporarily hold a limited set of information in our attention when we are processing it. This limitation is why we prefer to write down a phone number a few digits at a time rather than be told the whole number and write it down in its entirety at the end of articulation. The average upper limit is a bout seven chunks of information, but there are individual differences in this limit linked to differences in educational achievement:

BACKGROUND: Close links between children's capacities to store and manipulate information over brief periods have been found with achievements on standardized measures of vocabulary, language comprehension, reading, and mathematics. AIM: The study aimed to investigate whether working memory abilities are also associated with attainment levels in the national curriculum assessments at 7 years of age. SAMPLE: Eighty-three children aged 6 and 7 years attending local education authority schools participated in the study. METHODS: Working memory skills were assessed by a test battery designed to tap individual components of Baddeley and Hitch's (1974) working memory model. Children were assigned to normal and low achievement groups on the basis of their performance on national curriculum tasks and tests in the areas of English and mathematics.

RESULTS: Children with low levels of curriculum attainment showed marked impairments on measures of central executive function and of visual-spatial memory in particular. A single cut-off score derived from the test battery successfully identified the majority of the children failing to reach nationally expected levels of attainment.

CONCLUSIONS: Complex working memory skills are closely linked with children's academic progress within the early years of school. The assessment of working memory skills may offer a valuable method for screening children likely to be at risk of poor scholastic progress.

However, understanding children's' dependency upon working memory becomes more real when brain activity associated with mathematical training are visible. In one recent study adults learning long multiplication demonstrated a shift with practice, in the areas of the brain they were using to complete their calculations. At first considerable demand upon working memory was demonstrated by activity in the left frontal gyros, as students explicitly and formally followed the processes they were learning. After practice this activity reduced and was replaced by greater activity in the left angular gyros, as processes became more automatic. The images generated by this study provide a helpful and very visual illustration of how the types of mental resources required to solve a problem change with practice. They resonate well with classroom observations of the difficulties faced by learners when engaging with new problems. In such situations, it can be particularly helpful for pupils to show their working since, apart from other advantages, external representations can help offload some of these heavy initial demands upon working memory.



Hot spots show where brain activity decreased after participants undertook mathematical training – reflecting a decreased demand on working memory

A different analysis of the same participants, this time with hot spots showing areas where brain activity increased after mathematical training – reflecting an increase in automatic processing"

The construction of meaning has also been identified as a key to understanding and remembering information. When we learn new information the links that form between this information and our existing knowledge serve to make it meaningful. As an area of the left hemisphere, the left prefrontal cortex has been identified as a vital structure in this construction of meaning. When we learn something new additional activity in this area occurs when we try to decide upon its meaning in relation to what we know already. The new information becomes more memorable once we have completed this process of memory making. How much more memorable the information becomes is linked to the amount of increased neural activity in the left inferior prefrontal complex.

A better understanding of the earliest processes involved in learning a new subject may also help orientate new approaches to mainstream teaching. Again, psychological data suggests that we have an automatic and early preference to represent the magnitude of a number if on a line traveling from left to right. Neuroimaging studies have linked this ability to activity in the intraparietal sulcus and Goswami suggests that such evidence supports spatial based approaches to teaching about ordinalty, the order and sequence of numbers, and place value.

These approaches include using empty number lines to improve efficiency, especially when adding and subtracting numbers of more than one digit.

Biology provides no simple limit to our learning, not least because our learning can influence biology. For example, although the number of neurons we possess does not change greatly through our life course, it has been known for sometime that experience can change the number of connections between them, our synaptic destiny. More recently there has been several pieces of research demonstrating how even the structure of the brain, including the adult brain, can be changed by educational experience. In a recent study of juggling, the brain areas activated at the beginning of a three-month training period increased in size by the end of it. After three months of rest, these areas had shrunk back and were closer to their original size. This graphic example of "use it or lose it" demonstrates the potential importance of education in mediating the brain development throughout our lives. Further evidence of the effects of education on brain structure comes from research in to Alzheimer's disease, which is associated with the death of brain cells due to the development of deposits called plaques within the brain and the formation of tangible of fibrils within individual brain cells. Despite the biological basis for the disease, it is becoming increasingly clear that the risks of developing Alzheimer's disease later in life are reduced not only by educational attainment but also by the level of challenge encountered in one's working life. Even after the onset of Alzheimer's there is evidence that training can diminish the progress of some symptoms.

