

## **Socio-Technical Change**

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### 1. Educational neuroscience: Smart drugs / cognitive enhancers

There are already a number of so-called smart drugs being developed (e.g., donepezil) that have been shown to enhance memory and attention in healthy adults. Although much effort has been directed towards the development of such drugs to ameliorate conditions such as ADHD and Alzheimer's disease, there is already considerable discussion in the scientific and policy arenas and in the popular press about how such smart drugs, cognitive enhancers, or 'cogs' might be used to boost cognitive efficiency and learning in healthy people, including young people.

In 25 years time cognitive enhancers are likely to be even more specific and targeted, enabling us to choose particular drugs to enhance various aspects of memory, attention, processing speed, mood, motivation, perception to suit long or short timescales of activation. We will know even more precisely about the interactions between environmental conditions, genetic predispositions and the activity of psychopharmaceuticals to enable the development of a highly specific programme of drug therapies combined with specific learning experiences. Educational interventions that have hitherto taken for granted the inevitability of biological differences may need to be designed to actively manipulate biology as well as environmental experiences. Even if educators decline to take an active role in shaping the biological aspects of learning, they will have to face the probability that parents will want to take advantage of opportunities offered by pharmaceutical companies to enhance the learning potential of their children.

Uncertainties exist about possible side effects particularly from long term use of cognitive enhancers. There are a number of ethical issues about their use, just as there has been about drugs that boost physical performance in athletes. If science can develop safe and effective drugs to boost cognitive performance why shouldn't society accept these as cognitive enhancements? In the future it may be unethical to deny the chance for pupils to take advantage of such enhancements.

What might this mean for education in the future? Educators will at least need to know about what smart drugs are being taken by their pupils. They may need to have a hand in deciding whether some pupils need to take such drugs. There are ethical issues about haves and have-nots – if cogs are only available to those who can afford to pay for them, what does this mean for equity in education? Should there be drug testing in schools and places of further and higher education? How should the use of such drugs in education be monitored and regulated?

This challenge would need to engage neuroscientists, psychopharmacologists, geneticists, psychologists, educational researchers, science policy researchers and specialists in ethics. Methods for generating robust evidence and new perspectives would include systematic reviews, interdisciplinary workshops / sandpits. Research centres in the UK include the Institute for the Future of the Mind at Oxford University, the Institute for Science and Society at the University of Nottingham, amongst others.

### 2. Educational neuroscience: Brain imaging and neurofeedback

At the present time there are a limited number of brain imaging technologies that have a number of advantages and disadvantages. Functional magnetic resonance imaging (fMRI) enables scientists to pinpoint areas of the brain with differential levels of activation (based on blood flow and levels of blood oxygen) produced while participants are engaged in particular cognitive activities. Whilst fMRI has good spatial resolution, it has poor temporal resolution (because of the time it takes for the haemodynamic response) and so it is less suitable for studying the timing of neural events. Electroencephalography (EEG) uses the

event related potential (a stereotypical EEG event – a peak or trough in activation levels – in response to a particular cognitive activity) to enable scientists to identify the temporal nature of neural events. Whilst EEG better than fMRI for studying the timing of neural events, it has relatively poor spatial resolution. Magnetoencephalography (MEG) is used to measure the magnetic fields produced by electrical activity in the brain. It combines the advantages of fMRI and EEG in providing reasonable spatial and temporal resolution.

The current practical disadvantage of these techniques are that, whilst they are non- or minimally invasive, they are fairly intrusive, and they require participants to sit or lie very still in a large scanning machine in a dedicated lab. EEG is less restrictive but still relies on participants being tethered by wires to a computer whilst wearing a hairnet containing the electrodes. However future developments in imaging may mean that in 25 years we will have relatively affordable wearable portable brain imaging devices, transmitting wirelessly in real time. Functional near infrared (or functional optical) imaging (fNIR) is already being used to provide cheaper devices that allow continuous, portable and potentially wireless and wearable monitoring of changes in blood oxygenation and blood volume related to brain function. It is possible in the future that not only scientists but educators may be able to view real time readouts of brain events. These developments may allow neurofeedback to be used to tailor individual learning, as is currently proposed for treating ADHD.

Aside from whether or not technical developments will enable real-time brain imaging and/or neurofeedback in the classroom, rapid advancements in neuroscience are already impacting on educational policy and practice. An unfortunate aspect of this is the recent emergence of a host of neuromyths, and programmes such as brain gym and accelerated learning, that are supposedly based on neuroscientific findings. Such programmes may have had some origin in respectable scientific findings but their translation and exploitation by commercial companies have led to educational practice that is very far removed from the original empirical evidence and some of which is extremely dubious in terms of educational value.

