THE alliance OF GIRLS' SCHOOLS

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Research Review:

The brain and learning:
a summary of academic research

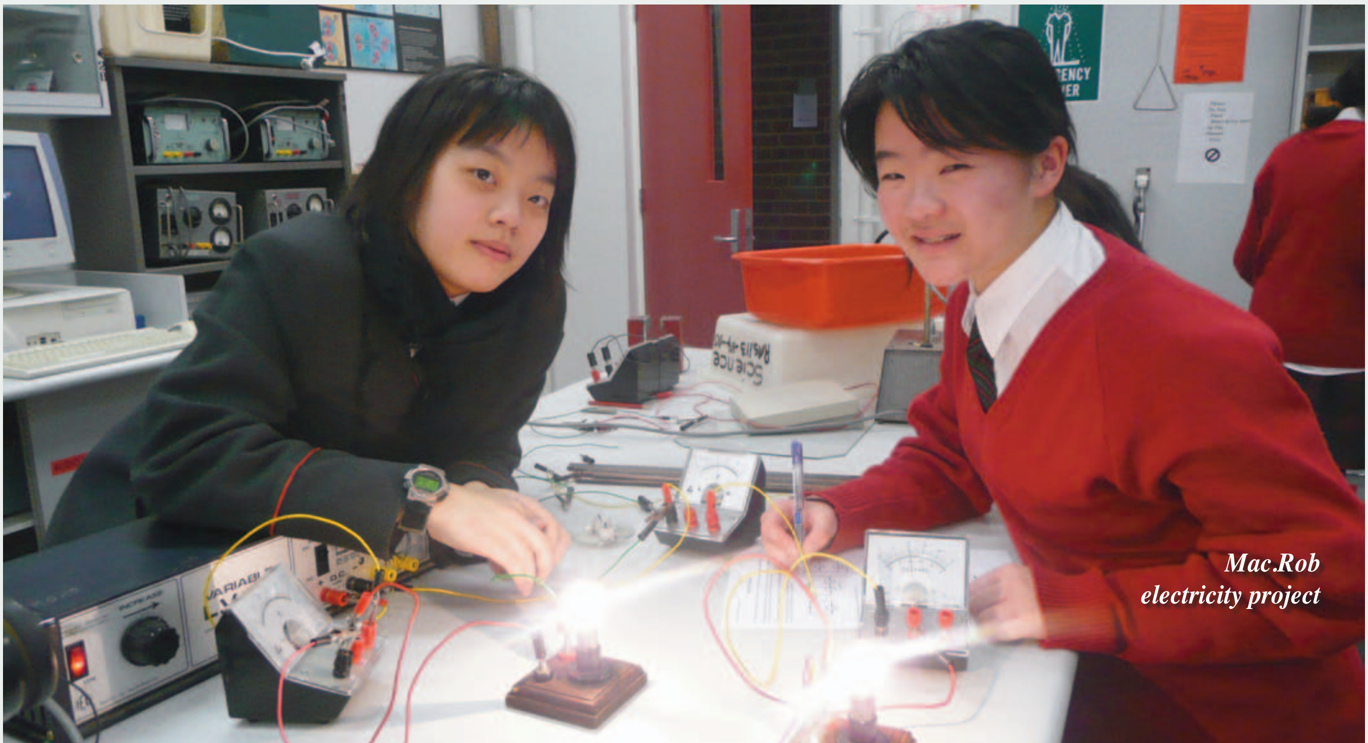
by Kate Broadley

If the brain were so simple we could understand it, we would be so simple we couldn't.
Lyall Watson

The function and structure of the human brain is an increasingly common topic in the mass media, popular culture, and in academic research. Neuroscientists are beginning to make direct links between their findings and educational pedagogy. 'Circumstances have converged to mean that there is now a global emergence of educational neuroscience' (OECD, 2007, p. 21). The past five years have seen an explosion in 'brain-based education' – in the publication of numerous texts, as the topic of educational conferences, in the production of websites and DVDs, and in professional learning seminars and speakers. Those who are in this field often claim to be using brain research to further the learning of students and the pedagogy of teachers. While the field of neuroscience is constantly updating what we know about the brain, the jump from brain knowledge to application in classrooms should be undertaken with caution.

