Running head: *Neuroscience Literacy*

The Neuroscience Literacy of Trainee Teachers

Paul Howard-Jones, Lorna Franey, Rasha Mashmoushi and Yen-Chun Liao

Graduate School of Education, University of Bristol

Paper presented at the British Educational Research Association Annual Conference, University of Manchester, 2-5 September 2009

Contact Paul Howard-Jones: Graduate School of Education, 35 Berkely Square, BS8 1JA, United Kingdom (e-mail: paul.howard-jones@bris.ac.uk).

Abstract

Background: There is concern about the prevalence of neuromyths in education, but little is known about how teachers think about the brain and how this may influence their practice.

Aim: To further understanding of how teachers, at entry to the profession, think about brain development and function.

Sample: 158 graduate trainee teachers at the end of their one-year course.

Methods: Preliminary semi-structured interviews contributed to the development of a suitable survey instrument. Participants were then surveyed during one of their final lectures.

Results: Trainees' ideas reflected misconceptions in public circulation and notions promoted by popular brain-based educational programmes. Most of the trainee teachers in our survey did not accept, or were unsure, about whether mental activity derives from biological brain function. Trainee teachers place equal importance on home environment and education as determinants of educational outcome, with genetics a significant but smaller influence than either. A follow up survey with a new cohort of trainees confirmed that constructs about development are linked to a sense of agency, with beliefs in strong genetic influence associated with stronger notions of biologically-defined limits on pupil achievement.

Conclusions: In the absence of formal training, trainee teachers acquire their own ideas about brain function, many of which are potentially detrimental to their practice as teachers.

Introduction

In 2002, the OECD's Brain and Learning project drew international attention to the many myths and misconceptions that had arisen around the mind and brain outside of the scientific community, including in schools. They defined the term "neuromyth" as being a "misconception generated by a misunderstanding, a misreading or a misquoting of facts scientifically established ...." (OECD, 2002, p111). Between 2005 and 2006, the ESRC-TLRP seminar series "Collaborative Frameworks in Neuroscience and Education" brought together over 400 teachers, neuroscientists, psychologists and policy-makers to discuss the potential for collaborative work that might lead to improved educational and neuroscientific understanding. The commentary arising from this seminar series proposed that education may have much to gain from greater cognisance of the workings of the brain and improved dialogue with those working in the neuroscience community (Howard-Jones, 2007). Amongst other things, it was proposed this dialogue would help scrutinise neuro-myths and evaluate programmes of "brain-based" learning. In May 2007, concerns about the prevalence of classroom neuromythology were voiced again at a meeting an all-party parliamentary group on scientific research in learning and education. Here, questions were raised about whether initial teacher training should included a greater emphasis on learning in terms of neural processes, as a way of deterring teachers from unscientific and unhelpful brain-based notions. In response to concerns focusing on Visual, Auditory and Kinaesthetic (VAK) learning styles, Alison Atkinson of the Teacher Development Agency admitted "...we do not specify that neuroscience or VAK should be part of initial teacher training, but we do specify that teachers should be up to date with knowledge on teaching and that they should engage with educational research, the idea being that standards are thereby to some degree futureproofed....I do not think we see ourselves as including brain science in any format within the standards under that very name, but we hope that teachers engage constantly with what is happening in educational research" (Institute for the Future of the Mind, 2007, p31). Such a "hands off" approach based on encouraging engagement with educational research may not, however, have adequately protected teachers and their pupils from a host of inappropriate practices associated with unscientific ideas about the brain. Indeed, it is possible to find examples of unhelpful brain-based ideas being promoted rather than scrutinised in the educational research literature e.g. (Moore & Hibbert, 2005).

