



Collaborative Frameworks for Neuroscience and Education

Scoping Paper

A new TLRP-ESRC Seminar Series for 2005-2006

1. Introduction

This document has been produced in preparation for the ESRC-TLRP Seminar Series “Collaborative Frameworks for Neuroscience¹ and Education”. It is for discussion purposes only and seeks to:

- Identify issues characterizing the broadest interpretation of the scope of the seminar series.
- Begin to raise questions that may be directly addressed through discussions arising from the seminar series and/or evaluated during the series for their tractability and value as potential future research questions

The document begins with a short *indicative* review of recent instances of neuroscience interacting with education and this is divided into 3 areas. These areas are formulated on the basis of 3 very broad interest groups within education. The first is “Developmental Disorders”, where neuroscience has made the most significant impact to date, chiefly supported by the interests and motivations of educational psychologists. The second is “Teaching and Learning”, which includes issues of broad interest to those involved with the daily practice of teaching and learning. The third is “Curriculum”, where policy makers and educators have traditionally drawn upon a wide spectrum of factors when determining what should be learnt and when, including those derived from our knowledge of human development. Section 3 involves a brief and speculative appraisal of recent developments in neuroscience that may be significant for education in the future. Section 4 discusses issues pertaining to the potential theoretical interrelationship between neuroscience and education, which is of undoubted importance to issues of perception discussed in Section 5. Finally, Section 6 touches upon research agendas and the general types of projects that might pursue them.

2. Review of present work of interdisciplinary significance

2.1 Developmental Disorders – the impact of neuroscience on educational psychology

2.1.1. Dyslexia

The neural mechanisms of normal reading and normal reading development are still to be fully understood. A popular model involves two processors, orthographic and phonological, interconnected to a meaning processor which, in turn, is interconnected to a context processor (Seidenberg & McClelland, 1989). This idea has been supported by a number of neuroscientific studies that have associated separate brain regions with these processes. Byrnes(2001a, p143) highlights, here in the context of reading, the need to bridge the gap between neuroscientific knowledge and teaching approaches - an issue of general importance to this seminar series:

“...there is a fundamental gap between any given theoretical carving and instructional practice. Teachers, for example, need to know more than the fact that reading involves four processors in order to know how to promote reading skills in their

¹ John Bruer (2004) has warned of the dangers of attempting to go directly from neuroscience to education without recognising the importance of the intermediate psychological science (although some successful examples exist of this type - see 2.2.3 below). The field of cognitive neuroscience is thus of particular significance to education and the term “neuroscience”, often used below and also referred to in the title of the seminar series, may best be considered as referring chiefly to cognitive neuroscience.

students. They also need to know how to promote the development of these four processors and their interconnections. “

In reading, particular attention has been paid to the difficulties encountered by dyslexics, which have been informed by, and informed, neuroscience. The nature of the brain-basis of dyslexia is still disputed. High heritability (40% of siblings share dyslexia, Shaywitz, 1996) point to a biological basis, but non-genetic environmental factors still account for more than half of the variance in the data (DeFries et al., 1993). Although some researchers suggest a visual basis for the disorder (Stein, 2001; Wilmer et al, 2004), dyslexia is most often explained in terms of problems with phonological processing. The usually rapid development of speech-sound and sound-to-letter decoding may be hindered in dyslexics, due to deficiencies in these start-up systems. This has prompted the suggestion that slower learning in the initial stages of literacy acquisition may be more easily facilitated by special programs (Frith, 1999). Recent investigations of auditory processing by dyslexic children using ERP's suggest that their phonological systems may be immature rather than developing in an essentially different way. Perceptions of dyslexia based on delay, rather than deviance, has clear implications for any remedial reading programmes. The unusual ERP patterns of dyslexics in phonetic distinction tasks (Csepe, 2003) has prompted suggestions that ERP might offer a method of identifying early those children at risk from dyslexia, thus facilitating appropriate interventions (Goswami, 2004).

Q: What are the issues and opportunities associated with “neurophysiological testing/screening” for disorders such as dyslexia, dyscalculia, in the early years?

Increases in reading skill are associated with increased activity in the temporo-occipital regions of the brain, and activity in these regions is decreased in children with dyslexia (Shaywitz, 2002). The main site associated with the types of phonological difficulties associated with dyslexia is the temporo-parietal junction, where dyslexic children also show reduced activation in rhyming tasks. Targeted intervention that increases reading skills can also increase activation in this area (Simos et al, 2002). However, such an apparently simple link between a cognitive difficulty, educational remediation and brain activity may be deceptive, since it has also been suggested that dyslexics compensate for their difficulties with increased right hemisphere activation, consistent with recent MEG findings (Heim, Eulitz, & Elbert, 2003).

Q: To what extent should we expect successful “educational” remediation to be linked with increased activity in particular areas of the brain?

Q: Can physiological measures/imaging help *evaluate* strategies for remediation? Can such physiological investigations ever provide insights that are more meaningful than appropriate educational/cognitive/behavioural assessment?

