ARTICLE

From brain scan to lesson plan

Paul A. Howard-Jones asks how can we use insights from neuroscience to provide more effective teaching and learning

The idea that we should use our burgeoning understanding of the brain to improve education has a commonsense feel about it. But the past history of brain-based learning, with its unscientific and unevaluated concepts, suggests there are many pitfalls. A new type of research is needed to bridge the gap between these two very different disciplines, and psychology will be an important part of this venture.

questions

What sort of research is needed to translate our understanding of the brain into educational practice?

What will be the role of psychology in such a venture?

resources

www.neuroeducational.net – website of the Neuroeducational Research Network, co-ordinated from the Graduate School of Education, University of Bristol.

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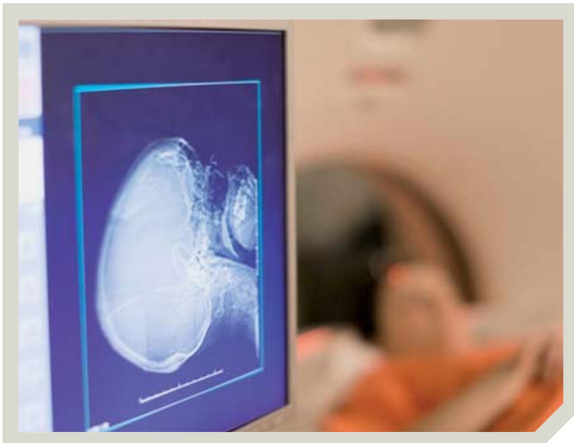
The last decade has seen something of a step change in efforts to bring cognitive neuroscience and education together in dialogue. This may partly be due to anxieties over the 'parallel world' of pseudo-neuroscience found in many schools. Much of this is unscientific and educationally unhelpful, and there is clearly a need for some serious 'myth-busting' (see box).

There may, however, be a more positive reason why discussions are breaking out between neuroscience and education. Ideas are now emerging from authentic neuroscience with relevance for education. For example, neuroscience has helped identify 'number sense' (a non-symbolic representation of quantity) as an important foundation of mathematical development and associated with a specific region of the brain called the intraparietal sulcus (Cantlon et al., 2006). As we learn to count aloud, our number sense integrates with our early ability to exactly represent small numbers (1 to 4) to 'bootstrap' our detailed understanding of number. Such insights have prompted an educational intervention yielding promising results (Wilson et al., 2009). Or take the field of reading: children with developmental dyslexia have shown reduced activation in typical left hemisphere sites and atypical engagement of right hemisphere sites, with consequent educational interventions improving language outcomes and remediating these differences in neural activity (Shaywitz et al., 2004; Simos et al., 2002; Temple et al., 2003).

Neuroscience is also shedding light in other areas of education, providing insight into the link between exercise and learning (Hillman et al., 2008), and prompting re-examination of teenage behaviour (Blakemore, 2008). Perhaps as importantly, it is established scientists that are now promoting neuroscience as having educational value (e.g. Blakemore & Frith, 2005; de Jong et al., 2009; Goswami, 2004). Indeed, neuroscientists appear increasingly willing to speculate on the possible relevance of their work to 'real-world' learning, albeit from a vantage point on its peripheries. Such speculation often comes under the heading of 'educational neuroscience' – a term that broadly encompasses any cognitive neuroscience with potential application in education. Accordingly, its research basis might be characterised by the epistemology,



Research is needed to bridge the gap between laboratory and classroom

methodology and aims of cognitive neuroscience. But, moving from speculation to application is not

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straightforward, since the educational value of insights from neuroscience rest on their integration with knowledge from more established educational perspectives.