It seems unlikely that this lack of neuroscientific training results in teachers possessing no working ideas about brain function. Indeed, our informal "theory of brain" develops early, such that by the age of 4 we consider it as an internal body part involved with a range of distinctly mental acts, but do not differentiate between mind and brain. During the school years, the concepts become increasingly differentiated such that, by the age of 10-11 years old, children often consider there is some cognitive function of the brain behind sensory-motor acts. Realisation grows with the approach adulthood that the brain is essential for all behaviour, including noncognitive involuntary responses such as fear and laughter (Johnson & Wellman, 1982). Experimental evidence demonstrates that adults possess an attraction to explanations involving the brain, helping to explain the high profile of neuroscience in the media and popular press (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Indeed, it has been suggested that this public interest is supporting the emergence of a modern folk neuropsychology, a network of culturally shared concepts that people use to explain their own, or another's, mind and behaviour (Rodriguez, 2006). Such explanations are expressed in ordinary everyday language. In metaphorical usage, the brain can be used in similar ways as the mind, e.g. as a container, a machine, a memory recording medium or muscle. However, differences in the way mind and brain are commonly used suggests a popular mind-brain dissociation and, thus, the possibility of a complex mind-brain interrelationship. The brain is often portrayed as the cause of a state of being (e.g. “now I’m brain dead” as an explanation for a mental state in which mistakes are being made). The fact that people often differentiate between their experiencing self (Subject) and their body (self) is well established. To some extent, phrases such as “this menu is confusing my brain” demonstrate how a reference to the brain can be used to support this subject-self dissociation, but the story may be complicated than this. For example, in matters such as perception it is still usually the Subject that sees, hears, feels etc., and yet references to the brain are now being used to avoid the subject’s role here (e.g. “my brain can’t see it”) and, unlike the role of the body self and more like the role of the Subject, it can take on direct agency (“My brain made me do it”). The use of the term brain is, of course, likely to be rapidly evolving, echoing the rate at which neuroscientific understanding and public interest in neuroscience is burgeoning. For example, at the moment, it is difficult to find examples of common speech that uses “brain” as an agent of either desires or intentions, although it may only be a matter of time before a popular understanding of the reward system gives rise to phrases such as “my brain wants chocolate”. Such a cognitive semantic analysis suggests the existence of a potentially complex, if not wholly scientific, interrelationship between matters of brain, mind and behaviour amongst the adult public. Further evidence for this was provided by a survey of the citizens of Rio de Janeiro carried out in 2002. Here, members of the public and a sample of neuroscientists were asked to respond with agree, disagree or don’t know to 95 assertions about the brain (Hurculano-Houzel, 2002). The survey revealed that the public, unlike the scientists, were evenly divided about the usefulness of studying the brain to understand the mind, suggesting a range of opinions regarding the brain-mind relationship. This was despite the same sample of the public holding many concepts about the brain that concurred with scientific opinion, such as the dependency of learning on attention, the association of different brain regions with different cognitive functions and the non-stop operation of the brain throughout the day and night. However, they were less sure of other basic scientific concepts, such as the dependency of learning upon the modification of connections between neurons. Assertions they generally agreed with, in opposition to experts, also included the idea that emotions always disrupt reasoning (they are often necessary for it), the existence of single memory system in the brain (there are several systems), that hormones do not influence personality (they do) and that the brain operates like a computer (when, in fact, memory and processing is distributed throughout the brain, unlike a computer).

As well as being influenced by the prevailing folk neuropsychology and opinions in general public domains, one can expect educators to have contact with an additional range of information sources associated specifically with their profession, these may also influence their constructions of mind and brain. Chief amongst these professional influences are the “brain-based” educational products and programmes that have been successfully marketed within schools in the last two decades, most of which appear to have little scientific merit. Two of those attracting particular concern have already been mentioned above: Visual, auditory and kinaesthetic (VAK) learning styles, learning preferences based on left-brain/right-brain categorisation (Institute for the Future of the Mind, 2007) and also educational kinaesthetics or ‘brain gym’ (Hyatt, 2007). The latter, in addition to promoting concepts about “repatterning” the brain to promote literacy, also claims a strong relationship between the drinking of water and learning. Other concerns include nutritional issues such as benefits of Omega 3 and the effects of sugar (Howard-Jones, 2008). Another popular neuromyth is the neuroscientific justification for stimulus-rich environments during the early years, partly based on unscientific notions of critical periods for formal learning (Blakemore & Frith, 2005).

