Fostering creative thinking:

co-constructed insights from neuroscience and education

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Introduction

The UK government presently considers creativity to be a key "employability" skill in terms of the creative industries and beyond, including within the sectors of science and technology (DCMS, 2007). There has been a recent flourishing of interest in the nurturing of creativity among young people (Roberts, 2006, Downing et al., 2007) and yet the provision of support for teachers and trainee teachers to achieve this remains a major challenge for education. This report contributes to meeting this challenge by reviewing the concepts and understanding about creativity that arose from a recent project in drama education. The project, funded by ESCalate, aimed to develop the reflective capability of trainee drama teachers regarding the fostering of creative thinking through enhancing awareness of the underlying cognitive and neurocognitive processes. Such an aim attends to the calls of those such as Chappell (2007) who have also highlighted the need within teacher training for a increased emphasis upon reflective practice in 'teaching for creativity'.

This report will focus chiefly on the constructions around the fostering of creativity that were developed during the project rather than dwell on insights about the process used to produce them. These insights about the process are reported elsewhere (Howard-Jones, Winfield and Crimmins 2008). However, it is worth briefly explaining the methodology used to develop the ideas presented, since this is suggestive of their potential value and validity. This is of key concern, since the history of the brain in education has already demonstrated how supposedly 'brain-based' concepts can arise in a variety of unsatisfactory and often unscientific ways producing ideas that are questionable not only in terms of their practical usefulness but also their scientific credibility (Institute for the Future of the Mind, 2007). The latter is an important issue, not least because many teachers would like to know not just what works but why and how, and whether the scientific basis used to promote an idea is scientifically meaningful (Pickering and Howard-Jones, 2007). Moreover, it can be argued that a sound conceptual basis for any intervention is essential for its effective implementation and evaluation.

The production of credible concepts spanning neuroscience and education may rely upon the development of improved communication and language between educators and scientists, and on the emergence of a two-way dialogue rather than a

one-way transfer (Geake, 2004). Building any useful conceptual bridge that spans neuroscience and education requires co-construction by those with expertise on both sides, as well as by those who we expect to travel across it regularly (for example, the trainee teachers in this project). The ideas reported here arose from a process of co-construction that involved a research team of two experienced educators (teacher trainers) Mitch Winfield and Gail Crimmins (Cardiff School of Education, University of Wales Institute Cardiff) and a psychologist with some educational and neuroscientific experience (the author), working reflectively with trainees in an action research cycle. Sixteen trainee teachers voluntarily took part in a short programme of seminars and activity-based workshops exploring concepts about creativity. Workshops, seminars and trainee discussions were videoed and, after each of these events, an analysis of this data was used as a basis for reflection by the research team and subsequent planning for the next event (see Fig.1). The methods used to communicate concepts and the details of the content covered in sessions were negotiated between members of the research team and informed by the responses of the trainees. The research team carefully monitored and supported trainees' interpretations of the scientific concepts that had been presented, taking heed of what trainees found useful for understanding their own and their pupils' creative experiences. By the end of the process, the trainees appeared more able to discuss their own practice of fostering creativity, with insights that were supported by reference to, and a better understanding of, underlying processes involving mind and brain. The concepts used to construct this understanding and a selection of the insights and ideas generated by the project are now reported.

What is Creativity?

Creativity is most easily considered in terms of outcomes: e.g. dramatic improvisations and artistic artefacts, but also innovative business ideas and scientific breakthroughs. Such outcomes usually share the two common characteristics of being both original and appropriate[1] . Creative ability, as in possessing the skills to produce such outcomes, is almost universally valued, but it is often regarded as something which is purely spontaneous and less amenable to a teacher's influence than other skills such as planning, calculating and communicating. At the beginning of the project, one of our trainees expressed this sense of spontaneity and mystery, and a conviction that creativity could not be taught:

Kids they just – they draw so many things from so many places and they can bring it all together and they can – and there's your creativity – you can't teach it

It is certainly true that there are no step-by-step instructions for having a good idea. Yet multiple reports from psychology suggest that our ability to think creatively is influenced by many things, including the environment in which we are situated. At a more basic level, the level of creativity we can exhibit in a task is, of course, influenced by the task itself. Although there may be an element of spontaneity involved in every creative act, by the end of our project participants were discussing a number of ways, set out below, in which the teacher may play a pivotal role in the fostering of creative thought.

