Engaging trainee teachers with neuroscience and cognitive psychology

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Abstract Initial teacher education (ITE) needs to respond to the huge increase in research in neuroscience that informs our understanding of learning. Educational applications of cognitive psychology, in particular from the field of memory, are strongly evident in government policy documents in England, but as yet the wider contribution of educational neuroscience is not explicit. ITE needs to open trainee teachers' thinking to these perspectives and what can be learned from them, but also needs to examine them critically and in relation to other forms of educational knowledge and aims. This article explains how one university is taking an interdisciplinary approach to this challenge to develop their ITE curriculum.

As science educators, we know that humans are material, biological beings as well as social, individual people with unique histories. We also know that scientific knowledge is complex, contested and tentative. Importantly, we know what it means to teach learners about both scientific processes and scientific ideas (disciplinary and substantive knowledge), and the fascinations and the challenges that come with that. This means that science educators at all levels of education are ideally placed to work with colleagues to make sense of the explosion of interest in the science of learning and to consider carefully what it means for teachers and students. This article explains how a research group at Bath Spa University, comprising teacher educators, education researchers, psychologists and a neuropsychologist, has responded to this challenge by developing the curriculum for initial teacher education (ITE) in a project funded by the Wellcome Trust.

We argue that considering neuroscience and cognitive psychology brings different perspectives and forms of evidence to existing educational ideas. As professionals, teachers should have an understanding of the different ways in which research can support practice and what it means for teaching to be research informed. It follows that ITE should support teachers in developing sufficient understanding of the contribution of these disciplines. This might challenge, support or extend our current thinking or open new possibilities. At the same time, we need to hold onto the value of educational research and the practical wisdom we have about teaching. Being open minded, but critical, demands our scientific literacy.

This article builds on two previous articles in *School Science Review* (Gittner and Harrison, 2019a; 2019b) that have addressed aspects of the *Improving Secondary Science* report (Holman and Yeomans, 2018) from the Education Endowment Foundation. In particular, it relates to Recommendation 4 Memory: *Support pupils to retain and retrieve knowledge*. The current UK Government position is to highly value established research findings from behavioural cognitive psychology that focus on memory as encoding, storing and retrieving information and experiences. It remains quieter about wider findings from neuroscience and the physical/biological basis of brain activity. This cognitive science lens is evident again in the recent Ofsted research review (Ofsted, 2021) framing of learning as the transfer and consolidation of information from 'working memory' to 'long-term memory' (Willingham, 2009).

Neuroscience essentially supports this two-part view of memory, although the physical basis of memory is still contested (e.g. Camina and Güell, 2017; Gallistel, 2020). But, neuroscience offers different insights too. A key message coming from the science of learning is that cognition and emotion are not separate, they are deeply intertwined, or even inseparable. By providing a wider lens on brain development, neuroscience can contribute to our understanding of the sensory, social and emotional dimensions of learning and what this means for education (see summary by Immordino-Yang, Darling-Hammond and Krone, 2019). Also, there is evidence that conceptual change during science education is not a matter of replacing misconceptions, but of learning to inhibit our everyday ideas when the context demands a more scientific account (Masson *et al.*, 2014). We argue that developing a critical approach includes seeing cognitive psychology as only one way of researching learning.

Initial teacher education – the policy context in England

In November 2019, a new *Core Content Framework* for initial teacher training (ITT) in England was published by the Department for Education (DfE, 2019a). As science educators, it was reassuring to see the content framework giving attention to building on pupils' existing ideas and addressing 'misconceptions'. The emphasis it places on concepts and research from cognitive psychology is striking. For example, in relation to promoting pupil progress it states that trainees should learn that:

An important factor in learning is memory, which can be thought of as comprising two elements: working memory and long-term memory. (p. 11)

The specific recommendations made for teaching practice based on memory research are to avoid overloading working memory by minimising distractions and by breaking content into manageable steps, and only increasing the challenge as knowledge becomes more secure. Trainees should also learn how to sequence lessons with regular spaced practice and retrieval. The findings of the research underlying retrieval practice are that, when compared with rereading a text, being tested on it leads to better retention. There is also reference in the document to 'dual coding', where it says that trainee teachers should practice:

combining a verbal explanation with a relevant graphical representation of the same concept or process, where appropriate. (p. 18)