At present neuroscience is developing at a far more rapid pace than the understanding by educators of its implications for practice. There is enormous interest in the potential for the development of educational neuroscience, but attempts to bridge the divide between neuroscience and education have been limited to seminars, workshops and publications arising from them (e.g., OECD Centre for Educational Research & Innovation's Brain and Learning project; ESRC TLRP seminar series on Collaborative Frameworks in Neuroscience and Education). There is of course a large amount of funded research effort devoted to neuroscientific studies relevant to education, but relatively little concerted effort devoted to translating such research into practice. Neuroscience does not to any large extent, in the UK at least at present, figure in the professional training of teachers. How to bridge the gap between neuroscience and education has been a matter of some debate for around a decade now, yet whilst the debate continues about this, educators and policymakers continue to read the scientific papers, or worse, the popular press interpretations about the scientific findings, and attempt to put the findings into practice. Some of these efforts have been misguided and may only have served to entrench the neuromyths alluded to earlier. There is a pressing need to develop a translational educational neuroscience that enables scientific research to be properly translated into efficacious practice. This has implications for the training and professional development of future teachers.

### 3. Ubiquitous computing and ambient intelligence

Just over a decade since Mark Weiser coined the phrase 'ubiquitous computing' we already live in a world of barcodes, RFID tags, location aware devices (GPS enabled PDAs and mobile phones) embedded into our daily, routine lives, whether shopping, travelling or working. In 25 years time it is possible that every physical object we use, consume, interact with, walk through and around will be logged continuously via what is called the 'internet of things'. Developments such as smart dust or 'motes' mean that tiny sensors

can be embedded into and distributed around the environment. Developments in ambient intelligence will enable environments that are responsive to individual behaviours, using embedded sensors, location and context awareness and personal profiling to deliver an environment that is adaptive and personalised.

Developments in display technologies will enable potentially any surface to become a display – and an interactive display. It is already possible to use such technologies to create virtual keyboards, using a mobile phone. Vision tracking technologies can be used to provide interpretations of gestural interactions with such displays. Touch interfaces are already incorporated into mundane technologies such as mobile phones (iPod and iPhone) and desktops. Digital paper is likely to become widespread.

Developments in tangible and haptic technologies may mean that teachers can have accurate assessments of developments in motor control that are related to cognitive processes in learning. Advances in the neuroscience of motor control, together with these technological developments may enable the development of intelligent tangible or haptic devices to train young children (e.g., in mapping between physical activity and symbolic understanding in mathematics and literacy).

#### 4. Web 3.0: The semantic & pragmatic web / Internet of things / Intelligent agents

Developments in the semantic and pragmatic web, together with intelligent agents, will enable vastly more intelligent and personally relevant searches for information. Already today educators are vexed with the problem of plagiarism from the web. In a world of intelligent agents, students will potentially be able to interrogate the web to provide individually tailored responses to queries that take account of the student's age, intelligence, past history and other information. A student in 2030 will be able to commission an essay on virtually any topic – one that is possibly unidentifiable as plagiarism because it is assembled on the fly and therefore unique and unreproducible. Far from canned and static texts, or even an amalgamation of texts from several sources, these assignments will potentially be truly unique – the work of the intelligent agent, in a sense masquerading as the student. Rather than seeing this as plagiarism or a threat, we might need to grasp the nettle that web technologies of the future enable students to augment their own capabilities with the services of ghost writers. How should we view such activity? How should we evaluate it? What could be valuable to the student in making use of such services? Does the web now become the calculator of the future?

Web 2.0 has seen the burgeoning of social networking, with Facebook, YouTube, del.icio.us and others. This and other developments, including Second Life and blogging, have seen a recent explosion in the development of user-created content and alternative identities. Increasingly in the future students will be developing alternative lives and identities online. How could or should education interface with such developments?

#### 5. Memories for life / Cyberinfrastructure for learning

A child of school age in the year 2030 could have an incredible amount of digital information recorded about them, from their ultrasound or other imaging data whilst in utero, to their DNA profile, data from their parents' life histories, every interaction they have ever had with a world of continuously monitored sensors, all their assessments through their schooling, their health history, behavioural data on their family (including lifestyle choices, shopping behaviour), as well as images and videos of their life events, marks made on digital paper, interactions with digital displays. If even a subset of such data were potentially available to inform their education, it would create a massive challenge of data mining and interpretation, but such an effort may be immensely valuable in tailoring educational experiences to the individual child. Even aside from the challenge of understanding how to analyse and exploit such data technically, what might this mean for how teachers and policymakers provide an appropriate educational experience?

Initiatives are already underway in the area of lifelong learning to provide ePortfolios. Research in intelligent tutoring systems is making inroads into techniques for data mining of very large databases of interactions between students and software environments to be able to reason about past history and predict and shape future interactions. Developments in machine learning may be able to go well beyond human capabilities in making sense out of such a vast array of data. But how can we make this intelligible to people, to teachers?

So far efforts to develop data mining techniques for education are very small compared to the efforts dedicated to such developments in scientific research (e.g., eScience and GRID developments), but there are a number of research centres internationally working in this area, and a relatively recent report by the US Computing Research Association and funded by the National Science Foundation (Cyberinfrastructure for Education and Learning for the Future, 2005) outlines a research agenda in this area.

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