[1] *As observed by Hayes (2004), although the term "creativity" is frequently used, its direct definition remains problematic, with recent attempts emphasising the role of factors beyond the level of the individual, and issues of ethics and morality (e.g. Craft 2000, 2006). In the initial discussions, the team drew on a simple definition of creativity as the type of imaginative thinking that produces an outcome possessing some level of originality as well as some sense of value (NACCCE, 1999), with the latter interpreted here as a sense of appropriateness.*

Where is Creativity?

Even a very small and controlled creative task recruits a wide variety of different brain regions. Carol Seger and her colleagues (Seger et al., 2000) measured the extra brain activity produced when participants generated an unusual verb to follow a noun, rather than the first one that comes to mind (e.g."the cat painted", rather than "the cat purred"). The additional creative effort was linked to a widely distributed set of 'hot spots' in the brain indicating areas of increased activity (see Fig. 2). However, these are in addition to the activities (excluded in this image) involved in producing any verb. These would include language networks usually found in the left hemisphere. If these were also shown on the diagram, the image would contain many more hot spots. A task that required the production of a complete sentence – perhaps the beginning of a story – would involve a host of further additional networks, including regions concerned with syntax, memory and the integration of concepts. Very quickly, as the task becomes closer to something resembling a simple creative classroom activity, you would find that most areas of the brain are more active than when our brains are completely at rest (if such a state can be said to exist). Thus, the types of hotspots seen in brain images such as Fig. 2 only *appear* to support the neuromyth that we use just a small percentage of our brains. In fact, hot-spots on a brain image usually indicate only where activity in one experimental condition has exceeded some statistical threshold relative to another condition. In reality, brain activity at any moment is occurring, to a greater or lesser extent, throughout the brain. Also, these static brain images belie the rapidly changing nature of real brain activity. If the technology was better, scientists would be able to show the spreading and contracting of regions of increasing and decreasing activity all over the brain, on time scales of milliseconds.

So, there is no single part of our brain responsible for our creativity. Creative thinking is a complex thought process that calls upon many different cognitive functions and involves many different regions distributed throughout the brain. Looking at Fig. 2, however, it is interesting that the additional effort required to produce an unusual verb is linked to extra activity in the right hemisphere – since, as already mentioned, language function occurs chiefly in the left hemisphere. It would seem that using language creatively can involve an increase in right hemisphere activity in an area suggested by Seger as involved with 'semantic divergent processing' – the making of unusual associations. This may remind one of 'left brain-right brain' theories of learning that claim we use the right hemisphere for creative work and the left for more logical thinking but, as already discussed, we know both sides of the brain are being used even in this simple creative task. Also, although some individuals may be more creative than others, characterising an individual as left-brained or right-brained is even less justified and unhelpful in understanding creative thinking processes that inevitably require many types of basic cognitive function and all of our brain. Individuals differ in terms of their abilities, but left-brain/right-brain approaches to thinking about these differences lack a credible scientific basis.

What do we do when we are being creative?

Thinking creatively may depend on our ability to use a range of cognitive processes in different ways and, crucially, to move between these ways as appropriate. In particular, creativity has been considered by psychologists and philosophers as an alternation between two very different modes of thinking, described here as generative and analytical (Howard-Jones, 2002). These terms emphasise the difference between the thought processes we use for critical evaluation or interpretation of an outcome and those we use to generate it in the first place, the latter requiring access to concepts that are more remotely associated with the matter at hand. When engaged in analytical thinking, an individual is expected to be focused and to constrain their attention upon the analysis. However, when accessing remote associations to generate novel ideas, there is benefit from being less focused and allowing attention to drift towards concepts not previously associated with the topic. The existence of two distinct mental states is not a new concept, but builds on the ideas of Ernst Kris (1952), Wundt (1896) and Werner (1948). Creativity, then, may be characterised by an ability to move from one mode of thought to the other without difficulty.