Thus, there are clear reasons to assume teachers, and the trainee teachers who have worked with them, possess concepts about the mind and brain despite this area being absent from formal requirements for Initial Teacher Training. Moreover, some of these concepts may be exclusively associated with their professional activities, thus providing teachers with a potentially distinct set of notions about the brain that differs from those of experts and/or the general public. Even leaving aside the common implementation of teaching strategies claiming to be brain-based, notions of mind and brain may be linked with educational attitudes and practices and are, therefore, a valuable focus of investigation. For example, it has been pointed out that public debate around dyslexia easily becomes polarised in terms of causes being either biologically determined or not, and that the arguments become closely bound up with whether dyslexia is amenable to educational remediation (Nicolson, 2005). It seems possible, therefore, that strong beliefs in genetic predisposition and biologically determined brain development are linked to teachers' perceptions of the extent to which they can influence a learner's progress. It has been reported that teachers believe genetics is a very important factor influencing their pupils' development. A survey received replies from 667 UK teachers asked to what extent nature (genes) or nurture (environment) was responsible for various pupil outcomes (Walker & Plomin, 2005). The percentage of teachers who perceived that genetics accounts for at least half of the influence, was 87% for personality, 94% for intelligence and the same figure for learning difficulties, 43% for behaviour problems and 91% for mental illness. Only 1-9% saw these behaviours as due to “all genes” and 0-1% as “all environment”. Walker and Plomin used their results to suggest that most teachers, despite a lack of formal genetics in their training and the frequent use of misleading phrases in the media (e.g. “dyslexia gene”), possess a balanced view of the importance of both genetics and environment as influences upon outcome. The survey did not ask what remaining proportion of environmental influence derives from formal education, although the authors of the study claim that teachers are undaunted by their perceptions of genetic influence. Indeed, contrary to such concerns, Walker and Plomin suggest that teachers want to know more about such biological influences, believing such knowledge can support their teaching, with 82% of teachers in their survey claiming they would change their method of tracking and instructing a child if they knew he/she suffered from a genetically influenced learning difficulty.

In a world where everyday language promotes contradictory ideas about the mind-brain relationship, and even professional development cannot be relied upon to deliver valid neuroscientific concepts, it can be expected that teachers’ ideas about the brain diverge from conventional scientific thinking. So how do teachers talk and think about the brain?

Preliminary interviews

This initial investigation began with some informal semi-structured interviews with a primary school headteacher, 6 teachers (3 primary, 3 secondary) each with several years experience and 6 trainee secondary teachers about to embark on their career. These were informal conversational affairs. We started by asking them what sort of ability range they had encountered as teachers, and what they thought produced such a diverse range of achievement. Some of our group, as might be predicted from the survey by Walker and Plomin, were convinced that genetics should be considered as the key factor or, as one primary school teacher put it:

> "I believe it's about genes, I believe you do see intelligent children from intelligent parents"

Our headteacher also put forward genetics as the key reason for such diversity, but suggested home environment was the next big factor:

> "It is genetically inherited. If I try to do calculus, high math, with some children it wouldn't matter how much I try they wouldn't understand it and then their motivation would decrease….I think it's genetics…genetics is a very high one and motivation and the environment at home is another one"

Indeed most of our group considered there was a balanced influence between genetics and environment on brain development, with a secondary school teacher explaining:

> "…. you've got the combination of nature and nurture because…it's a horrible kind of a sweeping statement and generalization…but often more educated parents would have more resources to help their children when they are young.."

It was also clear, however, that when different teachers discussed "environment", they rarely used the term as scientists do, i.e. as an umbrella term that covers all influences derived from social and physical settings. It could sometimes refer to just influences derived from the home:

> *Interviewer:* "Why do you think there is this range between students in the classroom?"
>
> *Primary school teacher:* "I think it has a lot to do with the environment"
>
> *Interviewer:* "Environment – what exactly?"
>
> *Primary School teacher:* "Kind of their home environment. Perhaps the way they have been brought up and the area that they live in, perhaps, but then also, I think, it could be genetic as well in their families. So it could be to do with the make up of the family"

Or, when used in the educational sense, the term "environment" could mean the influence or stimulus provided by the teacher and classroom, as in this comment by a trainee teacher:

> "I think maybe in a very enriched environment probably the brain will be bigger and heavier (from) lots of different kinds of stimuli, lots of changing activities very rapidly, a really good mixture of conventional grammar and spelling, at the same time doing fun stuff like music, images, sound."