The use of terms such as 'cognitive overload' and 'retrieval' is very much in line with the view of learning promoted in the *Early Career Framework* for teachers (DfE, 2019b), which is similarly informed by cognitive psychology. For example, it states that teachers should learn that:

requiring pupils to retrieve information from memory, and spacing practice so that pupils revisit ideas after a gap are also likely to strengthen recall. (p. 11)

Indeed, the *ITT Core Content Framework* (DfE, 2019a) explicitly mirrors the structure of the *Early Career Framework*. Both make a useful distinction between trainee teachers having propositional knowledge and putting it into practice: they should '*Learn that*', but also '*Learn how to*'.

Thus there is a clear policy intention to align ITT and teacher development in their early careers.

The similarities should come as no surprise as both the *ITT Core Content Framework* and the *Early Career Framework* have been informed by the *Education Inspection Framework: Overview of Research* (Ofsted, 2019), in which Key Judgement 1: *Quality of Education* is informed by: '*Research on memory and learning*' and:

For this, we can draw on a growing evidence base from the 'learning sciences'. Learning sciences is a relatively new interdisciplinary field that seeks to apply understanding generated by cognitive science to classroom practice. (p. 19)

This introduces yet another term: the 'learning sciences'. According to the International Society of the Learning Sciences (https://www.isls.org), the contributory disciplines include cognitive science, educational psychology, computer science, anthropology, sociology, information sciences, neurosciences, education, design studies, instructional design, and other fields. This draws on a much broader set of research than cognitive psychology alone. The Chartered College of Teaching (2017) similarly selects cognitive science to mention in its Professional Principle 3.4: '*Has up-to-date knowledge of theories and research from the field of cognitive science and understands how these can be used to inform practice in education*'.

These documents seem to be taking the position that, although neuroscience might inform cognitive psychology, it is only at the behavioural level (i.e. the psychological level) that research can directly inform teaching practice. Others have argued that by restricting ourselves to research from psychology, we are missing the potential of a wider range of new knowledge about the brain that includes neuroscience to inform education (Brookman-Byrne, 2017). Also, although a focus on practical applications of research initially seems very appealing, this could support a technicist view of teachers as people who simply receive and implement the findings of others (Winch, Oancea and Orchard, 2015). We agree with Gittner and Harrison (2019a) that teachers should be empowered through access to research to make considered developments to practice in collaboration with colleagues. It is worth noting that throughout the *ITT Core Content Framework* there is considerable, very welcome, reference to the value of discussion and analysis with expert colleagues, suggesting that the value of professional experience and judgment is indeed being recognised.

Some use the term 'cognitive neuroscience' for research into the biological substrates underlying cognition. The range of brain research is huge, not easily divided into distinct areas, and it could be overwhelming. It is certainly unreasonable to expect teachers to become familiar with it all! It is our view that universities should play a key role in managing this complexity by selecting key research and concepts and considering these in relation to existing educational research.

Our starting point was that teachers as professionals should have access to understanding developments across a broad range of research on learning, including neuroscience. Firstly, we saw better knowledge of the brain as a way of challenging 'neuromyths'. Neuromyths are ideas about the brain that have become popular but are not supported by current science. Examples of neuromyths are that people are 'left-brained' and creative, or 'right-brained' and logical, and that strategies for teaching children should be matched to whether they are judged to be visual, auditory or kinaesthetic learners. The VAK or learning styles myth is widespread in the UK and beyond (Gittner, 2018). Science teacher trainees are not immune from belief in neuromyths! In Germany, Grospietsch and Mayer (2019) found that biology trainee teachers held neuromyths in parallel with their neuroscientific understanding.