A meta-analysis of neuroscience research is necessary, perhaps coupled with a 'new kind of professional who specialises in connecting practical research questions with research findings and concepts' (Fischer, 2009, p. 12): a 'neuroeducator', who acts to bridge the gap between brain research and classroom learning.

Neuroscience is at a particularly exciting stage in the field's long medical history. New, non-invasive brain imaging techniques are allowing for the detailed exploration of active brains. The growing understanding of neuroplasticity is likely to lead to new strategies that will impact directly on learning. For example, it is now known that the adolescent brain undergoes waves of growth and change, whereas a decade ago young adults were believed to have fairly set and



Mac.Rob electricity project

Concentration - Mitcham Girls' High

Teamwork

Creativity

moulded brains. These advances have 'significantly increased [neuroscience's] relevance for education' (OECD, 2007, p. 21).

In the field of brain and learning, three major topics arose from recent publications. The first is a general explanation of recent findings, with a particular focus on the adolescent brain. The second is brain sex dimorphism: how brains differ between males and females (also the most contentious topic). The third area is neuroplasticity: how the brain is flexible, changeable and malleable in response to learning experiences. Each topic has relevance to learning and education.

1. Recent neuroscience research

Scientists once thought that the only critical period of brain development occurred in the first few years of childhood. Now it is understood that our brain responds to lifelong learning. 'Parts of the brain…have recently been found to generate new neurons all through life' (OECD, 2007, p. 41). There are clearly neurological 'sensitive periods', which can be seen as 'windows of opportunity' where the brain is at an optimal stage for a particular biological event to occur (OECD, 2007). One of these sensitive periods is early childhood. A great deal of research has also focused on the key period of adolescence. There are also ongoing neurological studies of children's brains, which have implications for educators at this level.

The brain in childhood

Childhood (ages 3 – 10 years) appears to be the optimal time for learning language and music. Children can generally 'learn foreign languages more rapidly and speak them more fluently than adults' (Eliot, 2009, p. 200). Second language learning involves both comprehension and production of words. 'Grammar processing relies more on frontal regions of the left hemisphere, whereas semantic processing (e.g. vocabulary learning) activates the posterior lateral regions of both the left and right hemispheres' (OECD, 2007, p. 44). 'Delaying exposure to language leads the brain to use a different process when processing grammar' (p. 44). While many adults obviously do learn second languages (see references to the Osterhout et al. study under neuroplasticity), the earlier a child is exposed to the grammar of a foreign language, the easier and faster it is mastered (OECD, 2007).

In a study which explored brain changes with musical training, 'non-musician' children aged eight years old were given musical training (Moreno et al., 2008). Event-related brain potentials were recorded as part of the research. The musical training positively affected neural processes in the brain by influencing 'electrical activity associated with the processing of linguistic pitch patterns'; this also provided evidence for 'transfer effects from music to speech processing' (p. 721). It was concluded that 'relatively short periods of training have profound consequences on the anatomical and functional organisation of the brain' (p. 721). Children who had six months of musical training improved their reading skills and the discrimination of small pitch variations in speech.

A snapshot of the adolescent brain

The focus on adolescents in neuroscience is of increasing importance, partially because of the higher rates of psychiatric disorders which can surface in this period. 'Although adolescence presents a period of maturation in terms of cognitive control, reaction speed, reasoning, and decision-making skills, compared with childhood, it also marks a period of increased rates of depression, substance abuse, suicide, eating disorders, and other risky behaviors' (Choudhury, Charman & Blakemore, 2008, p. 142). 'Roughly three-quarters of all mental health problems have their first presentation in adolescence or young adulthood' (Scott & Smith, 2009, p. 4).

There are two major neurological changes at puberty. 'First, there is an increase in axonal myelination, which increases transmission speed. Second, there is a gradual decrease in synaptic density, indicating significant pruning of connections. These neural changes make it likely that cognitive abilities relying on the frontal cortex, such as executive functions and social-cognitive abilities, also change during adolescence' (Choudhury, Charman & Blakemore, 2008, p. 142).