2.1.2 Dyscalculia

Byrnes (2001a) considers that instructional implications of our scientific understanding of mathematics should be based on the psychological perspective until more neuroscientific studies are conducted (see Byrnes 2001b for review). However, the work of Dehaene and Cohen (1997) has shown that cognitive neuroscience can take us beyond existing cognitive models, with their proposal of a “triple-code” model for representation of numbers:

1. Visual Arabic Code (left and right inferior occipital-temporal areas) – subserving multidigit operations, identifying strings of digit and making parity judgements (e.g. knowing numbers ending in 2 are even).
2. Analogical quantity or magnitude code (left and right inferior parietal areas) – for representing on a number line, allowing judgements of proximity (3 near 4) and ordinal relations (3 less than 4). This phylogenetically old ‘number sense’ is evident in animals and infants (Dehaene, Dehaene-Lambertz, & Cohen, 1998). It has been suggested by Dehaene and Cohen (1997) that problems with this innate approximation ability may explain many of the instances of dyscalculia, with Blakemore and Frith (2000, p40) suggesting that this may indicate the need for early intervention.
3. Verbal code (left perisylvian) – representing numbers via a parsed sequence of words - for rote learning of mathematical fact. It has also been suggested (Goswami, 2004) that if dyslexia has a phonological basis, then the types of dyscalculia so often comorbid with dyslexia may have their basis in this area too.

2.1.3 Attention Deficit Hyperactivity Disorder ADHD

ADHD occurs in 3-7 % of the population (Barkley, 1997) and is thought to be related to frontal lobe abnormalities. Medication such as Ritalin targets the dopaminergic (DA) and noradrenergic (NA) tracts that feature in neural models of attention (Solanto, 1998). In the NA system it has been shown to improve delayed responding and working memory and its effect upon the DA system of rats has been to improve responsiveness to reinforcement.

ADHD is of particular interest to educators because sufferers usually exhibit classroom behaviour that is particularly challenging and do not appear so amenable to routine management strategies. There are also various drawbacks to purely pharmacological treatments for ADHD that do not involve monitoring by teachers who are informed with an understanding of ADHD, and who are with the children daily. There are several additional arguments for educational practitioners and teachers to be more informed of the brain-basis of ADHD and its medication (Cooper and Bilton, 2002). The children themselves and their teachers may come to believe that any observed improvements are purely artefacts of the medication and there may be a need for teachers to anticipate

- the effects upon self-esteem of taking the medication itself
- the usual “ups and downs” of behaviour even when a positive result from or the medication has been obtained (DuPaul and Stoner, 2003, p224)
- rebound when the medication wanes (Brown and LaRosa, 2002).

Jones (2002) warns against allowing children to believe that they have a “broken brain” and that a narrowly neurobiological focus “discounts the uniqueness of the individual and the meaning of inner personal experience”. Rowland et al (2002) remark that approaches based purely on medical therapy ignore the complex interaction with ecological dynamics, this providing an exonerating excuse for teachers to justify problematic behaviours under the façade of within-child deficits (Breggin and Breggin, 1994). Success of treatment is determined in large part by changes in school performance (DuPaul and Stoner, 2003, p225) although the relationship between behaviour and achievement in these instances may not be a simple one (DuPaul and Stoner, 2003, p199). It may be important for teachers to understand the brain basis of ADHD to be clear that its associated medical treatment does not “cure” but rather manages AD/HD by helping “the individual to be present cognitively in such a way that learning of adaptive strategies can occur” (Cooper & Ideus, 1996, p70).

There appears to be a multimodality superiority effect of combined medication and behavioural (parent and classroom) treatments that, although not surpassing purely medical treatments in terms of alleviating the core symptoms, do show marked improvements in exchanges, conduct and compliant behaviour (Jensen et al, 1999). Classroom contingency management (DuPaul and Eckert, 1997), peer tutoring (DuPaul et al, 1998), computer assisted instruction (DuPaul and Stoner, 2003), task and instructional modification, and strategy training (DuPaul and Stoner, 2003) all show promise in terms of their positive influence upon the learning of children with ADHD.

Q: Can the development and use of instructional techniques for children with disorders such as ADHD (including as part of multimodal packages) benefit interdisciplinary approaches to educational research that also attend to the neurocognitive basis of the disorder and the medication used to manage it?

Randomised controlled trials of treatment with certain highly unsaturated fatty acids has shown that such dietary supplements can improve the academic achievement of children with ADHD (Richardson and Puri, 2002; Richardson, 2004). Such nutritional supplements are commercially available without prescription and increasingly widely used in the belief that they can enhance learning.

Q: Should educational researchers concern themselves with the broader effects of these nutrients, and others, on the achievements and behaviour of children in schools?

2.1.3 School Phobia

Miike et al. (2004) recently used radiological imaging techniques to identify disturbances in the metabolic system of the brains of children suffering from school phobia. They linked these disturbances, and thus the associated decreases in motivation and ability to learn, to modern environmental factors. They drew on these results to emphasise the importance of understanding the biological rhythms of children when attempting to support scholastic achievement.

2.2 Teaching and Learning – Using knowledge about the brain to improve the teaching of typical students

2.2.1 Attention and motivation

Vygotsky (1978) considered that there were two types of attention: a natural kind of attention that was involuntary and a higher order of attention that was voluntary and motivated by the individual. Educators are chiefly interested in the second type of attention that, with its association with free-will, is less amenable to scientific study. This may explain why, despite some overlap between the psychological and neuroscientific literature, neither has been very productive in terms of providing new strategies that encourage typical students to focus their attention upon typical tasks. Even the link between attention and motivation is rarely approached scientifically, and is best represented in the educational literature (Wittrock, 1991).