Secondly, we wanted our trainees to have some tools to raise critical questions about 'brain-based' claims for the value of different teaching strategies and packages. The package *BrainGym*®, in which children were encouraged to do exercises to connect the two hemispheres of the brain (they are already very well connected), is often held up as an example in which science was misused. Current examples where misunderstandings might arise include approaches to emotional self-regulation, in which children visualise their thinking forebrain suppressing their 'primitive, reptilian brain'. Human emotions are not some kind of evolutionary leftover that gets in the way of rational cognition. Attention, curiosity and motivation are vital components of engagement for learning (Howard-Jones *et al.*, 2020). The separation of emotion from cognition has been challenged by clinical findings (of neuroscientist Antonio Damasio). Brain surgery left a patient unable to connect emotions and reasoning and this patient was then unable to make any decisions at all. We wanted to support our trainees in developing their science literacy about the brain. This required supporting their understanding of the knowledge and concepts of neuroscience and also the nature of the scientific processes used to develop such knowledge.

Box 1 Project overview

Cycle 1 (2017/2018): Critical consumers of neuroscience through curriculum development

- Pre- and post-surveys of trainees' views based on Dekker *et al.* (2012).
- Trainee feedback and tutor feedback on critical consumer workshop and science workshop. Trainee focus group analysis.
- Outcomes – teaching and learning materials, better understanding of context and issues with a focus on the value of the interdisciplinary approach (McMahon and Etchells, 2018) and evidence of a reduction in trainee neuromyths and the development of trainees as critical consumers of neuroscience (McMahon, Yeh and Etchells, 2019).

Cycle 2 (2018/2019): Sharing and responding to feedback

- Feedback from other ITE institutions via conferences (ASE, Chartered College of Teaching, Universities' Council for the Education of Teachers, Teacher Education Advancement Network, Primary Science Teaching Trust).
- Trainee and tutor feedback on critical consumer workshop.
- Outcomes – refined open access web-based resources available at www.bathspa.ac.uk/learning-sciences, deeper understanding of concerns in ITE with a focus on tutors.

Cycle 3 (2019/2020): The place of scientific views of learning in ITE

- Dialogues with key agencies and ITE colleagues in 10 institutions (with the University of Bristol).
- Develop guidance for other ITE providers along with more web-based resources.

Design-based research

We took a design-based research (DBR) approach to the project. DBR involves cyclical processes of design, trial, feedback and reflection in a real-life context (Cobb *et al.*, 2003; Anderson and Shattuck, 2012). There are no set methods for DBR. To look at the experience of the trainees we obtained written feedback after sessions to inform the next iteration of the session. We looked at the impact on trainees by a statistical analysis of pre- and post-intervention surveys and through deeper one-to-one interviews. To date, we have undertaken two cycles, and further interations are underway. An overview of the cycles of the project is provided in Box 1.

The first cycle focused on developing new sessions for the PGCE curriculum to support trainees as 'critical consumers' of neuroscience and challenging 'neuromyths'. We then spent a year sharing our ideas with others, gaining feedback and improving the materials based on our own experiences and data.

Taking a critical view by learning more about the brain and brain research

Our work began with challenging the neuromyths held by trainee teachers by looking at simple brain anatomy such as the ways in which the two brain hemispheres are connected by the corpus callosum. We explained to the trainees how views of the brain as having distinct regions for different functions are being modified as new imaging techniques are looking at pathways and networks in the brain (Figure 1). This knowledge can also be used to challenge fixed ideas such as *'I don't have a maths kind of brain'*. The neuroscientist in the project team (Alison Lee) explained that there are different areas of the brain that interact to enable people to do maths: areas for language, areas for spatial awareness and areas for estimating quantity. Large areas of the human brain are 'association cortex' connected by fibres of 'white matter'. Association cortex is where different senses are

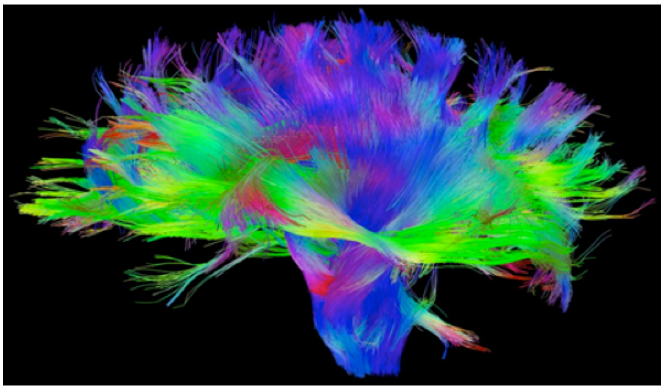

Figure 1 Neuroscience is changing our views of the brain: from regions to networks; image courtesy of the USC Mark and Mary Stevens Neuroimaging and Informatics Institute (www.ini.usc.edu) for the Human Connectome Project

combined to make recognition/memory easier, attention is shifted, planning occurs, and things are learned, stored and reconstructed (remembered). Neuroscience could support a similar argument that doing science involves many different brain areas. As teachers, we were reminded that images are very powerful in shaping our understanding and that we need to choose images of the brain carefully.