Ideas around the plasticity of the brain were diverse and sometimes complex, with the same trainee expressing how mental ability can develop, but uneasy about how such changes might be reflected at biological level:

> "I think the brain must be able to change to be honest. You see people who don't have hands so they (learn to) use their toes to be able to paint. So you work about the problem, not getting rid of it but you are certainly working about it. ….It's like a car and you have the engine and you can supe it up and rewire it and polish it but it is the same car"

Concepts about plasticity were also frequently linked to age, as in this comment by a secondary teacher:

> "I think your brain is always developing and I think it can develop in reaction to your environment so I think it can cause your brain to sort of develop more maybe when you are young…

Ageing of the brain was mentioned by some as providing a limitation on learning arising from lack of brain plasticity although, again, our teachers were unclear about how this worked. Explanations often touched upon neuromythology:

> *Interviewer:* Do you know how the brain grows?
>
> *Secondary school teacher:* I know that after you're 18, as far as I know, you don't regenerate brain cells anymore, so people shouldn't hit you on the head.
>
> *Interviewer:* If you're not hit on the head, can you learn new skills? For example, if brain cells are not regenerating, would that hinder your learning and your skills?
>
> *Secondary school teacher*: I don't think so, no, I mean we only use 10% of our brain anyway apparently, that's what I've been taught.
>
> *Interviewer:* Why don't we use the other 90%?
>
> *Secondary school teacher*: I have no idea.

The extent to which brain development was open to educational intervention proved an interesting area for discussion. On the one hand, as demonstrated above, direct questions about whether an improvement in ability might correspond to physical brain changes generally met with agreement. On the other hand, when learning difficulties were associated with differences in brain function, teachers appeared unclear about the effectiveness of educational solutions and thought more in terms of "coping", as in this exchange with another secondary school teacher:

> *Interviewer:* Does knowing this (a learning difficulty) has something to do with the brain change the way you're looking at the student?
>
> *Secondary school teacher:* "It certainly I suppose changes how you deal with it because, if you were told that it's entirely to do with the brain then you're kind of looking at ways to cope with them that would make things easier for them in the classroom."

There appeared to be a type of "all or none" theorising about problems being either biological in nature or not:

> *Interviewer:* What are the options in front of you do you think?
>
> *Secondary school trainee teacher*: I think…I suppose yes…if there's a biological problem, things like diet, drugs. I don't really like the idea of drugs, but I think some people do see them as a readily good option for some children.
>
> *Interviewer:* What exactly do you mean by diet?
>
> *Secondary school trainee teacher*: I mean avoiding colourants, avoiding fizzy drinks, avoiding too much sugar. So, you know, trying also I suppose fish oils as well, I am real believer in all of that.

One teacher explicitly categorised causal factors of learning difficulties involving the brain as medical, possibly implying they lay beyond the capability of her professional domain:

> “some of the causes are medical and have to do with the brain and some disorders are due to the environment….”.

This medicalisation of learning difficulties occurred in other interviews, linked to a reduced sense of agency and the use of medical words such as “cure”, “symptoms”, “diagnosis”:

> *Interviewer:* “What do you think causes pupils to have special needs, other than the environment?”
>
> *Secondary school trainee teacher*: “It is a diagnosable condition so it must be very physiological, neurological as well and related to the brain…I don’t know if you can cure kids with symptoms, by giving them strategies to get around it. If teachers have dyslexic students they may cope with it but you cannot cure it.”

Our headteacher explained that a sense of reduced agency might be why explanations involving the brain, which he perceived as deterministic, were less popular with some educators. He suggested that factors perceived to be less amenable to their influence might feature less in teachers’ discussions of cause (note that this teacher, like several others we spoke to, had previously used the word ‘environment’ to refer to home environment):

> “As a teacher you are faced with classes of children and you do your very best, I think teachers have an understanding that the environment and the emotional

responses of children have to do with things outside their control but they have to try to work it out. It's not much use if you are faced with a child and say it has to do with a dysfunction of the brain because if you are a class teacher that wouldn't help."