Q: What happens in the brain when we willfully concentrate our attention?

However, cognitive neuroscience may shed light upon the how our motivation to attend is influenced by reward and punishment. Zalla et al. (2000) revealed that different responses occurred in the amygdala, an area of the brain strongly connected with others associated with learning, depending upon whether a task

response was followed by “WIN” or “LOSE”. Although consistency in the classroom is seen as beneficial, the desire to carry out a task can be positively influenced by a reward being uncertain, as evidenced by the attractiveness of gambling. Elliot et al. (2000) has used fMRI to identify the neural correlates of gambling and these included areas also associated (Thut et al, 1997) with financial reward (e.g. the thalamic and ventral striatal regions). Studies with monkeys have also provided clues about how reward uncertainty may actually increase motivation, thus suggesting a brain-basis for the pleasures of gambling and also the addictive aspects of computer-games (Shizgal and Arvanitogiannis, 2003). Indeed, the uncertainty of outcome in some video games is an important aspect of the challenge that provides pleasure (Loftus and Loftus, 1983, p41). In education, there has been much discussion about whether the motivational aspects of computer games (Gee, 2003) can be identified and tapped into, in order to support the engagement of pupils in learning tasks.

Q: Can interdisciplinary approaches help to increase our understanding of children’s motivation in the classroom?

In a study involving a computer-based ball-tossing game, Eisenberger et al. (2003) demonstrated that the neural correlates of the social pain caused by exclusion from a collaborative computer activity appear to parallel those of physical pain.

Q. Many cognitive aspects of computer-based experiences, including learning and even collaborative learning, appear more amenable to investigation by neuroimaging than classroom experience. Should future interdisciplinary research be targeted here?

2.2.2 Memory and the retention of knowledge

Psychological models of memory have been produced through behavioural studies that offer a considerable number of insights and strategies to enhance memory retention. Neuroscience has contributed to these insights through revealing neural correlates of memory processes that are chiefly consistent with these underlying psychological models (for a review see Byrnes and Fox, 1998). Strategies for the enhancement of retention have been created using these models and evaluated for their educational potential (e.g. Pressley et al., 1982). More recently, studies that have attempted to train working memory have been carried out. Olesen, Westerberg and Klingberg (2004), for example, gave adults training in a visuo-spatial working memory task over a period of 5 weeks. fMRI scanning produced evidence of training-induced plasticity in areas of the brain associated with working memory performance (see also Landau et al., 2004; and Jonides, 2004).

2.2.3 Neurofeedback

A programme of training in the use of EEG feedback provided significant improvements for students of music in terms of their performance (Egner and Gruzelier, 2003). This is an interesting example of a technique being borrowed from neuroscience to provide direct improvements for learners and, as such, is unusual. Despite its apparent success, the intervention was not built around any particular cognitive model and the processes by which improvement were achieved are not well understood. Improvements in other types of cognitive performance have been fostered by similar means (Egner and Gruzelier, 2001)

Q: Since this was a successful intervention, should more be done to understand neurofeedback works and whether it can be more widely applied?

Technology is also now being developed to produce direct brain-computer interfaces based on EEG (BBC, March 2004).

2.2.4 Problem-solving and creativity

A recent fMRI study challenges the popular use of anomalous evidence in constructivist teaching (Fugelsang and Dunbar, in press – see Pettito and Dunbar, 2004). When students of physics were presented with evidence that was consistent with current theories, areas commonly associated with learning, such as the caudate and parahippocampal gyrus, were activated. When presented with evidence that was inconsistent with their theories, activation occurred chiefly in the anterior cingulate and the Dorso-lateral prefrontal cortex DLPFC. This was used as evidence to suggest that, since these latter parts of the brain are associated with error detection and conflict monitoring, the teaching strategy of using anomalous evidence encourages inhibition, rather than transformation, of naive concepts.

The inclusion of random material in an open creative task is a well known strategy for producing outcomes that are judged as more creative, although it is difficult to establish whether the strategy encourages additional processing of the type associated with creative thought. In a factorial fMRI study, Howard-Jones et al. (2005) showed that activity associated with pursuing a creative objective in a story-telling task was increased when participants were required to include words that were less semantically related. This result was used as evidence to suggest such strategies do encourage additional processing of the type associated with creative activity and are, therefore, beneficial to learners.

Q: Both of these studies make judgements about the effectiveness of learning strategies based on brain activity. It is true that increases in blood flow during tasks that are repeated in an “educational” programme have been associated with longer-term changes in volume of that structure (e.g. Draganski et al, 2004). However, these links between blood flow in the brain and effortful learning are not clearly understood (for example – we do not know the details of what physiologically accounts for increases in volume). Are these neuroscientific issues of general significance for education? Would a better understanding of learning-induced plasticity, and its apparent physiological precursors such as blood flow, be of fundamental importance in using neuroimaging, and other techniques, to make claims about the effectiveness of a teaching and learning strategy?

2.2.5 Learning about our own brains

The development of a theory of mind in the pre-school years has been linked to children’s later abilities to think critically and reason scientifically (Astington and Pelletier, 1996).

Q: Should educators focus more upon enhancing children’s understanding of their own and others’ minds, including their brains, in the belief that this construction of mind/brain is a fundamental tool of learning?