A simple notion of such a journey might be the production of a single creative idea that first requires a focused analytical state when exploring the topic, a generative state when finding associations beyond the topic, and a return to the analytical state to assess what has been generated. However, even in the production of a short story, more complex trajectories between these two modes of thinking can be imagined (see Fig 3). In a successful creative process, we are not likely to remain in one mode of thinking for any extended period, but different stages of a creative process can be characterised as requiring a more analytical or more generative approach. We asked our trainees to carry out a range of different dramatic exercises of the type frequently used in workshops. The first two exercises were 'talk for a minute' in which students spoke on a particular topic for a full minute without stopping, and a 'delayed copying' exercise in which trainees had to reproduce not the movement being made by the leader, but the movement previous to it. During these exercises, they were occasionally prompted to hold up a card (with "G" on one side and "A" on the other) to signify whether they were using a more generative or analytical mode of thinking. Trainees almost always held up the generative symbol when interrupted during the first exercise and the analytical symbol during the second. When talking-for-a-minute, trainees generated ideas with little time to reflect or to reject unsatisfactory elements. When copying, trainees focused on a very specific routine, analysed what they saw and rehearsed this mentally before reproducing it. However, a more complex task was "story in the round", in which participants formed a circle and each took a turn in continuing a story, taking over from their neighbour when signaled. This produced a spread of "As" and "Gs", which trainees explained in terms of individual differences in approach, but also according to where they were in their own creative process when asked to report. Trainees often held up a "G" when generating links with the previous story, or produced an "A" when evaluating their own ideas or those they were hearing. This was a helpful exercise to begin working meta-cognitively with the students, as it raised their awareness of when one mode of thinking dominated more than another, encouraging them to begin monitoring their own thought processes in this way.

What is fixation?

Although a successful creative process is not likely to involve being fixed in one mode of thinking for any extended period, things can go wrong. Cognitive fixation occurs when we become unable to move beyond an idea or set of ideas to produce new thoughts (see, e.g., Jansson & Smith, 1991). This can be interpreted as being stuck in analytical mode, and being unable to think generatively (for discussion see Howard-Jones and Murray, 2003, p156). A mild form can occur if, after doing something very focused, we have unusual difficulty in being generative. This can mean that a very analytical learning experience can diminish our creative ability in a subsequent task, as observed when young children use fewer colours and produce less creative collages following a dictation lesson (Howard-Jones et al, 2002). Extreme examples of fixation can be found amongst sufferers of Obsessive Compulsive Disorder, who rehearse the same rituals and thought patterns many times over. The pre-occupations of OCD sufferers have been linked to over-activity in the anterior cingulate cortex (Fitzgerald, et al. 2005). This is the front part of an island of cortex below the surface of the brain (see Fig. 4) that shares a controlling function with the frontal lobes and is thought to be involved with our ability to control the focus of our attention (Gehring and Knight, 2000). In some respects, the ritualistic rehearsals of OCD sufferers may resemble the repetitive rehearsal processes sometimes used to hone a piece of creative work. However, in OCD, these rehearsals are taken to an obsessive and very unproductive extreme, as described here by 'Hilary', who posted her account on an OCD community website[2]:

> *I worked in a pizza store and was put in charge of closing the place down at night. I found myself checking the ovens the locks, the safe and ALL appliances (even the refrigerator doors) several times over. This was very aggravating for the person closing with me but VERY embarrassing for me, but I just couldn't help it. I would often get home and then drive back to the restaurant to check the door to make sure that I locked it, get in my car,sit there for a few minutes and get out and check the door again. I would do this over and over a few more times before I could finally go home. At home the rituals continued….*

[2] *www.healthyplace.com/Communities/OCD/doubt/lookhill.html accessed 1-12-07*

Is there an opposite of fixation?

Although more unusual, damage to the same pre-frontal regions of the brain can also result in the other extreme. Tommy was a 51 year old builder with no previous interest in the arts, who suffered a subarachnoid haemorrhage – a bleeding in the space around the front of the brain – resulting in frontal dysfunction. In the weeks following his injury, Tommy became a prolific artist. He first began filling notebooks with poetry, then began drawing sketches and in the following months produced large scale drawings on the walls of his house, sometimes filling whole rooms. His artistry continues and has become more developed. Tommy cannot stop generating material, often only sleeping 2-3 hours a night between days filled with sculpting and painting. Interestingly, he wouldn't want to give up his new found creative ability, but he would like to gain greater control over it and understand it. He shows verbal disinhibition, albeit creatively, by constantly talking in rhyming couplets. His case study was written by Mark Lythgoe (Lythgoe et al., 2005), to whom he wrote a poem describing what it's like to be held in a generative state:

…As I watch my thoughts ride out on parallel lines
Flashing out straight from my head
Never stopping ongoing straight ahead
Were they go and what they see
Is blank and discomforting to me
I cannot understand the thoughts I am thinking
Somewhere inside my brains are blinking….