Teachers sometimes associated the amelioration of brain-referenced learning difficulties with controlling diet and this may be due to a belief, expressed by one teacher, that 'fixable' issues to do with the brain revolved around chemical imbalance:

> *Interviewer:* When we were talking about dyslexia, we were saying that the working memory of the brain might not be functioning well. If we know the reasons, can we fix it?
>
> *Secondary school teacher*: I guess it would depend if it's a chemical imbalance.
>
> *Interviewer:* What do you mean by a chemical imbalance?
>
> *Secondary school teacher*: Well…if what's there in the brain is more of a certain chemical or less than a certain chemical then yes you can fix it. But if it's a structure in the brain then I would imagine you can't fix it.

When asked what foods were good for the brain, the issue of fish oils came up regularly, but also some more surprising ones:

> *Interviewer:* Can you improve this connectivity in the brain?
>
> *Primary school teacher:* Probably there is some food.
>
> *Interviewer:* Like what?

Primary school teacher: There are lots of traditional recipes to neuralize the brain.

Interviewer: Like what?

Primary school teacher: Like walnut…it has the shape of the brain…and also I think there are some components of walnut that kind of help to improve the neurons in your brain or to kind of…moisturize it[1].

More predictably, our teachers also referred to the effects of too much sugar and not enough water on children, as in these comments by two trainee secondary school teachers:

> "When they have too much sugar in breaks, they come to class very active. If they are dehydrated – dehydration is a serious issue"

> "Sugary food ….after break time they are a bit lively"

Survey of trainee teachers' neuroscience literacy

Our initial interviews had revealed a mixture of ideas strongly influenced by those in public and educational domains, and also raised questions about how constructions around brain function and development might influence teachers' sense of their own agency. To understand more, a survey was undertaken to explore the level of knowledge and understanding about the brain amongst a sample of trainee teachers about to qualify and begin their careers in UK secondary schools.

Method

[1] Apart from its visual resemblance to the wrinkled exterior of the human cortex, this idea may be related to the fact the walnut has a higher Omega 3 content than any common nut (Davis & Kris-Etherington, 2003)

Participants were 158 trainee teachers (102 females, 52 males, 4 unspecified) attending an Educational Studies lecture on a PGCE course at an established centre of teacher training in England. Trainees were asked to complete a survey consisting of 38 assertions (15 correct, 16 incorrect, 7 open to subjective opinion) to which participants were asked to respond agree, don't know or disagree. 16 assertions were adapted from a study of the neuroscience literacy of the South American public (Hurculano-Houzel, 2002). This allowed comparison of trainee responses to those of the subgroup of this South American sample that were also educated to graduate level.

Adaptation of these assertions involved straightforward improvements in expression to support clarification (the published assertions had been translated from Spanish) and occasional reversal of sense to allow balancing of correct and incorrect assertions. Additionally, in two instances, examples were provided to help clarify meaning.

Assertions were chosen from Hurculano-Houzel et al, on the basis that, in the broadest sense, they focused on learning (e.g. those dealing with memory) or aspects of behaviour that could be associated with behaviour management (e.g. those dealing with personality and emotion). These were combined with 15 additional assertions representing ideas promoted by popular brain-based educational programmes, prevalent neuromyths and other concepts identified in preliminary interviews and previous research (e.g. Pickering & Howard-Jones, 2007).

Additionally, the 6 assertions of subjective opinion from Hurculano-Houzel et al. about the mind-brain relationship were included, together with an extra one. This extra assertion arose from concerns about biological determinism similar to those discussed above, but this time in relation to learner agency. It explored trainees' opinions about whether individuals should be held responsible for behaviours associated with a developmental difference in their brain function.

Presentation order of assertions in the survey was randomised and correctness of assertions was balanced. Respondents were asked to select either “yes”, “no” or “don’t know” as the answer that most closely reflected their opinion. At the end of the survey, they were also asked to indicate their specialist subject, gender, whether they read popular science magazines and/or newspapers, and how many books they read per month (0, ½, 1, 2, 3, 4 or more). Finally, they were asked to estimate the percentage contribution of home environment, school environment, genes, and ‘other’ influences upon educational outcome, and which (if any) of three major brain-based educational approaches they had encountered in their schools (Multiple Intelligences, Learning Styles (e.g. VAK), Brain Gym).

Trainee teachers attending an Educational Studies lecture in the final weeks of their PGCE training course were asked to complete the survey prior to the commencement of the lecture. 158 student teachers attended the lecture and completed the survey.