2.2.6 Other approaches – “brain-based” learning

There are a host of approaches to teaching that claim to be brain-based. Some of these offer general advice which is not strikingly different from common sense, such as the importance of positive emotional support (Diamond and Hopson (1998) p107).

Q. The claims that such intuitive advice is brain-based can be debated at length, but is the role of science to produce more counter-intuitive insights anyway (Blakemore and Frith, 2000)?

The effectiveness of all popular brain-based approaches, however, often remains unscrutinized by scientists and unevaluated by educators. Aside from this, there are also a number of myths about the brain that exist in popular culture and may be applied and even reinforced through pedagogy (see Neuromyths).

Q. How does this lack of scrutiny and popular “psycho-babble” influence perceptions about the practical worth of brain science in education? What should/can be done about it?

2.3 Curriculum: When should we learn what?

Neuroscientific findings have been used to support proposals that children should start studying languages, advanced mathematics, logic and music as early as possible (Beck, 1996; US Dept of Education, 1996). However, there is no established approach to interpreting what we know about plasticity in educational terms and the processes themselves are still being researched. It is known that synaptogenesis is greater in the earlier stages of the human life course. For example, in the human visual cortex, a peak in the number of synaptic connections occurs between 8-10 months with synaptic density levelling out at around 10 years (Huttenlocher, 1990). However, the link between synaptic genesis and cognitive capacity is not straightforward (Golman-Rakic, 1987). We do know, however, that there are sensitive periods regarding cognitive development, as demonstrated by the difficulties we have in distinguishing between the language sounds we have not heard in the first 12 months of our lives (Kuhl, 1998). Importantly, early introduction of a second language also appears to provide additional “cognitive advantage” in other areas, helping children become better “multi-taskers” (Baker et al, 2003).

Neuroscientific findings support the notion of a young brain as being more flexible, sensitive and plastic than it is in later life, with predispositions to learn in certain domains (Blakemore & Frith, 2000). A better understanding of the late development in puberty of cognitive control has been provided by measurements of myelination (Giedd et al., 1999), gray matter reduction (Sowell et al. 2001) and synpatogenesis (Huttenlocher, 1979). This research indicates that the prefrontal cortex, relative to other brain areas, lags behind in its development and reaches maturity only in late adolescence. This provides interesting insights into teenage behaviour, although the educational implications of such knowledge are still to be determined.

Q: How, and by whom, should these practical implications be determined?

Imaging studies have suggested that the naive scientific theories that so often provide stumbling blocks for physics students are not entirely lost with the acquisition of more accurate models but only inhibited by them (Fugelsang and Dunbar, in press – see Pettito and Dunbar, 2004). This has prompted the proposal that scientific concepts should be introduced earlier to children before their naïve ideas have become too ingrained (Pettito and Dunbar, 2004).

Q. Why do we assume that inhibition of existing concepts is an extra “cognitive load” for students? More generally, can we assume that additional blood oxygenation is even a rough indicator of the extent of cognitive “work”?

Q. What are the issues and opportunities for using neuroscientific evidence to inform the curriculum debate?

Although the overall synaptic density of different brain regions tends to level out before adulthood, the adult brain remains flexible. Several studies have shown how adult brain structure can be changed through learning experiences. These include

- Increases in size of part of the hippocampus of taxi-drivers (Maguire et al., 1997,2000)
- Enlargement of a motor region from 5-day piano course (Pascual-Leone et al., 1995)
- Enlargement (and subsequent diminishment) of areas associated with perception in a juggling task after a 3 month course (Draganski et al, 2004).

3. Further Horizons

Recent research has shown the existence of mirror neuron circuits that produce motor mimicry in response to perceived actions (e.g. Rizzolatti et al., 2002). It has been suggested that such circuits provide a fast learning mechanism for new actions through imitation (e.g. Meltzoff, 2002). Also, through the unconscious use of gesture and body-language, these may also induce similar emotional states in “conspecifics”, as well as empathy and cooperation (e.g. Dijksterhuis and Bargh, 2001). These findings support proposal for a type of “mind-reading” (Gallese and Goldman, 1998) that suggests interpretation of some types of interaction in the classroom may require a level of subtlety that has not been previously recognized, especially in areas such as modeling and vicarious learning. As well as gesture contributing to a mechanism for “mind-reading”, there is evidence that gesture can influence conceptualisation, and the neurocognitive mechanisms of “spatial thinking” are currently being investigated (Kita et al. 2004 – ref requested).

Q: Do such findings counter notions that neuroscience has an inevitably reductionist influence upon educational perspectives?

Q: Should these findings prompt educational researchers to broaden the focus and interpretation of their observations in the classroom?