There are many challenges in moving from brain scan to lesson plan, as we seek relationships between neural processes and the types of complex everyday learning behaviours we can observe in schools and colleges. To begin with, we have to draw together at least three very different types of evidence: biological, social and experiential. One thing appears clear from the outset: a simple transmission model in which neuroscientists advise educators on their practice should never be expected to work. Neuroscientists are rarely experienced in considering classroom practice. Since neuroscience cannot provide instant solutions for the classroom, research is needed to bridge the gap between laboratory and classroom. To emphasise the key role of educational values and thinking in the design and execution of such a venture, workers at the University of Bristol have found themselves using the term 'neuroeducational research' to describe this enterprise (Howard-Jones, 2010). For both scientists and educators, co-construction of concepts requires broadening personal epistemological perspectives, understanding different meanings for terms used in their everyday language (e.g. learning, meaning, attention, reward, etc.) and appreciating each other's sets of values and professional aims. This boils down to having a dialogue about how the different perspectives and their favoured types of evidence can inform about learning in different but potentially complementary ways.

In contrast to such authentic interdisciplinary work, brief intellectual liaisons between education and neuroscience are never likely to bear healthy fruit. These flirtations may, indeed, spawn further neuromyths, often due to a lack of attention to psychological concepts. A common example is when synaptic connections in the brain are used to explain how we form connections between ideas. Although association between ideas is a well-studied psychological concept, it is currently impossible to study at the level of the synapse. Conflating brain and mind in this way allows some educational practices to gain an apparently neuroscientific flavour. This can, somewhat deceptively, add to their attractiveness because explanations provide greater satisfaction when they include neuroscience (Weisberg et al., 2008).

Having this important conversation about how different perspectives inform learning is a first step towards a theoretical framework for research at the interface of neuroscience and education. This can help us combine findings more judiciously across perspectives to develop a better understanding of learning, but such an aspiration also has implications for methodology. If there is a genuine commitment to interrelate findings from component perspectives, then the methods associated with these perspectives can be adapted to better support such interrelation. For example, qualitative interpretation of classroom discourse can draw usefully on neurocognitive concepts in the interpretive analysis of its meaning. Some brain-imaging studies can contribute more meaningfully to the construction of neuroeducational concepts if they include semi-structured interviews of participants, to derive experiential insights about their constructs, strategies and attitudes. In some bridging studies, judicious compromise and innovative approaches may help improve the ecological validity of experimental tasks while still attempting to control extraneous variables. Perhaps most unusually, researchers in the same team may find themselves sequencing radically different methods to collect biological, social and experiential evidence as they attempt to construct answers that, collectively, help span the social/natural science divide.

The unusual sequencing of methods in neuroeducational research can be illustrated by two sets of investigations involving our lab (NEnet at www.neuroeducational.net). In the first of these, we used functional magnetic resonance imaging (fMRI) to investigate a popular strategy for fostering creativity: the incorporation of unrelated stimulus into an outcome (e.g. combining unrelated words into a story, or 'found' objects into a piece

Myth-busting

Say you want to communicate scientific and educational understanding to teachers – how would you go about it? In the absence of an appropriate forum, neuromyths have flourished.

We surveyed 158 graduate trainees about to enter secondary schools (Howard-Jones, Franey et al., 2009):

- 82 per cent considered teaching children in their preferred learning style could improve learning outcomes. This approach is commonly justified in terms of brain function, despite educational and scientific evidence demonstrating the learning-style approach is not helpful (Kratzig & Arbuthnott 2006).
- 65 per cent of trainees considered that coordination exercises could improve integration of left–right hemispheric function.
- 20 per cent thought their brain would shrink if they drank less than six to eight glasses of water a day.

None of these ideas are supported by what we know from scientific studies (for a review, see Howard-Jones, 2010).

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of visual art). This type of strategy is well known to artists and was beloved by surrealists such as Kurt Schwitters, who would set himself the task of creating something from found objects, such as whatever he found in his wife's wastepaper bin. The strategy operates by encouraging an individual to combine unrelated concepts and so generate more original ideas, but our fMRI study suggested that this also results in a need for more neural processing aimed at filtering out the good ideas from the many bad ones (Howard-Jones et al., 2005).