Both Tommy and Hilary appear as prisoners of one mode of thinking, Hilary unable to leave her state of constant analysis, and Tommy unable to stop generating. Reading their experiences makes these two states very real, but it also provides a moving reminder of the value of being able to move between them. Those fortunate enough not to suffer from disorders or brain trauma are more able to vary their mode of thinking. It appears our ability to move from one mode to another is amenable to metacognition in the sense that, in addition to just monitoring, some regulation of the current mode of thinking is possible. This was illustrated by the reports of a trainee asked to visualize creatively a particular scene they were listening to:

I started off by being analytical thinking 'what am I expected to get out of it - what am I supposed to be doing with this visualisation?' And then I just thought no, right, cut that off, just leave it, let it go, and just made myself switch off that….

As the trainees worked on a task to improvise and develop a script, we interrupted them at moments of explicit transition in terms of approach (such as beginning a rehearsal, sitting down to reflect, starting to discuss links between elements, etc) and asked them to consider why/how this transition was occurring. Every instance of a creative process is different to any other, but some types of transition do seem to indicate movement on the generative-analytical continuum. For example, transition to rehearsal was often justified in terms of a need to

evaluate and hone what had been generated, and thus any attempt to run through the work in progress was usually seen as a return to a more analytical state of mind. Decisions to generate and analyze material were also linked to different emotional experiences. Generating can feel like a step in the dark and, for some, analytical rehearsal can feel like a reassuring response to anxiety:

> *when I'm creating work I feel like I have to keep going back, and like you said 'what would happen if I didn't go back?' I don't know, but that's what I'm too afraid to find out, I couldn't just keep on creating…*

It is often possible to detect a similar type of anxiety in the behaviour of students asked to produce ideas with few guidelines or constraints, who may still ask a large number of questions about what is and isn't allowed.

Anxieties about generating ideas can become self-fulfilling, since anxiety favours a more analytical approach that can, in turn, further reduce the ability to generate and so lead to a state of fixation. Some level of guidance, stimulus or constraint can help here:

> *We had a group of super intelligent girls who sat there for 40 minutes really mulling it over and one of the boys just said to them "er...why don't you do the title 'the day I went mad with a spade'?" and they said "THAT'S IT!" and started writing....*

So, although creativity may contain a spontaneous element, it can respond favourably to the right level of constraint – not so constrained that it cannot flourish, but with enough guidance to provide emotional reassurance. Such ideas have been expressed in studies of creativity in dance education, as a balance between control and freedom (Chappell, 2007). One trainee reflected on whether she would have preferred to work without any constraints at all:

> *I think I would have felt a bit lost, I think I would have found it quite overwhelming, and I think I would have felt the need to impose guidelines upon myself – but if it's too constrained then it stifles the creativity and you just don't have the kind of scope required for the kind of work and outcome you want to have.*

Generative steps in the dark may sometimes seem daunting but they are also exciting. While our trainees described their generative thinking process as sometimes "scary", they were also seen as a "delight". It was noted that younger children are particularly good at enjoying the experience of being generative, in their drawings, stories and in their daily exploratory play. One can speculate that their generative ability is, perhaps, less impeded by well developed analytical ability and this is why as one of our trainees said:

> *They seem to take a lot more delight in being generative, they enjoy the creative process. Rather than 'oh we got to be creative now', (it's) "oh and then there's a dinosaur and it went to the moon" – and they love it!*

How does the classroom environment influence creativity?

Psychological studies have shown that the conditions for supporting analytical and generative thinking can be quite different. Analytic abilities can often be helped by an encouragement to remain focused, being offered some reward for our performance or by the mild stress of knowing we may be evaluated and assessed. Generative ability, on the other hand, can benefit from changes in context (Howard-Jones and Murray, 2003). This was illustrated by one of the trainees describing how his group had been just "hitting walls" and were "frustrated enough to hang someone" but, after relocating discussions to the local park, ideas had begun to flow.

Intrinsic motivations such as fascination and curiosity (Cooper and Jayatilaka, 2006) also seem more important in supporting generative activity than the provision of extrinsic rewards such as marks or material incentives. Although engagement in any task is important for its completion, a relaxed and uncritical environment appears most helpful for generative thinking (Forgays and Forgays, 1992). Thus, for example, warm-up exercises may be particularly helpful prior to sessions when participants intend to produce novel ideas. On the other hand, inducing an atmosphere of even mild anxiety can have a detrimental effect on ideation. As one trainee had been noticing with one particular class:

> *"…if you're telling them that at the end of the lesson they're going to be doing a performance then straight away they're not in generative mode anymore…"*

Influencing the working environment provides one set of ways in which we can promote analytical or generative thinking. However, since every creative journey is different, there is a need to assess continuously whether, in relation to an individual person and process, there may be benefit in influencing thinking mode. So, for the example just given, the slightly more tense atmosphere created by an imminent performance can be helpful if, at a particular stage in a creative process, it can be judged that a more critical analytical approach is needed.