4. Perspectives, aims and roles

4.1 Models of Learning

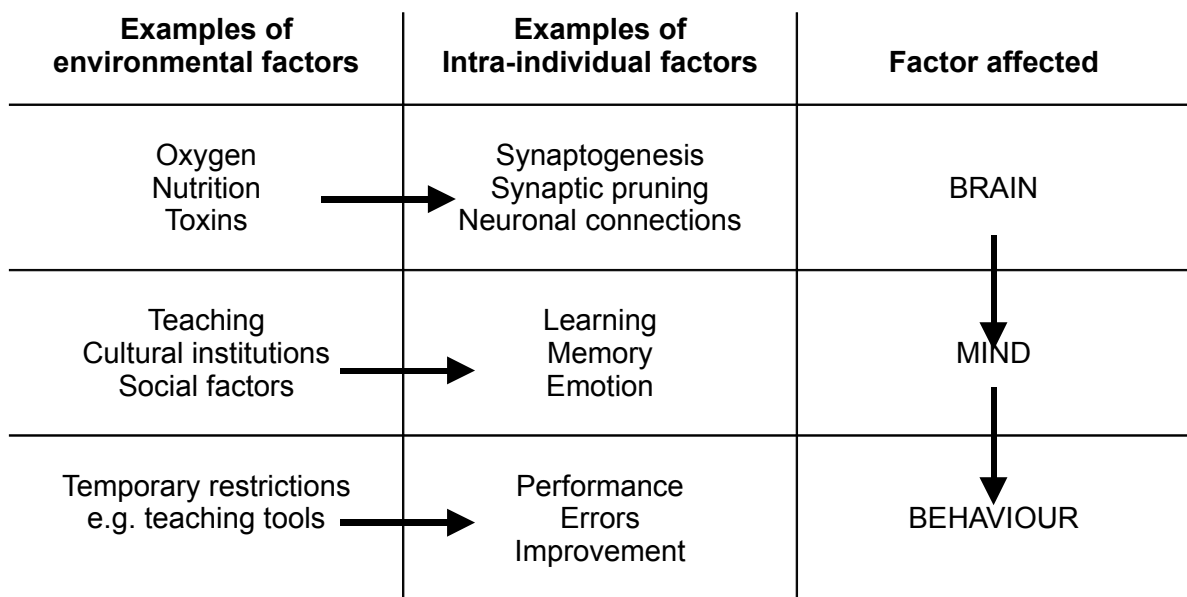
The basic notion that brain science can be worth considering within an educational context has been challenged by educators. Such challenges often refer to the dangers of ignoring the wider social environment, and thus could equally be applied to much of cognitive science in general:

“...however extensively we investigate brain processes and states we will be unable thereby to make direct positive discoveries about learning. For many of the intentional states figuring in learning are not restricted to the internal states of an individual. They incorporate the complex practices and cultures in which she is embedded. These intentional states cannot be characterised without reference to crucial aspects of these social externalities.” (Davis, 2004, p31).

This rejection of the relevance of brain science appears to emphasise the need for a clearly articulated model of how our knowledge of the brain, and the epistemologies related to its determination, interrelate with other perspectives on learning. Additionally, it has been argued that the influences between education and

neuroscience should be two way (Berninger, and Corina, 1998), again highlighting the need for a model that interrelates theoretical approaches. A major issue in integrating our cognitive neuroscientific knowledge with our educational understanding is the dominant role of interpretivism in education. Interpretivism has been called an “embarrassing partner for the searcher after causal explanation” (Bruner, 1996, p110), and yet scientific explanation and situated interpretation can be mutually enlightening, even if not reducible to each other. As a means of initiating discussions about what such an integrative model might look like, two related models are now briefly discussed, one from cognitive science and one from social psychology.

A cognitive scientific model has been proposed that combines environmental, biological, cognitive and behavioural levels of description (Morton and Frith, 1995; see below).



The notation in the diagram uses arrows to indicate causal connections. Interactions of external factors with factors that are internal to the individual contribute to a causal explanation. “Facts” are situated at a behavioural and biological level, theories at the cognitive level. The notation can be used to think about links between biology and behaviour via the inferred cognitive level that bridges the gap between them.

Cognition is portrayed as sandwiched between quantifiable performance and scientifically determined biological processes. The model emphasises well the mediating role of mind in the relationship between brain and behaviour and provides a means of studying cause-effect relationships and examining mind-brain phenomena in controlled scientific studies. However, many of those researching in education believe that the behaviours that concern them on a day-to-day basis are so immersed in context that they are not amenable to causal explanation and significant insights are only possible through a meaning-based interpretation of observations in a naturalistic environment. In practical terms, focusing data collection upon the constrained set of behaviours that might be feasibly studied using the above theoretical model, diminishes consideration of those socio-cultural forces that some consider to be most responsible for diversity in learning outcomes. Clearly, there is a potential conflict between epistemologies. Whatever model describes the mind-brain-

behaviour relationship in education needs to interrelate, rather than exclude, both epistemologies and concepts.