Grey matter, 'the thinking part of the brain' (Giedd, 2002. ¶ 1) increases in volume throughout childhood, peaks at puberty and is followed by a sustained loss and thinning in latter adolescence. This peak and growth correlates with advancing cognitive abilities in the pre-puberty years. Giedd believes that the influences of 'parents or teachers, society, nutrition, bacterial and viral infections' are highly important during this period (2002, ¶ 2). Likewise, during the grey matter pruning period in adolescence, the 'use-it or lose-it' principle may come into play.

Adolescence is also a 'crucial period in terms of emotional development partly due to surge of hormones in the brain' (OECD, 2007, p. 47). The development of grey matter 'in certain brain regions is associated with sexual maturation and… pubertal hormones might have organisational effects on the developing human brain' (Neufang et al., 2009, p. 464). Sex hormones are 'active in the emotional centre of the brain [the limbic system]…these hormones directly influence serotonin and other neurochemicals which regulate mood and contribute to the known thrill-seeking behaviour of teenagers' (OECD, 2007, p. 47).

The pre-frontal cortex, which is responsible for higher-order thinking and skills such as planning, organisation, decision and judgment making, is still maturing in the adolescent brain. Young people tend to focus on what is happening immediately around them and to them; 'the social world is paramount' (Scott & Smith, 2009, p. 1). 'The general consensus among neuroscientists is that the maturation process is not completed until young adulthood: perhaps as late as 30 years of age, making the teenage brain inherently less capable of balancing emotions and more likely to exhibit risk-taking behaviour' (Carr-Gregg, 2009, ¶ 19).

> ***"There is currently a fiery educational and neuroscientific debate about whether male and female brains are alike or vastly different."***

Negative influences on the adolescent brain

Jay Giedd, who is a neuroscientist at the National Institute of Mental Health in America believes there is a 'cruel irony of nature' with the developing adolescent brain. 'Right at the time when the brain is most vulnerable is also the time when teens are most likely to experiment with drugs or alcohol' (Giedd, 2002, ¶ 2). Clearly drugs and alcohol affect all brains. Researchers have found other environmental impacts which negatively affect the brain to some degree: malnutrition, negative social interactions, a lack of physical exercise, a deprivation of learning and education, lack of sleep, stress and illness.

A recent study explored how mobile phone use affected cognitive functioning of the adolescent brain. There has been increasing concern about the potential adverse health effects of exposure to radio frequency among children and adolescents who use mobile phones. The focus of much research is on how radio frequency exposure affects the developing brain of children and adolescents. Abramson et al. (2009) found that, mobile phone use was associated with faster and less accurate responding to higher level cognitive tasks. Results suggested that mobile phone use affected the impulsive responsive style of children: the tendency for children to respond before they knew the correct answer. There is 'now sufficient experimental evidence that mobile phone exposure does alter brain activity in young adults' and children (Abramson et al., 2009, p. 679).

Conclusions from recent neuroscience research

There are obviously some implications that follow the analysis of neuroscientific research. For early-childhood and primary educators, the knowledge that children's brains are ripe for first and second language learning, and learning music, is probably not new. However, the precise way in which the developing brain is open to this type of learning has been discovered in recent years. The implication for the early childhood curriculum is evident.

For adolescents 'a system of education operating on the basis of progressive selection according to "ability" at particular ages does not fit with the evidence…a lifelong system of education is required' (OECD, 2007, p. 200). As there are considerable variations in brain maturation across individuals in any given class, 'mastery approaches to learning are needed, where learners aim to improve their own performance and/or that of their work group, without reference to the relative progress of other individual learners' (p. 200).

Adolescents also need to be educated about how their brains are developing and changing. Giedd has said that he shows adolescents brain development curves, 'how they peak at puberty and then prune down, and [I] try to reason with them

Planning the future – Palmerston North Girls' High School


Precision

that if they're doing drugs or alcohol that evening it may not just be affecting their brains for that night or even for that weekend, but for the next 80 years of their life' (2002, ¶ 2).

