Stirling and Clackmannanshire Educational Psychology Service
Research review

Neuroscience and education

Introduction

Neuroscience is concerned with understanding the mental processes involved in learning, e.g. learning how to learn, how to become literate and numerate, cognitive control and motivation (The Royal Society, 2011). As knowledge from neuroscience develops it has the potential to influence children's learning and as such is the subject of much enthusiasm within education. Care, however, requires to be taken to ensure that ideas from neuroscience are not accepted uncritically or over simplified to become what is known as neuromyths (OECD, 2002). Research has identified some promising developments for education.

Brain development

Many important aspects of brain development are complete before birth and by 7 months gestation almost all of the neurons that make up the mature brain are formed (Goswami, 2004). Throughout childhood changes occur in the connections between neurons, often being described as coming in waves. Synaptic pruning, where connections are cut back, then occurs. Periods of increased neuron formation and pruning are times when there may be an increased sensitivity to learning (Howard-Jones, 2010). Learning is mainly associated with neuron development and changes in the connections between them.

The frontal lobes of the brain are associated with higher order processing and undergo radical structural changes until the late teens. At puberty myelination (where the axons carrying messages to and from the neurons become insulated by a substance called myelin), occurs. This process improves the efficiency of communicating information within the brain and occurs considerably throughout adolescence and to a lesser extent during adulthood (Howard-Jones, 2010).

Our brains are considered to be 'plastic' which means that everything we do can change the structure of and connectivity within our brains, ensuring that the brain is well placed for lifelong learning. Interactions between experiences and the environment are, therefore, considered to play a crucial role in brain development. Our genes only play a part in making us who we are; our experiences and environmental factors also make an important contribution.

Neuromyths

Neuromyths describe 'received wisdom', i.e. ideas or practices that originated from scientific ideas but which do not stand up to scientific scrutiny. A number of neuromyths have influenced educational practice at times, a few of which will be referred to below.

Critical periods for learning in early childhood

This myth suggests that if children are not taught particular skills during a critical period of development then they will have missed the chance to learn that particular skill. In fact most research on critical periods has looked at visual or movement functions and it is not known how the notion of critical periods might apply to aspects of learning such as reading (Blakemore and Frith, 2001). What is more helpful is to think about *sensitive* periods during which a child's brain might respond particularly well due to its plasticity at that time, e.g. skilled learning of a second language is generally easier before puberty (Hernandez and Li, 2007).

Multiple Intelligences Theory (Gardner, 1983)
This theory suggests that individuals have a range of relatively independent intelligences, e.g. musical, linguistic, spatial etc, rather than one all-purpose intelligence. Waterhouse (2006) reviewed the research basis for this theory and found that whilst there was a vast range of complex individual differences at neural and cognitive levels there was no empirical evidence linking it to the capabilities suggested by Gardner. This does not mean, however, that there is evidence for any fixed all-purpose intelligence but might indicate a role for more debate within education about our understanding of intelligence.

Learning styles
Another myth is that each child has a particular learning style that influences how they process information and that teachers should teach children in accordance with the child's learning style. A review of the literature by Coffield et al (2004) identified 71 different models of learning styles and found that only a few of the measures used to assess the learning style had been evaluated for validity. Furthermore, they found no convincing evidence that teaching adapted to suit the preferred learning style of the child was effective. There is evidence, however, that if you present information *simultaneously* in both visual and textual form that this enhances memory - it creates additional brain activity indicative of increased processing (Beauchamp et al, 2004).

Left brain, right brain
This myth suggests that different sides of the brain hemispheres work differently, with the left side being specialised for language, reasoning and logic and the right being the source of creativity and intuition. It was argued that children could be split into those who were 'left-brained' or 'right-brained' learners depending on how they were seen to process information. Language, for example, is mainly lateralised in the left hemisphere but it is not totally localised there. In reality performance in most everyday learning tasks require both hemispheres to work together in a sophisticated manner (Woolfson, 2011).

Brain Gym (Dennison 1981)
Dennison argued that Brain Gym 'balanced' the hemispheres of the brain to improve their integration, which in turn improved learning. Howard-Jones (2010) noted an absence of credible evidence that brain gym contributed to learning in the manner ascribed. There is, however, evidence that aerobic exercises are correlated to many categories of cognitive performance in children (Hillman et al, 2008), so encouraging physical activity in children is a useful goal to promote learning.