The field of social psychology also attracts work based upon a variety of epistemological perspectives and suffers many of the philosophical conflicts arising in education. Here, however, a “Trimodal” theory has provided an interesting model that interrelates perspectives in a practical manner based upon “mode of action” (Stevens, 1996). Although originally intended to describe social behaviour, the trimodal approach will be illustrated here in terms of learning. In trimodal terminology, the *primary* mode of learning arises from the physical embodiment of the learner. This provides a basis for learning that is best described in terms of biological and neurophysiological processes. Cognitive science also follows a systematic approach in attempting to explain our thinking and learning mechanisms in terms of causal models that may be informed by, and inform, a burgeoning understanding of brain function. In trimodal theory, these primary biological and cognitive mechanisms support the emergence of symbol systems and the use of language, thus facilitating a *secondary* basis for learning. This use of symbol systems makes it a meaning-based mode of learning that involves interpretation by those participating in it and by those attempting to investigate it. The experimental study of language has revealed much about its biology, its cognitive basis and also its complexity but the methods of natural science have not facilitated broad objective analyses of meaning that are devoid of subjectivity. The meanings ascribed to our actions, including our use of language, are multiple, ambivalent and transitory. Interpretations of meaning that cannot be judged by the methods of natural science may be considered beyond its jurisdiction (Medawar, 1985). Thus, at this secondary symbolic level of learning processes, the perspectives of social science with their subjective qualitative methods hold sway. Our ability to use symbols crucially supports our formation and manipulation of concepts, including those that describe ourselves. Thus, from the secondary symbolic mode of action emerges a third basis for action – our reflexive awareness. This *tertiary* mode involves self-awareness and reflective choice. Here our actions are less determined solely by primary biological and cognitive processes and/or by secondary meaning-based processes. This is the level at which the learner generates some autonomy through a capacity to reflect upon his/herself and the events in his/her life. At the tertiary level, investigation becomes something of a moral science, in that it is concerned with the choices we make and how things, including ourselves, *could* be. Investigation can still, however, be informed by knowledge of learning processes at the primary and secondary levels.

Both models, in terms of avoiding neural precedence, resonate with recent neuroconstructivist ideas but may also over-emphasise a single direction of interaction. For example, the learning environment we encounter and the decisions we make about our learning appears, in some instances, to influence our biology.

4.2 The aims of Education

The resonance between the emphasis of cognitive neuroscience upon brain function, and education’s increasing interest in transferable “soft” skills may help redefine what education is for. Koizumi (2004) has proposed a radical re-definition of education in terms of the brain:

“Education is a process of optimal adaptation such that learning is guided to ensure proper brain development and functionality”

Q. What are the implications of such a definition?

Q. Should educators consider how the curriculum contributes to maintaining the mental health of students (e.g. through providing understanding of the

interrelationship between our thoughts and our affective well-being and disorders, and through destigmatisation of mental illness?

Q. Are cognitive programs, such as those for the control of Alzheimer's, a suitable target for interdisciplinary education/neuroscience research?

Koizumi (2004) proposes a "need to create a new methodology and new organizations, including a common language that makes it possible to transcend the borders between disciplines....A strong incentive is necessary for bringing the precession of disciplines into convergence"

Q. What are the incentives that would bring about such a convergence?

4.3 The role of teachers: Teachers as Neural Sculptors

An increasing awareness of how the brain is influenced by education may bring about a reappraisal of the role of the teacher. The effect of education on the brain has been revealed in a number of different ways. For example, a study by Castro-Caldas et al. (1998) revealed that illiterate Portuguese women activated entirely different brain regions for non-word recognition compared with their more educated counterparts. In post-mortem examinations, Jacobs et al (1993) revealed the positive effects of time at school upon dendritic growth in children.

If school is such a strong determinant of brain development, it appears likely that an increasing knowledge of cause-effect relationships may begin to influence the perception of teachers' roles and their professional aims. In two engaging scenarios, Geake and Cooper (2003) illustrated the diverse ways in which these roles may, or may not, develop in future years (see Appendix 3).

Q. Which of the Geake scenarios is more favourable/likely?

Q. Is the generation of such scenarios a helpful way of concretising these and other issues?

5. Perceptions

There is little doubt that the perceptions, attitudes and understandings of teachers and other educational practitioners are vitally relevant to the success of neuroscience/education initiatives.

There is very little literature investigating these issues. It is, however, worth noting that a recent ESRC report on the influence of neuroimaging in psychiatry refers to the power of neuroimaging to reconceptualise patients' ideas about their own mental illness (Cohn et al, 2003).

Q. What are the opportunities and risks associated with this power of neuroimaging to culturally transform ideas?

It has been commented upon that several constructions about the brain are already in circulation that are essentially inaccurate and misleading(OECD, 2002). All neuromyths appear to be associated with concepts that have some scientific basis and some are not dissimilar to typical representation of these concepts by the media. These "neuromyths" include:

1. the idea of left brain versus right brain learning
2. the notion that the brain is only plastic for certain kinds of information during certain critical periods

3. that most effective educational interventions need to be timed with periods of synaptogenesis

Further neuromyths have been identified by Goswami(2004):

1. a person has a male brain or female brain
2. implicit learning can open up new avenues educationally

Some so-called “brain-based” approaches may also fall under the category of neuromyths (see 2.2.6)

Q: Is it worthwhile to investigate the channels by which these concepts have increased their presence beyond Piagetian and Vygotskian theories in the minds of most teachers?

Q: What should be done about neuromyths?

The consultation exercise (Desforges,2001) on the report by Blakemore and Frith (2000) also revealed a variety of views and opinions about what is meant by neuroscience in education. To inform this seminar series, the original data from this exercise is currently being analysed further.

7. Research Agendas

7.1 Types of Project

In education, research is usually expected to have a prompt observable impact in terms of practice. In neuroscience, research is usually expected to provide fundamental knowledge about the brain. Different categories of interdisciplinary neuroscience/education projects may vary in the extent to which they serve these very different aims. For example

- 1) Laboratory-based projects that extend neuroscientific knowledge in ways that provide insights to educators. These may more comfortably serve the professional aims of neuroscientists.
- 2) Classroom-based projects that involve field-testing of approaches inspired by insights from neuroscience. These may more comfortably serve the professional aims of educators.