Such studies, however, provide little insight into what the strategy *feels* like. fMRI studies are chiefly from an 'outsider' perspective and take place in very constrained contexts, so a subsequent two-day theatre workshop was arranged to investigate 'insider' insights related to this and other concepts about creativity that have been explored in the laboratory. The team consisted of three professional actors, a theatrical director, a drama consultant and myself, all actively participating. The workshop was filmed so that excerpts could provide meaningful starting points for later discussion with drama teachers aimed at developing educational praxis. Apart from investigating the experience of creativity-fostering strategies related to those investigated in the MRI scanner, the workshop allowed dramatic exploration of neural and psychological constructions about creativity. This was a valuable introduction to understanding the existing field of cultural values with which ideas involving the brain and creativity might interact.

That understanding was helpful in the next stage of the investigation, when we explored the meaning of our findings for pedagogy. This final stage required a deeper involvement of educational practitioners and took place back at the Department of Drama Education where discussions had originally begun. The objective now was to 'co-construct' pedagogical concepts enriched by scientific insights about the brain and the mind, with a group of trainee teachers led by a team with both educational and scientific expertise in the area (Howard-Jones et al., 2008). Special attention was given to what trainees found useful for understanding their own and their pupils' experiences and learning. We pursued an action research spiral consisting of an initial discussion between members of the research team and the trainee student teachers, followed by three cycles of research meeting, seminar, activity-based workshop and student discussion.

Through this iterative process of action and reflection, a range of scientifically valid and educationally relevant concepts was produced for helping drama teachers foster the creativity of their students (Howard-Jones, 2008). These concepts included the potential of metacognitive processes to combat fixation, the need to consider the learner(s), their progress and the context when intervening in their creative process, and the need for additional time to filter out poor outcomes when making links between concepts that are not usually associated with each other.

These different studies about creativity were able to inform each other because of, rather than despite, each study being derived from an entirely different way of looking at things. As well as providing scientific insight, the fMRI study was a useful stimulus for the performance research. The performance research, in turn, provided experiential insights into experimental conditions used in the fMRI study. The action research drew on fMRI findings, and concepts and video footage from the performance research, but also prompted new research questions of educational interest that might be amenable to further imaging studies.

Another area that has involved sequencing a diverse range of methods has been our research into learning games. This began by asking whether educators needed to rethink how reward (in the educational sense of the word) is used in the classroom. Why, for example, do students who cannot focus attention in lessons become so absorbed in other activities, such as computer gaming? Computer games involve large amounts of uncertainty, and this may help explain their attractiveness. The predictability of an outcome has been shown to influence the reward signal it generates in the brain, with maximum response for rewards that are halfway between totally unexpected and completely predictable, i.e. 50 per cent likely (Fiorillo et al., 2003). This has been used to explain why humans may be so attracted to games

Why do students who cannot focus attention in lessons become so absorbed in other activities, such as computer gaming?

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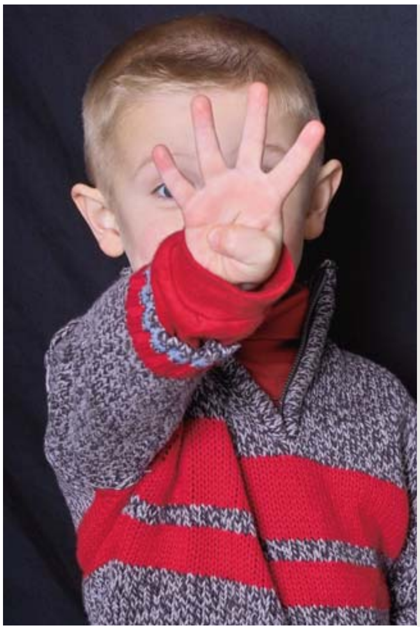
of chance (Shizgal & Arvanitogiannis, 2003). Our research investigated the relevance of such neural concepts in educational games, and it began with a series of bridging studies. Firstly, we tested a hypothesis generated from the science, and demonstrated that students preferred educational tasks when they were embedded in a gaming context involving uncertain rewards (Howard-Jones & Demetriou, 2009). A second classroom study revealed how reward uncertainty subverted the discourse around learning in positive ways, encouraging open motivational talk of the type found in sport (e.g. 'Yeah…come on!', 'We're gonna win, we're gonna win!'). A further study compared the physiological response of adults carrying out a learning task with and without chance-based uncertainty, and showed that reward uncertainty in a computer-based learning game heightened the emotional response to learning.