Results

Respondents (N = 158, 102 females, 52 males, 4 unspecified) had been trained to teach pupils (aged 11-18) in the specialist subjects of science, maths, modern foreign languages, English, history, geography, citizenship, music and religious education (N=32,22,22,17,16,15,13,10,6 respectively) with 5 respondents failing to clearly report their specialism. The percentage of respondents who had encountered concepts of Multiple Intelligences, Learning Style and Brain Gym in schools were 56%, 83% and 58% respectively.

Responses to assertions of subjective opinion about the mind-brain relationship, and to our assertion regarding learner agency are shown in Table 1, together with data provided by Hurculano-Houzel et al. for their sample of the public who had been educated at graduate level.

TABLE 1 ABOUT HERE

The mean number of correct responses of trainee teachers to the 16 general assertions about the brain selected from the survey by Hurculano-Houzel et al. was 9.15 (SD=2.85). The percentage of trainee teachers responding agree, don't know and disagree to this selection of general assertions about the brain are shown in Table 2. Again, for comparison, these are shown with the results for graduates from the Hurculano-Houzel et al. survey of the public.

TABLE 2 ABOUT HERE

The mean number of correct responses of trainee teachers to the 15 assertions about the brain relating to common neuromyths and misunderstanding relevant to education was 5.13 (SD=2.15). The percentage of trainee teachers responding agree, don't know and disagree to these assertions are shown in Table 3.

TABLE 3 ABOUT HERE

The mean number (with standard deviations in parentheses) of correct responses of trainee teachers who were newspaper readers (N=109) to the 16 general assertions and 15 neuromythological assertions about the brain were 9.19 (3.02) and 5.09 (2.13) respectively, compared with 9.04 (2.47) and 5.21 (2.21) for trainees who did not read newspapers (N=49). T-tests showed the differences in mean scores for these two groups were not significant. Similarly, the mean number (with standard deviations in parentheses) of correct responses of trainee teachers who were science magazine readers (N=26) to the 16 general assertions and 15 neuromythological assertions about the brain were 9.85 (3.38) and 5.69 (2.05) respectively, compared with 9.01 (2.73) and 5.02 (2.16) for those who did not read science magazines (N=132). T-tests showed the differences in mean scores for these two groups were not significant. No statistically significant association could be found between numbers of books read and numbers of correct responses to either the 16 general assertions or the 15 neuromythological assertions about the brain.

A scatter plot and Spearman's rank correlation analysis was undertaken to test for association between individuals' scores for the 16 general assertions about the brain and the 15 assertions about the brain relating to common neuromyths and misunderstanding relevant to education. This revealed a statistically significant correlation between these two measures of participants knowledge (Spearman's rho = 0.43, $p<0.0001$).

The mean percentage contribution (standard deviations in parentheses) to educational outcomes that trainee teachers attributed to education, genes and home environment were 36.9(16.7), 25.5 (14.9) and 36.4 (15.5). This data is displayed in Fig. 1. 14 trainees responded in the "other" category, but all naming influences that might be placed under home environment (e.g. "social status", "community"), or both education and home environment ("experience").

FIG 1 ABOUT HERE

Discussion

Opinions regarding the six mind-brain assertions revealed considerable uncertainty. Around three-quarters did not consider that consciousness was possible without a brain, and only 15% wished to consider the mind as arising from the action of a spirit or soul on the brain. However, most did not agree that "state of mind" reflects brain state, that the mind is in this way, or any other, a product of brain function, or that the mind can be studied through studying brain activity. This conflicts markedly with current scientific opinion, including the opinions of the neuroscientists sampled by Hurculano-Houzel et al. (2002) but also, as can be seen in Table 1, the majority opinion of the South American public they sampled who had benefited from graduate level education. It should be noted that these issues are matters of opinion, rather than scientific fact and the results from Hurculano-Houzel et al.'s survey showed no effect of education level on respondents' confidence in a meaningful brain-mind relationship. Here, it is tentatively suggested that many of these trainee teachers may have been recently impressed by the social complexity of behaviour in the classroom. This may have caused them to be less certain than other non-specialists about a model of mental activity based on biological function, which might seem an overly-reductive approach to explaining cognition and behaviour in educational contexts. However, this is a purely speculative explanation. Uncertainties regarding the brain-behaviour relationship were also reflected in the large number of trainees who were undecided about whether students should be considered responsible for behaviours associated with a developmental disorder (55%).