Q. Can projects be envisaged that would serve both sets of aims?

In education, the involvement of practitioners in research has become an increasingly popular approach to developing and implementing new ideas. Although considered by some to be at the “flabby-end” of educational research (McWilliam, 2004), the potential for such involvement to motivate and engage practitioners towards new understandings and ideas cannot be ignored.

Q: What are the opportunities and issues for cognitive neuroscience to support practitioner research in education?

In terms of educational impact, it may be worth noting the great success of Gardner’s theory of multiple intelligences in entering the educational bloodstream (Gardner, 1983, 1999). This collection of ideas has been used as the basis for a variety of educational research projects.

Q: Gardner’s theory is thought by many educators to be a successful example of neuroscience informing education. Is this an example of an uncontroversial (in

educational terms), unthreatening and simple idea becoming easily accepted and “owned” by education? Should neuroscience be focused more upon counter-intuitive insights, as suggested by Blakemore and Frith (2000)?

7.2 Research Questions

The research questions suggested by Blakemore and Frith (2000) have been reproduced in Appendix 1. The suggestions of Geake and Cooper (2003) have also been provided in Appendix 2. Participants involved in the consultation exercise on Blakemore and Frith (2000) were asked directly to make suggestions for a research agenda. Responses are currently being reanalysed for consideration by this seminar series.

Q: How do the suggestions of educators and neuroscientists differ and where do interests appear to converge?

Q: Can research questions/studies/programmes be designed that would provide publishable outcomes for neuroscientists *and* educators? (see also 7.1 above)

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Appendix 1: Questions from the Blakemore and Frith(2000) Report

Seven research questions relating to childhood learning

1. In theory, neuroscience should be able to tell us what is good and bad for young brains. Is 'hot-housing' useful or damaging?
2. Research on the timecourse of brain development and critical periods has implications for the optimal times for introducing material in the school curriculum. Is it better to concentrate in the early years on music and language, and only later on more abstract things like maths concepts/metalinguistic awareness, for instance?
3. It is important to make the distinction between *critical period* as the duration and quality of the stimulus needed for imprinting, and *sensitive period* as the 'window of opportunity' for the imprinting to take place. Is it important to catch the window of opportunity? How can it be established that the window is open and closed?
4. Are the 'windows' for learning specific things due to unalterable physiological processes or can they be extended by teaching? Can neurological changes underlying learning be speeded up by teaching?
5. If specific aspects of neurological development and learning can be speeded up - does it have a deleterious effect? Does encouraging development in one brain area have a positive effect on whole brain development?
6. What are the limits of plasticity? Does the brain rewire so that certain taught abilities take over to the detriment of other abilities (e.g. social and emotional development)? For instance, if formal teaching of reading, writing and maths occurs earlier, is there rewiring that detracts from other types of learning?
7. It is not clear what the effect on brain development might be of chronic emotional disturbances. If there were long-term neurological changes they would certainly have consequences in the classroom. Studies on, for example, the children of mothers who suffered post-natal depression, could give an indication of the educational and psychological outcomes of early maternal incapacity. This would indicate whether such children would benefit from remedial teaching early on.

Seven research questions related to lifelong learning

1. Does evidence from brain changes during learning suggest age-related teaching in which methods of teaching are changed according to the age of the learner, in nursery, throughout school and beyond into adulthood?
2. What are the costs to the brain of acquiring a new skill or improving an old skill? Does enhancement of certain brain regions compromise other regions? Does getting better at one skill mean taking away space from another skill? What brain systems are involved in transfer of learning and can they be boosted?
3. Are there verbal and spatial/pictorial learning styles and how do they relate to brain differences? What is the effect of verbalisation on tasks that can be done non-verbally, and what is the effect of visualisation on verbal tasks?
4. Some things are easy to learn because of a natural predisposition for learning built up through evolution. For example, phobias of snakes and spiders are easier to acquire than phobias of harmless objects (Ohman et al., 1975), which are not 'pre-wired' into the brain circuits by evolution. It is possible to override such 'prepared' learning, for example by behavioural therapy. How do these types of learning differ?
5. Is it necessary to learn implicitly first, then explicitly? Can explicit learning happen when intuitive grasp is lacking? What does it mean to teach so that implicit learning is facilitated?
6. What is the difference between imitation of actions performed by peers and those performed by remote role models? Does brain activation differ?

7. There are many unanswered questions about the importance of sleep for learning in adults and children. A programme of research on 'sleep as a teacher' could be set up to consider effects such as timing, delay and interference between different tasks. Are time of day learning effects related to sleep patterns?