2. Brain sex dimorphism

There is a currently a fiery educational and neuroscientific debate about whether male and female brains are alike or vastly different. The popularity of books like Moir and Jessel's *Brain sex: the real difference between men and women*, (which claims that women and men are hard-wired so differently that they cannot share equal emotional or intellectual traits), has added greatly to gender stereotypes. Education specialists like Michael Gurian and Leonard Sax are also in the camp that strongly believes in hard-wired brain differences between the sexes.

'We're very fond of regarding any differences in attainment between boys and girls as the result of some inbuilt, unchangeable essence… usually discussed in the pseudoscientific language of differences in brains, brain wiring and learning styles supposedly caused by genes' (Scott, 2008, p. 46). Lise Eliot in her book *Pink Brain, Blue Brain* contests the absolute way in which brain differences are polarised between males and females. Researchers have also been studying brain dimorphism more closely in the past five years. There is irrefutable evidence that the male and female brains are different in a number of ways. The contentious issue is how large these variation are, and how we should treat these differences as educators.

Structural brain differences between males and females

So what does the research say about brain sex dimorphism? There are a number of structural differences in the male and female brain. These variations have been consistently concluded by researchers:

- Total brain size is approximately 8–12% larger in males (Lenroot & Giedd, 2010; Neufang et al., 2009; Eliot, 2009; OECD, 2007).
- Longitudinal studies have shown sex differences in the trajectory of brain development, with females reaching peak values of brain volumes earlier than males. (Lenroot & Giedd, 2010). Total cerebral volume peaks at age 10.5 in females and age14.5 in males. Cortical and subcortical grey matter trajectories peak 1 to 2 years earlier in females than males (Lenroot et al., 2007). Overall, girls' brains mature earlier than boys' brains.
- The regions most frequently reported by imaging studies as showing morphological sex differences include the basal ganglia, hippocampus, amygdala and limbic structures. The basal ganglia are larger in females (Giedd, 2002).

It must be stressed that these structural differences 'should not be interpreted as implying any sort of functional advantage or disadvantage' (Lenroot et al., 2007, p. 1072). 'Causality has not yet been established between any normal variation of brain development and functional ability. Neuroimaging findings should be taken as clues pointing us towards different processes affecting male and female brain development rather than definitive statements about the capabilities of male or female individuals' (Lenroot & Giedd, 2010, p. 53).

Sex hormone differences in the brain

There are also a number of neurological differences which present because of the effects of sex hormones or sex steroids. Neufang et al. (2009, p. 464) concluded that 'many sex differences in brain structures seem to occur after the age of 9 or 10' and that 'development in certain brain regions is associated with sexual maturation… pubertal hormones might have organisational effects on the developing human brain' (p. 464).

"The environment plays a huge part in gender behaviour."

Specifically for girls, brain activation levels have been found to change as a function of the menstrual phase. Lenroot and Giedd (2010) reviewed research which demonstrated that the menstrual phase may be related to cognitive function. These studies found that performance and brain activation fluctuate across the menstrual cycle on tasks including spatial ability and semantic performance. Tests of learning and memory also show fluctuations across the menstrual cycle, suggesting that temporary changes in sex steroid exposure can affect neuronal plasticity.

The extent of brain sex dimorphism and neuromyths

The variation between male and female brains is surprisingly small overall. Many claims have been made by people of influence about brain sex dimorphism. Often these claims are based on one study, which may or may not have been scientifically rigorous. Only in a meta-analysis of neuroscience research can a complete picture be formed.

There are many myths that flourish, for example the notion that females are better at language than males. In a review of the research about gender, language and the brain, Cameron (2009) found that 'systematic studies using a variety of methods and measures overwhelmingly contradict the notion [that modern women are more talkative than men], showing that in informal peer-interaction there is typically no sex/gender difference, while in formal and status-marked situations it is most commonly men who talk more' (p. 6). Furthermore, researchers have also raised doubts 'about the strength of the modern psycholinguistic evidence for female verbal superiority, pointing out that meta-analytic studies have found the overall effect of sex/gender to be slight' (p. 8).

'No study to date has shown gender-specific processes involved in building up neuronal networks during learning' (OECD, 2007, p. 118). The 2007 OECD report *Understanding the Brain: the Birth of a Learning Science* describes 'masculine' and 'feminine' brains as a neuromyth – myths that belong to brain science but which 'bring unfortunate consequences and must therefore be dispelled' (p. 108).