As a part of setting up trainees to be 'critical consumers' of brain-based claims in the future, a psychologist in the team (Pete Etchells) introduced us to research on the '*seductive allure of neuroscience*' (Weisberg *et al.*, 2008). This research showed that the addition of spurious neuroscience to an argument makes it more persuasive. The concern is that we are all prone to being persuaded that 'brain-based' claims and products are worthwhile. By building a mock version of the original cognitive psychology experiment into a workshop, the trainees saw for themselves how susceptible we can be. At the same time, they gained an insight into the kind of research that cognitive psychologists conduct.

The next part of the workshop took five claims that the trainees might encounter (Figure 2) and provided them with a scaffold to support them in making a critical analysis of the claim. The scaffold takes the form of *PowerPoint* slides with links to accessible articles and key questions. We have done this as a group activity, with trainees exploring alone and feeding back to the whole class. They could also be used as a source of personal professional development or to work through with colleagues.

Two of the claims address neuromyths (VAK and left brain/right brain); one explores the limits of 'brain training'. The fourth looks at the contested concept of 'growth mindset' (Dweck, 2008) and encourages trainees to think about whether studies have been independently replicated. The last explores the value of 'retrieval practice' as an example of where lab-based cognitive psychology findings have also been tested in classroom settings. Trainees had responded to earlier versions of the workshop by saying that they wanted positive examples as well as what not to do; hence the later inclusion of retrieval practice. However, retrieval practice is not uncontroversial so trainees are asked to think about what kinds of knowledge and views of knowledge it supports.