So what is a "creative strategy" for a teacher?

Apart from social and environmental effects upon creativity that may be influenced by the teacher, there are also strategies that can be used. Given that generative thought appears more intrinsically motivated, one way of helping a student produce more ideas might be to encourage her/him to operate in an area of personal interest. Here, however, a balance appears necessary between making a piece of work meaningful and attractive to students through encouraging links to personal experience, and the need to explore new ground. Concepts with strong pre-existing associations can sometimes inhibit the formation of new ones. This was illustrated when students were asked to choose objects for an 'object improvisation'. Generally, objects were chosen for which students already perceived an obvious relationship – and outcomes were predictable and less interesting than when the objects were selected for them. (Because of the way our memory is organised, thoughts in 'free' association tend to be automatically related even without any conscious effort – try asking someone to give you any 10 words that come to mind.) One trainee also reflected on how she had asked every pupil in her class to construct a story around any two of four items: a map, a set of car keys, a ballet show and a bottle. Two of these items, the map and car keys, seemed more obviously related and they noticed the effect:

> *…the majority of people in the class chose the map and the keys and there were just different variations of car crashes and that was pretty much all they came up with, but the bottle and the ballet shoe – that really worked a lot more creatively.*

Providing students with tasks that require the making of unusual connections will encourage movement towards a mode of generative thinking. The strategy of having to incorporate unrelated material in an outcome has often been used by teachers to provoke creative thinking. It has also been a favourite of many artists, including Kurt Schwitters, who famously created a collage from the contents of his wife's bathroom bin (recently exhibited in the Tate). This strategy was recently investigated by the author in a study that scanned the brains of (other) trainee drama teachers to find out what happened when they were generating creative stories from sets of three words (Howard-Jones et al. 2005). Sometimes the three words were related but sometimes they were not. Stories produced using unrelated words were rated as more creative by a panel of independent judges. But the strategy might be just a bit of a cheat. Perhaps just having three unrelated words in the stories caused the judges to rate them higher? However, the brain images showed that the neural activity associated with creative effort did increase when the strategy was

used, suggesting that it does increase the intensity of creative thought. The chief area in which this occurred was the right medial gyrus – an area associated with higher level conscious control, presumably due to increased amounts of filtering out of inappropriate combinations of ideas (see Fig.5) So, although the strategy encouraged greater generation of ideas, it may also have required increased amounts of conscious analysis and effort. This suggests why extra time may be needed when students use these types of strategy and why object improvisation with given, rather than selected, objects can be more challenging . As one of our trainees commented when faced with such a task:

> *"…the fact that you'd given us objects and the fact that we couldn't choose our own … I was going to have to really think about how I was going to move on…"*

Our understanding of the brain also supports the use of visualisation as a powerful tool for fostering the generation of ideas (and for many other educational purposes). For example, consciously visualising an issue/topic within a range of different contexts can help boost idea generation by encouraging new associations (Howard-Jones and Murray, 2003). At least two-thirds of visual brain areas can be activated when we visualise something as when we perceive the real thing (Kosslyn, 2005), suggesting visualisation may serve as a reasonable substitute for actual experience.

However, considerable caution must always be applied when using findings from imaging studies to make inferences about teaching strategy. For one thing, the images produced in such studies are from data averaged over many participants. Therefore, at the level of an individual, this type of neuroimaging study neither supports nor dismisses a particular teaching strategy with certainty, because no one individual's brain is the same as another. In the classroom, strategies to foster creativity need to arise from a balanced consideration by the teacher of a learning context that is changing moment by moment, and this needs to take account of differences between groups and the individuals that comprise them. For example, a student or group that is producing large numbers of unusual but undeveloped ideas may benefit from strategies that will encourage more analysis, perhaps including an imposed schedule by which to evaluate their ideas systematically.

On the other hand, a student or group that is becoming fixated, or 'stuck' within a limited set of ideas, might well benefit from a more relaxed working environment, and/or from considering the issues within a different context. Whether the type of 'random strategy' discussed above might help here would depend greatly on the context or problem being solved, since these strategies are effective for many "ill-defined" problems with outcomes that are essentially unlimited in their range and number (e.g. open 'artistic' tasks) but may be less appropriate for well-defined problems involving multiple constraints (e.g. lighting a stage or, beyond drama, designing a bridge).