On the topic of neuromyths, Kurt Fischer, a professor of Education and the Director of Harvard's *Mind, Brain and Education Program*, warns that 'One of the major problems we face is that there are a whole lot of things that claim to be "brain-based education" that are nonsense. One of them is the belief that boys and girls have totally different brains and learn totally differently. That's not what the evidence shows. Not at all. The other is kind of a rigid idea of sensitive periods: that after a certain age you can't learn a foreign language. You've also heard that there are left-brained and right-brained people. Total nonsense, unless they've had their left or right hemisphere removed. All of us use all our brains' (Hernandez, 2008, p. 2).

There are obvious generalised differences in male and female behaviour. What is now understood is that these behavioural differences cannot be attributed solely to brain sex dimorphism. Each of these behavioural traits 'are heavily shaped by learning and…massively amplified by the different sorts of practise [sic], role models, and reinforcement that boys and girls are exposed to from birth onwards' (Eliot, 2009, p. 7). The environment plays a huge part in gender behaviour.

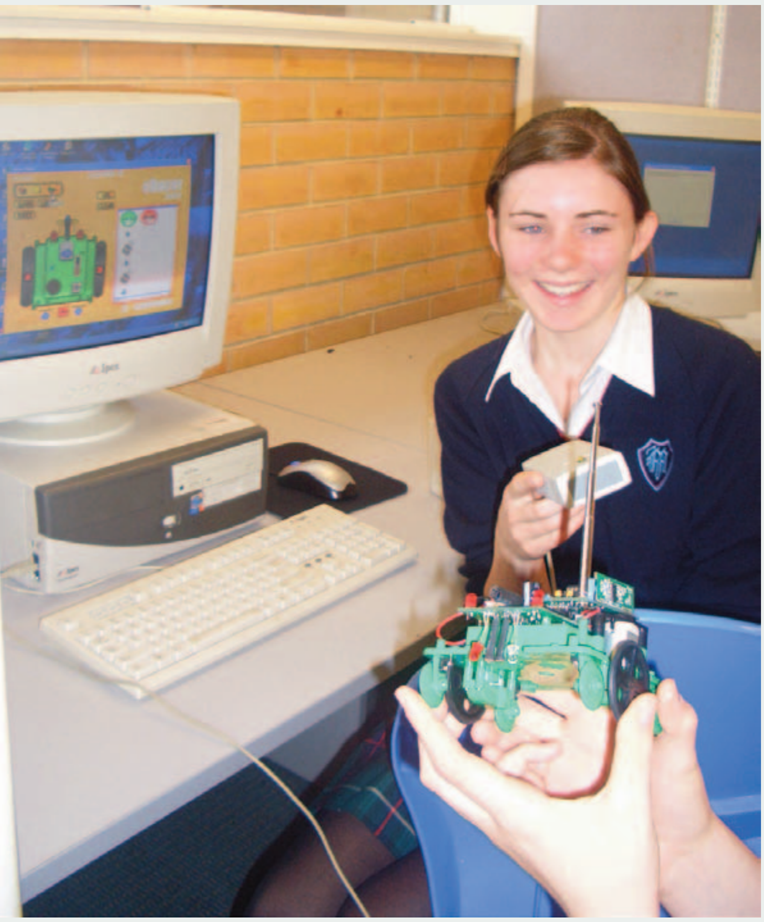
What brain sex dimorphism means for educators and schools

Claims that 'most educators will admit that schools are designed to be more left-hemisphere friendly… and girls are going to find school in general more comfortable than will many boys' (Gurian, Stevens & King, 2008, p. 13) are damaging in light of the neuroscientific evidence. Likewise when Leonard Sax (2005) says that girls and boys brains are wired differently, and therefore they should be educated in different ways, caution must be advised. Each child's brain is unique and not gender typical, so brain sex dimorphism actually means little for educators. Eliot says that 'there are many sound reasons to advocate single-sex schooling, but sex differences in children's brains or hormones are not among them' (2009, p. 305).