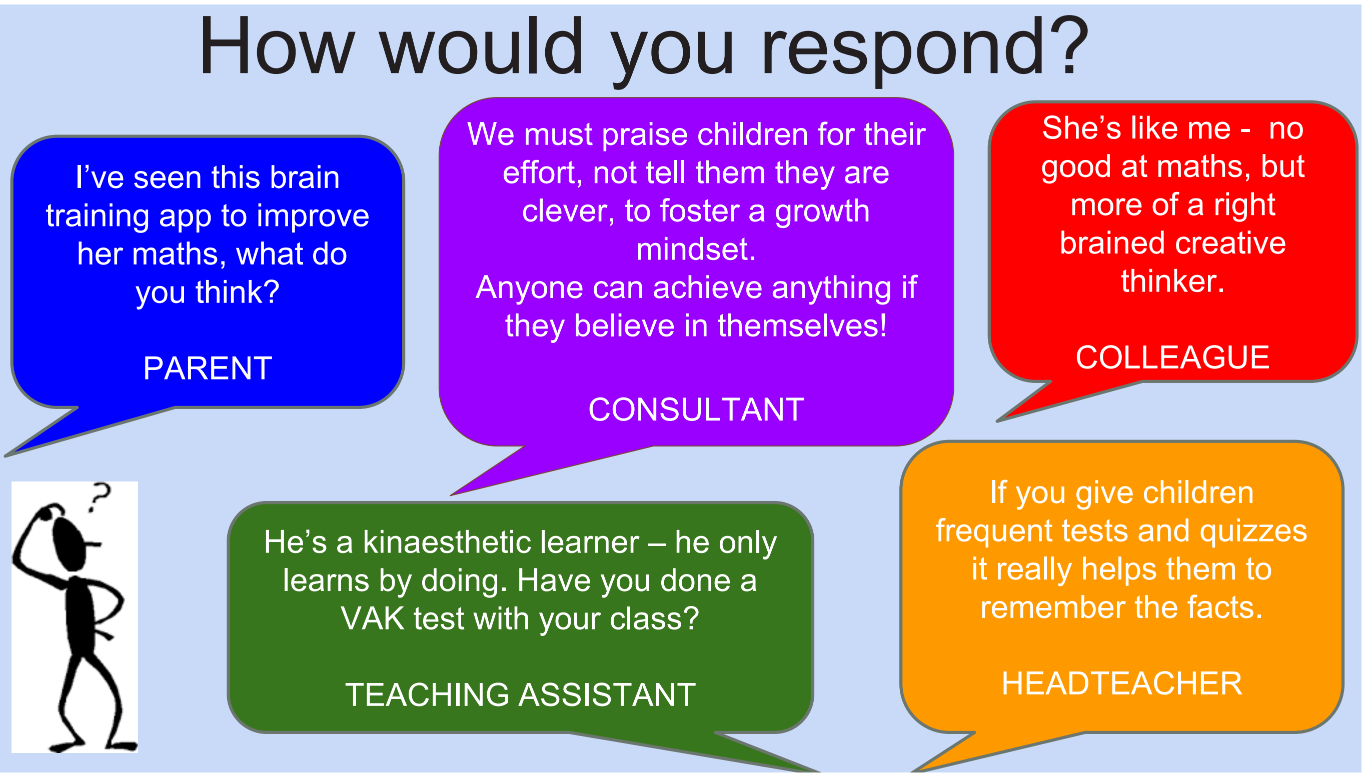

Figure 2 Slide from the workshop resource showing five claims that trainees might encounter

In science education we are always wrestling with the tension between helping pupils to understand the tentative nature of science while simultaneously asking them to accept and recall facts from an unknown authority. We should be thoughtful about how we present and use retrieval practice as a learning strategy and about the discourse we establish around it.

We directly addressed trainee science literacy in their first science session. Trainees considered questions they would want to ask about claims that fish oil supplements support learning. We also developed resources to critique claims about the need to drink six glasses of water a day to enhance brain function. Again in science, a session on the systems of the human body was modified to help the trainees look at the brain in relation to body systems such as digestion and respiration. This was a small step in the direction of an embodied approach by seeing the brain as part of a whole living being, not as an isolated organ.

A further modification to the ITE curriculum was the inclusion of ideas about cognitive load and working memory in a session on SEND, along with a neuroscience-led account that 'every brain is different'. The plasticity of the brain means that a child 'grows their own brain' through their actions and unique experiences. This challenges the idea that categorising children, for example as dyslexic, produces a prescription for teacher intervention and instead recommends a more holistic and creative approach to children as individuals.

The impact of these modifications to the curriculum on trainee thinking were judged by pre- and post-intervention comparisons of trainee belief in neuromyths and their responses to open-ended questions. We found that belief in neuromyths had been reduced, although not totally dispelled, but there had been a significant shift towards uncertainty overall as trainees' ideas were disrupted and unsettled (McMahon *et al.*, 2019). There was also evidence from their written comments that many trainees were taking a critical view of brain-based claims at the end of the course; for example:

> *Don't believe everything you read about the brain just because they have a picture of a brain scan and tell you that scientists say.*

Having refined the curriculum to support trainees to become critical consumers of neuroscience, we have now moved on to look further at what ideas from psychology and neuroscience new teachers should be aware of and what they should know about them. The third cycle of the project has been developed alongside a parallel project led by Paul Howard-Jones and colleagues at the University of Bristol, who are integrating the science of learning into their secondary PGCE courses (www.scienceoflearning-ebc.org). This next phase will be to produce guidance and materials that support engagement with the learning sciences in ITE with critical appraisal of how it relates to existing educational know-ledge and ideas.

Reflections

The value of interdisciplinary work within the team must be emphasised. Cognitive and neuropsychologists were aware of the limitations of their own fields and therefore more cautious and critical of its applications than the educationists, who tended to look for (and find) congruence with our existing ideas. Cognitive psychologists would call this 'confirmation bias'! Working together enabled us all to recognise that each discipline is rich and complex with contested knowledge and varied perspectives. This was evident in the different priorities we brought to the evaluation of research, with psychologists particularly looking for replication of findings and educationists raising concerns about the educational aims and values (McMahon and Etchells, 2018).