"Dementia is among the most feared consequences of growing old, and with the aging of the generation born after World War II, its prevalence is expected to increase in most industrialized nations in the coming decades. Cognitive decline and dementia in late life are the result of multiple environmental and genetic risk factors interacting with multiple age's related pathological changes taking place in the brain. The good news is that recent studies have identified a range of lifestyle factors associated with risk of dementia, including characteristic levels of cognitive, social, and physical activity and proneness to experience negative emotions, suggesting that some proportion of risk may be modifiable" Wilson R S (2005)

Geake and Cooper argue that as cognitive neuroscience advances our understanding of the very basics of learning, so there is a need for educationists to appropriate this research with regards to implications and applications for teaching in formal educational settings, especially school classrooms (Geake, 2000). Such a return to the fundamentals of teaching and learning might even help to reclaim the education agenda from those politicians and board room directors whose predominantly instrumental objectives for schooling and further education have caused such dismay within the teaching profession of late (Walden, 1996; Johnson & Hallgarten, 2002; Woodhead, 2002).
In other words, a good reason for educationists to embrace cognitive neuroscience is the hope that such an endeavour might stem the increasing marginalization of teachers as pedagogues. We can only agree with Johnson and Hallgarten (2002), that 'teachers

must be empowered once again … to design curricula and pedagogies, because they are in the best position to judge how to engage young people' (p. 12). Our argument is that some knowledge of cognitive neuroscience should be included in the knowledge base, which underpins such re-empowerment. This may be all the more urgent given current global political and commercial pressures, particularly from the information and communication technology (ICT) industry, to replace human teaching with on-line information retrieval. We assume that education will remain largely a human endeavour and, to that end, teachers will always be interested in gaining a better understanding of the multitude of factors which govern the learning of their charges. Such teacher professional development, we suggest, should embrace an understanding of developments in cognitive neuroscience. Therefore, we propose that education adopt an interactive bio-psycho-social model, which can only come about if educationists engage cognitive neuroscientists in dialogue to share each other's professional knowledge.

Conclusion:

Our burgeoning knowledge of the brain is producing expectations of new educational insights and many such insights are already beginning to surface. At the same time, neuroscientists are becoming increasingly interested in how the brain functions in complex environments more closely resembling those found in classrooms. Education thus appears set to become an interesting area of challenge for cognitive neuroscience as it attempts to explore new contexts. Some neuroscientists have even suggested that education might be considered as a process of optimal adaptation such that learning is guided to ensure proper brain development and functionality. This sense of increasing mutual interest underlies calls for a two-way dialogue between neuroscience and education that could helpfully inform both areas.

"Research into the functioning of the human brain, particularly during the past decade, has greatly enhanced our understanding of cognitive behaviours which are fundamental to education: learning, memory, intelligence, emotion. Here we argue the case that research findings from cognitive neuroscience hold implications for educational practice. In doing so we advance a bio-psycho-social position that welcomes multi-disciplinary perspectives on current educational challenges. We provide some examples of research implications, which support conventional pedagogic wisdom, and others which are novel and perhaps counter-intuitive. As an example, we take a model of adaptive plasticity that relies on stimulus reinforcement and examine possible implications for pedagogy and curriculum depth. In doing so, we reject some popular but over-simplistic applications of neuroscience to education. In sum, the education profession could benefit from embracing rather than ignoring cognitive neuroscience. Moreover, educationists should be actively contributing to the research agenda of future brain research." Geake, J. G., & Cooper, P. W. (2003). Implications of cognitive neuroscience for education. Westminster Studies in Education, 26(10), 7-20.

Of course brain scans cannot give rise directly to lesson plans. There is a need for bridging studies that interpret scientific results in terms of possible interventions and evaluation of these interventions in suitable learning contexts. One example of such research comes for InnsBruck, where brain imaging and educational interventions have been used to understand the basis of dyscalculia and methods to remedy it. Experimental imaging results suggest the need for basic numeric and conceptual knowledge at an early stage of mathematical education. A classroom intervention also demonstrated that children with dyscalculia can show considerable improvements ion a broad range of calculation abilities when these areas of learning often neglected in mathematics are specifically focused on. Another challenge for professionals dealing with dyscalculia concerns the fact the calculation abilities often appear to be related to non numerical skills such as visual spatial cognition, language and working memory. A deeper understanding of the interplay between numerical and spatial cognition appears likely to influence teaching methods and mathematics curricular in the future. Therein lies the belief that developments within neuroscience should inform education in to the future.

Simon Lamb
Principal
Takapuna Grammar School
June 2009