How neuroscience research can influence learning

Learning about the brain
There is evidence that teaching children about the plasticity of the brain can influence perceptions and motivations. Adolescents who believed that intelligence was malleable demonstrated increased grade performance over a two year period compared with adolescents who viewed intelligence as a fixed entity, with their grade performance remaining flat (Blackwell et al, 2007). An intervention designed to teach children about the brain's plasticity and that by implication intelligence is not fixed, resulted in a positive change in classroom motivation and upward mobility of grades compared to the control group who had not received the intervention.

Memory
Factual recall, such as being able to explain the steps required in carrying out a process, (developed by rehearsal and repetition of material to be learned to enable automatic and effortless processing) is crucial in freeing up working memory space.

Working memory is our capacity to temporarily hold a limited amount of information in our attention when we are processing it. The upper limit of information we can hold in our working memory is about seven chunks of information, although there is individual variability in this, which in turn is linked to educational achievement (Pickering, 2006). Rehearsal and repetition of material to learn allows the demands on working memory to decrease, freeing up resources for problem solving. Other strategies, which reduces the cognitive load, such as getting children to show their working, can be helpful as these external representations can in turn reduce some of the demand on working memory.

Stress can play a part in memory also, e.g. stress hormones appear to facilitate learning if they are present at the time of learning but have the opposite effect if present before or after the learning event (e.g. Kuhlmann, 2005). So, some psychological stress at the time the material is being learned might be helpful but is liable to have an adverse effect on memory if it occurs during an exam.

Maths

Brain imaging research is contributing to models of mathematical development useful in developing interventions, e.g. children with dyscalculia showed improvement in a range of calculation activities when teachers focused on basic numerical and conceptual knowledge in the early stages of mathematical teaching (Kaufmann et al, 2008). Finger gnosis (being able to differentiate between different fingers in response to one or more being touched) has been shown to be a strong predictor of mathematical ability (Noel, 2005). Fingers represent concrete tokens involved in the estimate of number magnitude, i.e. basic ‘number sense’. This suggests that children should not be discouraged from using their fingers whilst counting. Research involving training first grade children (6 years old) to have improved finger gnosis found that the training (two-weekly 30 minute training sessions for eight weeks) resulted in an improvement in quantification tasks in the trained children compared to the control group (Gracia-Bafulluy and Noel, 2008).

Learning by imitation and visualisation

Visualising an object involves most of the brain regions activated by actually seeing it, suggesting that visualisation may be a useful strategy for learning (Kosslyn, 2005). Likewise observing someone else carrying out the action we are about to learn activates some of the same brain regions as if we were carrying out the action (Rizzolatti and Criaghero, 2004), supporting imitation based learning.

Creativity

Research has suggested that creativity requires moving between two different types of mental processes: generative thinking (where new ideas are generated) and analytical thinking (where ideas are analysed) with each benefiting from a different attentional state. Analytical thinking requires focussed attention whereas generative thinking requires more diffuse attention, supported by more relaxed environments and the absence of critical evaluation by the self or others. The challenge is how to ensure opportunities for both types of thinking in the classroom to foster opportunities for creativity (Howard-Jones, 2010).

Adolescence

Whilst some parts of the brain undergo rapid change during adolescence there is evidence of a ‘pubertal dip’ in some aspects of performance, e.g. 11-12 year olds performed less well than younger children at matching pictures of facial expressions to descriptors of emotions (McGivern et al, 2002). The areas of the brain which are changing rapidly include those responsible for self awareness, understand of intent, internal control and perspective taking (Blakemore, 2008). Awareness of such changes in adolescent brains make it important for us to consider the kinds of environment in which our young people experience as they lay down neural pathways in relation to the social domain, e.g. whether these pathways are influenced by threat or by security (Sercombe, 2009).

Implications for education

Bridging the gap between neuroscience research and education is at an early stage and has been hindered by a tendency for neuromyths to emerge. Neuroscience is, however, providing insight into issues pertinent for learning such as the continuing plasticity of the brain, and effects of stress on memory.

In broad terms we should review and consider:

- The impact of Neuromyths on current practice and ensure that new developments are clearly supported by emerging research evidence
- How we can teach children about the plasticity of the brain to influence self concept and academic performance;
- How learning is affected by different types of thinking, such as generative and analytic;
- The importance of teaching children strategies to learn and memorise important processes so that this frees up working memory capacity to enable scope to engage with the new learning.

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Resources

- www.neuroeducational.net