What does it means to respond critically to neuroscience-based claims? In the online resources, we focused on developing awareness of the seductive allure of neuroscience and misinterpretations of the science, especially as manifested as neuromyths. We supported scientific literacy by asking trainees to consider issues such as replication of results and any conflicts of interest. We also began to raise questions about how 'success' is measured in research trials. Discussions within and beyond the team opened up further critical perspectives that we wish to integrate into future iterations of resources.

Neuroscience findings are inevitably shaped by the tools that scientists use. Much recent research depends on different neuroimaging techniques that produce images that appear to indicate brain areas lighting up. It is important to understand that some imaging techniques use computers to select and enhance data to generate the image, and the ways in which they do this are determined by the scientists. For example, a scientist will decide the threshold at which brain activity is coloured yellow or red, or left colourless. Scientists will also decide which brain areas to include in the image and which to leave out. This is important, as text with brain images alongside is more persuasive (McCabe and Castel, 2008). Bell and Darlington (2018) give a good account of such methodological issues in the *ASE Guide to Primary Science*.

Social perspectives on education suggest that scientific perspectives can promote a narrow view of learning as knowledge acquisition and argue that education is also about participation, such as involvement in knowledge-based communities (Hordern, 2019). The importance of science capital in influencing pupil career choice that was found by the ASPIRES project (2013) is an example of this. In the same way that being able to decode text is not the same as being a reader, being able to respond correctly in a science exam does not necessarily mean that pupils see science as being for them.

At the moment, the science of learning has focused attention on learners as individuals, undervaluing social/cultural dimensions of learning (as introduced by Vygotsky and Bruner), such as the role of language and the ways in which pupils learn from each other. This might be partly an effect of the current technology: there is only room for one person in a brain scanner! Interestingly, there are moves to make neurological studies of whole classes of children and their teachers, as at the Science of Learning Research Centre in Queensland, Australia (www.slrc.org.au). A focus on individual learning can also promote the 'cruel optimism' of personal responsibility for self-development, while ignoring society-level effects on inequality. This concern that pupils might feel entirely to blame for their own lack of success is one critique of approaches based on growth mindset.

As the project developed, we wondered how trainee teachers' ideas about learning and the brains (and minds) of their pupils might affect practice in subtle ways that are not immediately obvious. Neuroscience offers some alternative insights into what it means to restructure a 'misconception'. It seems that what we actually do is not replace the original idea, but learn to inhibit it to allow new ideas to predominate (Masson *et al.,* 2014). This has implications for how we conceive the outcomes of teaching and learning in science and may have practical implications for how we help children to inhibit alternative ideas – to pause and think slowly (see the 'Stop and Think: Learning Counterintuitive Concepts' project on the Education Endowment Foundation webpages). If trainees look at learning primarily through a selective cognitive psychology lens on memory, what views of learning will they be developing and what will they miss? The emphasis on memory is closely linked with the current emphasis in England on a knowledge-rich curriculum; views of how we learn are always intertwined with what aims of learning are valued.

There are efforts underway to support a wider view of the 'learning sciences' and education. The organisation Learnus (www.learnus.co.uk) brings together neuroscientists and teachers – see their blog pages. You might consider participating in the new online platform 'UNIFIED' (https://unifiededu.org) that brings teachers and researchers together on an equal footing (Hobiss *et al.*, 2019). At Bath Spa University we are continuing to refine our work in ITE and would welcome feedback from school teachers and ITE providers. You can find the open-access materials we have developed to date at www.bathspa.ac.uk/learning-sciences. Please feel free to use them for trainee teachers, early career teachers, by yourself and with colleagues. We not only welcome feedback, but very much need it in order to continue to improve our resources. We have recently considered the ITE curriculum and where the 'learning sciences' should sit within it in response to both the policy context and research, and have developed further materials and guidance for ITE providers that you can find on our webpages. The document on the learning sciences in primary science may be of particular interest. Do get in touch if you would like to help develop one for secondary school science!

As we continue the dialogue between education, neuroscience and psychological perspectives through interdisciplinary DBR we look forward to discussions with policy-shaping bodies and others involved in ITE. Do get in touch!

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