All of this suggests there is no such thing as a "creativity strategy" or "creative environment" that teachers should generally use, because 'what works' depends on the type of thinking a teacher wants to encourage at any particular moment in the creative process, and that depends on the learner(s), their progress and the context. When a teacher considers that an individual, or group of individuals, would benefit from a change in their mode of thinking, there are ways in which help can be provided. However, we can't make statements such as 'planning is/is not creative' or 'a completely relaxed environment is good for creativity' because the usefulness of any strategy and/or environment will depend on many factors beyond the strategy and environment themselves.

What about the creative teacher?

It can be argued that the fostering of generative thought processes is particularly challenging in school environments, since these have traditionally placed greater emphasis on analytical processes. Furthermore, the automatic nature of making divergent associations leaves the generative mode of thinking less amenable to direct instruction. When asking students to generate ideas, there cannot be a single correct answer towards which students can be directly guided. The teacher is left with the task of encouraging a style of thinking (or more, accurately, a style of moving between modes of thinking) rather than directing student to the thoughts themselves. This suggests that creative direction often has to be indirect.

There are, however, several ways in which this 'indirect direction' can be achieved. One method already mentioned is the use of questions to deflect any sense that analysis can produce a single correct answer. Another is the use of imitation. When encouraging students to be generative, it may be helpful if teachers can demonstrate their own ability to be generative. This may be in small ways, through the use of humour, or through providing their improvised performance as an example – not to be copied, but as a means to communicate about thinking processes. Our trainees were able to provide multiple examples of having used this strategy successfully, although the question arises as to how one can vicariously learn a mode of thinking. Our emerging understanding of the role of "mirror neurons" may suggest an interesting explanation (see Fig.6). When we watch the movement of others, some neurons in our brain are activated as if we were making the same movements ourselves. There has been much discussion and speculation about why this happens, but it may support our ability to put ourselves "in the minds" of others, possibly as a means to predict their behaviour (Rizzolatti et al., 2002). One can imagine how this would have helped our prehistoric ancestors, which makes such an explanation plausible in evolutionary terms. It also suggests that this is a mechanism by which, when we watch others, we can vicariously learn not just their ideas, but also the mind states they are using to produce them. So, for the teacher, it may not be just a case of "do as I do" but "think as I think".

Making a personal interpretation of the actions and ideas of others can also, in itself, be a creative act that supports the generation of new ideas. One trainee reported how she used her creative skills to improvise a mysterious character while prompting suggestions from her class about who she was and what was happening. She reflected on how this worked particularly well with less able students who lacked confidence when it came to generating their own ideas. At first, students sought a single correct answer, asking whether or not their suggestion about her performance was correct. Such questioning was deflected by the response "it's whatever you think it is", leaving the arena open for other pupils to make suggestions while legitimising all students' thoughts as valid self-generated ideas. Initially, it was the louder children who were questioning her for the right answer but then, when it was clear that so single solution existed, the quieter children came forward with their ideas. In this way, she supported an efficient transition in the pupils' thinking from analytical to generative. Interpreting the creative outcomes of others can itself encourage creativity. As one trainee commented:

> *…but also working with other people and seeing what they do and taking your own interpretation of what they do – because they don't explain what they're doing and what they're saying – that in turn helps you generate ideas…like with the Rorschach tests with the ink splots - what do you think you see? – you take your own interpretation and that helps you create your own mental links which puts you on further in the generative process*

What can and can't the sciences of the mind and brain tell us about creativity?

There are many aspects of creativity that neuroscience is, and may always be, unable to tell us much about. For example, feelings have had to be discussed in this report, as these appear vitally entwined with our generation of thoughts and ideas. But neuroscience presently has very few insights to offer education about emotion (Byrnes, 2001, p112) and certainly cannot tell us how it feels to be creative. Neither is neuroscience well poised to discuss issues of free-will and autonomy. However, in our project, insights about mind and brain did successfully highlight how creativity involves a type of generative thinking that is essentially different to the analytical thinking predominantly emphasised in schools, and this gives rise to a number of implications for educational practice. Even so, it is clear that individual creativity will always involve a journey whose destination is unknown. Each of these creative journeys is a unique experience, just as every brain is unique in terms of its structure and functioning. For these reasons alone, neuroscience will never entirely explain or demystify creative processes and experiences. It may, however, provide new ways in which we can think and talk about these, and reflect upon the daily decisions we make as educators when trying to foster creativity in our students. In this way, scientific insights about the mind and brain have the potential to transform educational perspectives or, as one participant explained:

> *…as soon as you build an understanding of how people work, and why they work like that, then you don't necessarily see someone's behaviour in the same way…*

Summary

The following educationally relevant and scientifically credible concepts were identified in this project:

- Although every creative act contains elements of spontaneity, teachers can play a critical role in fostering creative thinking processes through use of environment and strategy.