3. Neuroplasticity

'The idea that the brain can change its own structure and function through thought and activity… will have profound effects' (Doidge, 2008, p. xvi). Neuroplasticity is a mechanism which operates 'in various ways at the level of the synaptic connections. Some synapses may be generated (synaptogenesis), others eliminated (pruning), and their effectiveness may be moulded, on the basis of the information processed and integrated by the brain' (OECD, 2007, p. 30).

Education affects neuroplasticity. Moreno et al. (2008) demonstrated brain plasticity in eight year-old children with relatively short periods of musical training. Their experiment 'had strong consequences on the functional organisation of children's brains' (Moreno et al., 2008, p. 712). Yet the brain retains its plasticity with lifespan. Osterhout et al. (2008)



found evidence of neuroplasticity in young adult's brains when they were taught a second language - 'classroom-based, second-language instruction can result in changes in the brain's electrical activity, in the location of this activity within the brain, and in the structure of the learners' brains' (p. 509).

The implications of neuroplasticity for educators

Neuroplasticity is an exciting concept for neuroscientists and educators. If the brain is flexible, then perhaps we can find better ways to train the brain to learn to read, or solve complex physics problems. It is also a critical juncture for brain disabilities and conditions, such as autism and dyscalculia. Much research is beginning to discover how neuroplasticity can help to lessen the effects of, or even solve these conditions. If the brain can be rewired, it 'offers the promise of teaching someone who has had a brain injury to walk or talk again' (Hernandez, 2008, ¶ 10).

'The concept of plasticity and its implications are vital features of the brain. Educators, policy makers and all learners will all gain from understanding why it is possible to learn over a whole lifetime and indeed brain plasticity provides a strong neuroscientific argument for "lifelong learning". Would not primary school be a good place to start teaching learners how and why they are capable of learning?' (OECD, 2007, p. 30).

Educational neuroscience?

A trans-disciplinarily approach is needed in order for research on the brain to be brought into the classroom. There is some progress: the establishment of the *Mind, Brain and Education Program* at Harvard, a new journal called *Mind, Brain & Education* (founded in 2007), the publication of the OECD report *Understanding the Brain: The Birth of a Learning Science*, (and a fabulous website for students called *Neuroscience for kids*). These initiatives are only preliminary steps. 'Any education reform which is truly meant to be in the service of students should take into account neuroscientific studies and research, while maintaining a healthy objectivity. Similarly, brain researchers should not exclude themselves from the world of education and the broader implications of their work' (OECD, 2007, p. 124).

Kurt Fischer believes a threefold, trans-disciplinary approach is necessary for neuroscientists and educators:

1. Research schools where practice and science jointly shape educational research. They should be 'real-life schools' (public and private), solely affiliated with a university where educators and researchers work together to create research that guides pedagogy.
2. Shared databases on learning and development. For example, a database on neuroscientific research that is applicable to education.
3. The creation of neuroeducators – people who specialise in connecting and applying neuroscience research with educational questions, methods, practice and policy.

Neuroscientific 'evidence will lead to better choices of ways to teach, and to facilitate learning pathways for different learners' (Fischer, 2009, p. 14).

Conclusions

Recent brain research has shed light on how flexible the human brain is throughout life. Early childhood is a wonderful time for the acquisition of language and music. School is an important time to introduce the concept of the working brain and neuroplasticity so that students see their potential and begin to understand the rapidly advancing field of neuroscience. Adolescent brain research shows what a critical time pre- and post-puberty is for brain development and maturation. Nurturing the growing brain at this stage, both environmentally and educationally is a vital task for educators.

Neuroplasticity demonstrates the importance of lifelong learning. Brain sex dimorphism studies on the whole, conclude that males and females are not beholden to brain sex stereotypes. The latest neuroscientific research should be used to dispel neuromyths and link to educational pedagogy. Neuroscience is not a panacea for education but educators ignore this rapidly advancing scientific field at their peril.

Single-sex girls' schools have the opportunity to keep their staff and students abreast of neuroscientific research. There is also the wonderful prospect for girls to enter this expanding field: to be the first generation of neuroeducators or to use neuroscience to solve complex problems such as dyslexia.

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