Seven research questions related to individual differences and learning disabilities

1. How do individual differences as manifested in neurological structure and function interact with learning progress and outcome? Can anyone become a Mozart given appropriate teaching?
2. Does brain-washing exist? What can brain science tell us about deliberate and directed learning and forgetting? What can it tell us about the consequences on quite different skills after a new skill is acquired? For example, what is the effect of literacy and numeracy on other cognitive functions?
3. Imagery in different modalities as an aid to learning and teaching (including remedial teaching) be monitored through brain scanning and manipulated through TMS. Are there individual differences? What type of imagery is most effective for learning?
4. The brain's limbic (emotional) system is different from brain systems that process academic abilities, but they are strongly connected. Does learning skills such as reading and writing and maths affect emotional development and vice versa?
5. Learning disorders are estimated to affect at least 5% of the population. Much more research is needed if we are to understand its biological underpinnings and possibilities for remedial teaching.
6. Research programmes on mathematical learning and teaching would benefit from links to neuroscience research. Previously intractable questions can now be tackled. Are there sensitive periods for maths in which the brain is particularly responsive to learning maths? Do these differ for different kinds of mathematical ability, for example exact calculation versus approximation? Can a motivation for maths be embedded early on? Does avoiding maths lead to a deterioration in mathematical ability?
7. Does knowing about the brain aid learning? Should children and adults (pupils, teachers and parents) be taught about their brains and learning? These are questions amenable to empirical research. Are there differences between teachers who are aware of neuroscience/psychology and teachers who are not? For example, are there differences in their methods or success? If teachers know about how the brain learns do they behave differently towards children? Would they change their class size, teaching or testing methods?

Some additional questions:

There seems to be a dissociation between declarative and procedural learning, confirmed by functional imaging studies (Gabrieli et al., 1998). For purposes of teaching it might be important to know that learning facts, such as mathematical equations and historical dates, relies on different brain regions than learning to do sport or play a musical instrument. A possible research question is whether the two kinds of learning can occur in parallel rather than each having to be taught separately. For instance, can teaching usefully combine counting and skipping?

What is the role of imitation in formal school-based learning? How is it distinct from orienting one's behaviour relative to a role model? Is implicit imitation of peers different from imitation of the behaviour of adults? Social psychology studies suggest that there are massive effects of peer groups. A deeper understanding of imitation, its role in learning and its brain basis might enable us to understand how it can be exploited for beneficial learning, or controlled in the case where it might be harmful.

Should girls be taught some things at a different time from boys?

Appendix 2: Questions from Geake and Cooper (2003, p12)

1. What is the current level of knowledge of cognitive neuroscience amongst the education community? (In 1998, The Sunday times claimed 1000 UK schools using “brain-based” strategies)
2. In particular, is there a describable folk psychology of school teachers regarding the genetic heritability of intelligence and learning abilities, and genetic correlates with classroom environment?
3. To what extent do university educationists in teacher preparation programmes incorporate cognitive neuroscience into their courses?
4. To what extent do parents expect teachers to employ cognitive neuroscientific evidence-based practice?
5. To what extent do students perceive their teachers as being in or out of touch with modern developments in understanding brain function?
6. Another topic for research could be a rigorous evaluation of existing interventions in schools which claim to be based on neuroscientific evidence, e.g. brain gymnastics which purport to increase cerebral blood flow. Would a psychometric analysis of a well-designed (e.g. using matched controls) quasi-experiment find the same level of benefit in school performance that anecdotal reports indicate?

Appendix 3: Extract from Geake and Cooper (2003)

The scene is a parent-teacher night at a local primary school. A parent is discussing the poor maths results of her child, Chris, with Chris’s class teacher. In the first scenario, the teacher acknowledges that Chris’s maths performance has been under surveillance for a while. To that end, the teacher has available Chris’s event-related neuroimaging report captured in the school’s neuroimaging assessment room. Here, the whole class regularly undertakes their term assessment tasks while wearing individual neuroimaging headsets. (The school bought a class set of neuroimaging head-set scanners some years ago. They’ve been set up in the former class computer room, long abandoned when all students were issued with hand-held computer note pads with infra red links to their teacher’s PC). The class set of individual images is statistically analysed by a dedicated computer, and parent-teacher reports generated.

After scanning Chris’s report, the teacher brings her professional knowledge to bear, and recommends a course of real-time biofeedback utilizing mental multi-step arithmetic problems to strengthen Chris’s short term memory circuit for number solutions, which the imaging has shown to be relatively weak. On-going neuroimaging assessment during the next month will determine the effectiveness of this individually-specific intervention,

The parent is pleased with the professionalism of the teacher, especially that the teacher knew what was the matter, and could do something about it. The teacher was pleased to be able to act in such a professional manner. Her considerable training, including an M.Phil (Oxon) in education and cognitive neuroscience, had been worth it, especially her research thesis on the neural correlates of learning difficulties in mathematics.

In the second contrasting scenario, the teacher is at a loss to explain why Chris might be having maths learning problems.

“Could it be motivation?” the teacher offers.

“Obviously,” says the frustrated parent, “but that is circular. If Chris had more maths success, Chris would be better motivated.”

“I suppose so,” replies the teacher. “I barely scraped through the lowest level of maths at my school certificate.”

“Well” says the parent, “what are you going to do about it?”

“Me?” says the teacher. “How would I know what to do? After all, I’m only a teacher. I don’t know what is causing the problem. Why don’t you take Chris for an assessment with Cognitive Services Inc? Here is their card. They’ll know best what to do.”

In either case, the remedial intervention is undertaken by biofeedback with the subject viewing a suitable neuro-image while undertaking the remedial learning task. In the first future scenario teachers have developed a similar professionalism to that of doctors and engineers, and are accorded commensurate social status (and salary?). Obviously, there are commensurate issues regarding selection for teacher preservice courses. In the second future scenario, the professionalism of teachers has been usurped by other professionals, mainly those with training in cognitive neuroscience.