- No single part of our brain is responsible for creativity. Some regions linked to producing divergent associations, of the type needed for creativity, appear usually located in the right hemisphere. However, creativity is a complex thought process that calls on many different brain regions in both hemispheres. Left-brain/right-brain theories of learning are not based on credible science and are unhelpful in understanding creativity, especially when used to categorise individuals.

- Creativity appears to require movement between two different modes of thinking: generative and analytical.

- Cognitive fixation occurs when we become unable to move beyond an idea or set of ideas. It can be thought of as being stuck in analytical mode. However, in normal circumstances, we can monitor and, to some extent, regulate which mode we are using. In this sense, creative thinking appears amenable to metacognition.

- Analytical thinking can benefit from extrinsic rewards such as assessment praise, whereas generative thinking can benefit more from more intrinsic motivations such as fascination and curiosity. Analytical thinking can also be encouraged by mild anxiety, while a stress-free and uncritical environment can produce more generative thinking.

- Rehearsing the same idea can feel reassuring, whereas generative thinking can feel like a step in the dark, especially when there are few constraints or guidelines. To avoid anxiety, and thence fixation, the right level of constraint is sometimes required: not so constrained that creativity can't flourish, but sufficient to provide some level of reassurance.

- When we visualise, our brain activity can resemble that associated with real experience. This suggests visualisation is a potentially powerful educational tool. For example, enhancement of generative thinking can be achieved through visualising changes in context.

- Generative thinking can be supported by strategies that require the making of unusual connections, such has being required to incorporate unrelated stimuli into an outcome. For this reason, given stimuli can be more effective than selected stimuli, since otherwise we tend to choose elements that are easily and obviously related. A recent neuroimaging study supports the notion that incorporating unrelated material into a creative outcome enhances the rehearsal of creative thinking processes. This study, together with reported experience, also suggests that such strategies can be challenging and extra time should be provided to ensure quality outcomes.

- Although mirror neurons are still the subject of scientific debate and discussion, they help provide a potential mechanism by which creative thinking processes can be learnt vicariously, when students watch their teachers being creative. Deflection of questions away from any sense of a closed solution is another way of supporting students in developing their own generative thinking.

- Teachers can help their students during a creative process by identifying when their thinking needs to be more generative or more analytical and enabling this transition through influencing their working environment and/or through the application of particular strategies. However, the decision to apply such influence at any moment in a creative process must take into account the learner(s), their progress and the context.

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Further information

Neuroeducational Research Network (NEnet):
www.bris.ac.uk/education/research/networks/nenet

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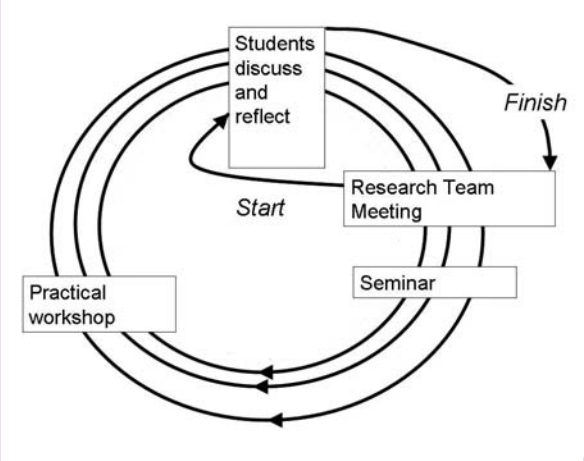

Fig. 1 The action research spiral followed by the researchers. After an initial meeting of the research team and initial discussion, there were three cycles of research meeting, seminar and workshop and student discussion, ending in a final meeting of the team to reflect on the project as a whole.