Trainees' views on the 16 general assertions about the brain were characterised similarly to the sample of the graduate public reported on by Hurculano-Houzel et al. (2002), with a few exceptions. More members of our sample correctly disagreed with "Keeping a phone number in memory until dialling, recalling recent events & distant experiences, all use the same memory system". However, this may have been due to better comprehension of the question, due to the authors providing examples in the survey given to trainee teachers. A high number in our sample also agreed with the statement "Learning is not due to the addition of new cells to the brain". However, the incorrectness of this statement has recently become more moot, making subjects' responses to it potentially difficult to interpret in terms of general neuroscientific awareness. Conventionally, it has been assumed by scientists that changes in neural connectivity are sufficient to explain learning but well-publicised research during the present decade has also revealed examples of neurogenesis associated with memory formation (Shors et al., 2001). However, most trainee teachers in our sample either disagreed or were undecided about the more conventional explanation based on neural connectivity, and this tends to suggest that the popularity of the neurogenesis explanation arose out of a general lack of understanding, which surpasses the levels found by Hurculano-Houzel et al. in the general population, rather than over-interpretation or confusion arising from the latest scientific findings. Perhaps the most surprising response of our trainee teachers to these general assertions was that most did not agree (43%), or did not know (13%), whether it was necessary to pay attention to something in order to learn it. In the sense of learning that is commonly used in education, it is difficult to imagine how learning without attention can occur. This may be due to an interpretation of 'attention' in a more educational sense (i.e. paying attention to the teacher), although the assertion said clearly 'attention to *it*'. Alternatively, this response may indicate the rise of a new misunderstanding about the brain related to implicit learning. Work with artificial grammars, in which participants are able to acquire grammatical rules by observing examples of artificial language, demonstrates our ability to learn implicitly, i.e. without being able to report explicitly what we have learnt (Johnstone & Shanks, 2001). Such experiments have contributed to enthusiastic calls for more educational focus on implicit learning (e.g. Claxton, 1998). However, there are considerable barriers to the practical application of such ideas, making their usefulness to education questionable and causing some scientific authorities to label them a new source of neuromyth (Goswami, 2004). A non-specialist interpretation of the phenomenon of implicit learning might involve ideas about absorbing information and concepts from the environment without attending to them, but such ideas have no scientific basis. For example, in the artificial grammar scenario, formal rules may be acquired without the learner consciously formulating them, but the learner must pay considerable attention to the examples of artificial language in order to facilitate this. In a more 'real world' context, we may also implicitly develop understanding about, for example, the motivations of people around us, without being able to articulate how we have achieved this. Again, however, this is only possible by paying attention to their behaviour. "Implicit learning" does not equate to "learning without attention". Even given the popular rise of ideas about implicit learning, it seemed somewhat surprising to the authors that 43% of our sample of trainee teachers, towards the end of their training, appeared to consider that their pupils might learn without paying due attention, and this finding may justify further research.

In some instances, trainees' opinions about the 15 assertions about the brain relating to common neuromyths showed a majority in agreement with present scientific opinion. For example, 62% considered that "Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain", a fact which has been demonstrated in at least two well-reported instances (Draganski et al., 2004; Maguire et al., 2000). Additionally, 63% considered (correctly) that the production of new connections in the brain can continue into old age, fact which can be assumed on the basis that learning relies on synaptic plasticity, and learning can be shown to continue throughout life. There was also a majority (55%) able to agree with the current notion amongst neuroscientists that sensitive, rather than critical, periods exist for learning, such that there is no clearly defined window of opportunity for learning outside which progress is impossible, just periods when learning can be more efficiently achieved. However, it is also worth noting that the contexts of learning for which even sensitive periods have been observed are chiefly those involving primary sensory or motor function, rather than the higher types of learning process that are usually the subject of formal education (for further discussion, see Blakemore & Frith, 2005, p26-36).