However, to understand how the response of the brain's reward system influences learning from one event to another in a learning game, it was necessary to apply a neurocomputational model. In this type of approach, a computer programme is built that mimics how our present understanding of the brain might predict behaviours such as decision-making. Essentially, it is just a more sophisticated version of having a hypothesis linking brain to cognition. The actual decisions made by the participants are fed into this programme, which then adjusts the model (such as those parameters which may be expected to vary according to the context) to provide a model that most closely fits the overall behaviour of the group. This best-fit model can then be used to estimate the response of the reward system at different points in the game for an individual. In support of our theory, we found this estimated neural response provided a better prediction of whether a learner would recall new information than just the points available for a correct answer (Howard-Jones, Bogacz et al., 2009).

If, in such ways, concepts from cognitive neuroscience can provide a scientifically valid basis for understanding human behaviour in learning games, then these concepts may have considerable value in developing educational software. They also have potential in developing pedagogy for whole-class gaming managed by the teacher. Through further action research, concepts from neuroscience and psychology have provided the basis for developing a pedagogy for teaching with immersive gaming (or 'twigging') (Howard-Jones et al., 2011).



Good neuroscience in education

When teenagers understand more about the plasticity of their own brains, this can have a positive influence on their self-concept and their academic achievement (Blackwell et al., 2007).

The proximity of brain regions involved with the processing of numbers and fingers has prompted successful educational interventions based on improving finger awareness (Gracia-Bafalluy & Noel, 2008).

Measurements of brain-related electrical activity can be used to predict at birth whether a child is at risk of dyslexia (Molfese, 2000), allowing the earliest possible intervention.

As with our research on creativity, our studies involving learning games have again emphasised the need for interdisciplinary research across natural and social science perspectives, employing a radical mixture of methods adapted to support their interrelation. The initial bridging study was quasi-experimental but was adapted to collect evidence of how students talked about their feelings when experiencing chance-based uncertainty in their learning. This qualitative experiential evidence prompted the second study focusing on student discourse. The second study involved the qualitative interpretation of dialogue but applied neuropsychological concepts in developing the analysis. Also, observations in the classroom have raised questions about the types of reward signal generated during competition, which is a key feature of most educational games but with little existing neuroscientific research to provide insight. These research questions have now been addressed in a neurocomputational study of competitive learning using brain imaging (Howard-Jones et al., 2010), and the models developed in this study are forming the basis of further classroom investigations into learning games.

This is just a selection of the ways in which the natural and social sciences can meet and support each other in neuroeducational research that attempts to develop both a scientific and educational understanding of learning. The active involvement of educational and neuroscientific experts in collaborative research has also highlighted the need for care when communicating messages and findings from integrating perspectives. This is essential for avoiding the types of neuromyths that introduced this article. For example, words such as 'motivation', 'reward', 'attention' and even 'learning' appear to have different meanings within neuroscience and education. A neuroeducational research approach, based on dialogue and co-construction of concepts, can help identify these issues and develop appropriate messages that are, as far as possible, inoculated against misinterpretation and misunderstanding.

The dialogue between neuroscience and education is still in its infancy, but already it suggests the need for a new field of inquiry that is both scientifically and educationally grounded. Psychological understanding of learning will be crucial in linking neural processes to learning achieved in a classroom. Educational thinking also needs to be involved at every stage, from developing tractable and useful questions, to executing the research and communicating its findings. Innovation will be required in developing the methodology to embrace both natural and social science perspectives in this way. If it can rise to these challenges, neuroeducational research may enrich both education and the sciences of mind and brain.

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