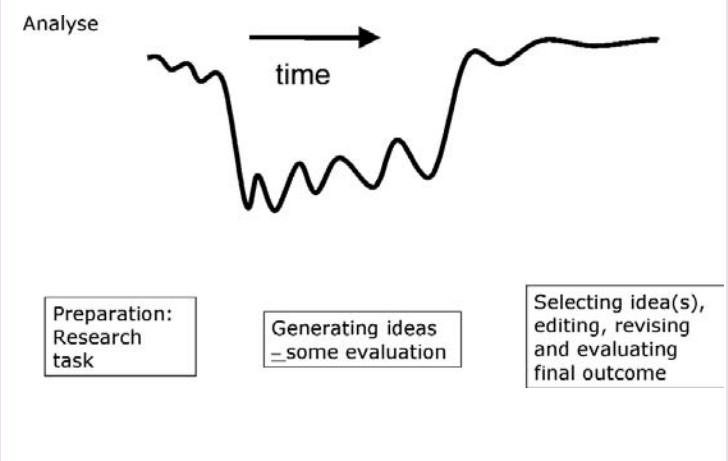

Fig. 3 A hypothetical movement between analytical and generative modes of thinking when developing an idea. In a successful creative process, we are not likely to be entirely fixed in one mode of thinking for any extended period, but the different stages of the process can generally be distinguished as more analytical or more generative.

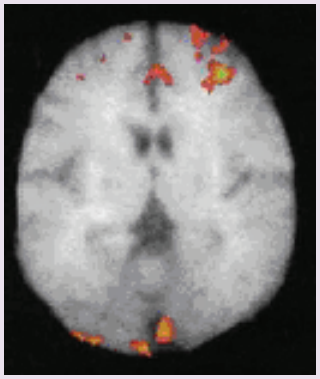

Fig. 2 Carol Seger (Colarado State University) asked people to produce an unusual verb for the nouns she presented to them (e.g. The cat danced) and identified where in the brain activity was greater than just producing the first idea that came into their heads (e.g. The cat purred). The extra creativity required to produce more unusual ideas involved extra activity in wide variety of areas, including visual cortex at the back of the head (bottom of image) for visualising the idea, and right frontal areas (at top of image) involved in finding unusual links. (However, note that producing any word, unusual or not, also involves many more language areas chiefly in the left hemisphere, but since these are common to both conditions, they simply don't show up in this contrast.) (Seger et al., 2000)

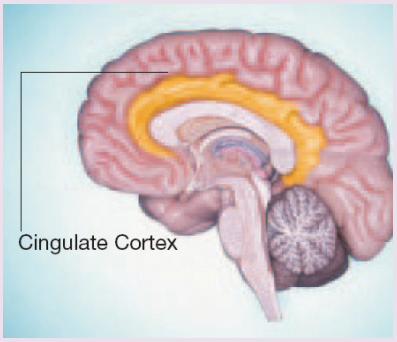

Fig. 4 The evolutionary pressure to maximise cortical area has resulted in some of our cortex existing well below the outer surface. One notable example of this is the cingulate cortex. The anterior (or forward) part of the cingulate cortex (ACC) becomes active when we engage with a wide variety of tasks. Together with prefrontal areas, the ACC appears to have a significant role in controlling how we allocate our attention (TLRP).

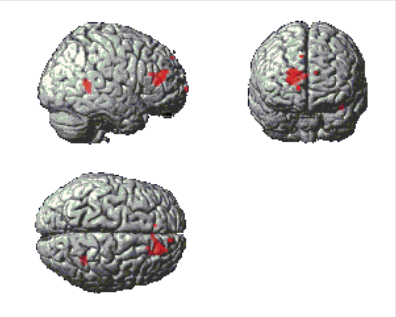

Fig. 5 Activation of frontal medial areas associated with higher level conscious control, when participants attempted to be more creative with unrelated material (Howard-Jones et al., 2005).

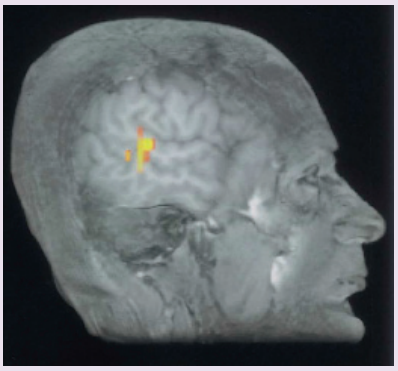

Fig. 6 Brain activity due to observing biological rather than random motion. This suggests there are regions of our brain that have evolved to detect the movement of other humans and animals (Grossman and Blake, 2001). It is possible that we have developed such abilities because they help us put ourselves in the minds of others, and thus contribute to a type of "mind reading" (Rizzolati et al., 2002).

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