Most trainees had, however, already come into contact with approaches such as multiple intelligences, learning styles and "Brain Gym" that involve concepts claiming a brain-basis, and this may explain the large numbers of trainees suffering misconceptions in related areas. This contact had occurred by the end of a one-year course, presumably through school placements. This speaks of the extent to which learning styles, "Brain Gym" and multiple intelligences have become prevalent in state schools in the UK, despite their dubious scientific basis (see Geake, 2008; Hyatt, 2007; Waterhouse, 2006 respectively for a critical review of these ideas). Such contact may explain why 82% of trainees considered that "Individuals learn better when they receive information in their preferred learning style", even though an extensive review of the educational evidence is unable to support the educational value of identifying learning styles (Coffield, Moseley, Gall, & Ecclestone, 2004). Moreover, a recent psychological investigation of the VAK principle tested recall of information presented in the three different styles (Kratzig & Arbuthnott, 2006) and showed no benefit of having material presented in one's preferred learning style. It may be, as agreed with by 79% of trainees, that individuals show preferences for the mode in which they receive information but, as concluded by this scientific study, identifying these preferences serves no demonstrable educational purpose and attempts to focus on learning styles appear to be "wasted effort". Most trainees (60%) also revealed their belief in the usefulness of hemispheric dominance (left brain, right brain) as a means to explain individual differences amongst learners. This belief is also used as a learning style approach to categorizing learners and as a means to differentiate teaching strategies accordingly. It is true that some tasks can be associated with extra activity that is predominantly in one hemisphere or the other (e.g. language can be considered in most individuals to be left lateralised). However, no part of the brain is ever normally inactive in the sense that no blood flow is occurring. Furthermore, performance in most everyday tasks, including learning tasks, require both hemispheres to work together in a sophisticated parallel fashion. The division of people into left-brained and right-brained takes the misunderstanding one stage further and there is no reliable evidence that categorisation based on hemispheric dominance is helpful for teaching and learning.

Although most trainees (63%) were correct in believing that vigorous exercise can improve mental function, there was also a majority in favour of the concept that co-ordination exercises can help integrate the functions of left and right hemisphere. This latter assertion cannot be supported by reviews of the scientific literature (Arter & Jenkins, 1979; Bochner, 1978; Cohen, 1969; Hammill, Goodman, & Wiederholt, 1974; Kavale & Forness, 1987; Sullivan, 1972), yet over a third of trainees (35%) felt this type of exercise could contribute to development of literacy skills, with most (56%) expressing uncertainty as to whether this might be possible or not. This belief contributes to the dubious theoretical approach of programmes such as “Brain Gym”, but is not supported by scientific evidence (Hyatt, 2007). Approaches such as “Brain Gym” also promote the drinking of water as way to support learning. Apart from circumstances involving vigorous exercise, ill health or unusually hot weather, there is no evidence of children suffering from voluntary dehydration in the classroom or the cognitive effects associated with it. However, the prevalence of myths around the health-giving properties of water (Valtin, 2002) and those that now associate it with learning, may help explain why 39% of trainees were not sure if their brain would shrink if they drank less than 6-8 glasses a day, with a further 18 % agreeing that it would. In other nutritional areas of interest to educators, most trainees were unaware (22%) or unsure (45%) about the fact that habitual caffeine use suppresses cognition rather enhances it. In fact, children commonly experience caffeine withdrawal (James, 1997). Heatherley and colleagues showed that children aged 9-10 who habitually consumed the equivalent of no more than 2 cans a day of cola demonstrated decreased alertness relative to low users (Heatherley, Hancock, & Rogers, 2006). Their alertness only rose to baseline levels when they had received some caffeine and then, of course, only temporarily. In terms of the potentially positive effects of Omega 3 supplements, there is currently no scientifically valid evidence showing positive outcomes in the general population, with studies involving children with developmental disorders revealing mixed results. Nonetheless, it appears 23% of our trainees already believe this is the case, with the majority (54%) unclear about this issue. Most trainees (63%) believed in the myth that children are less attentive after sugary drinks and snacks. On the contrary, although certain food additives have been shown to increase hyperactivity amongst children (McCann et al., 2007), sugary drinks and snacks are associated with increases in children's ability to attend (Busch, Taylor, Kanarek, & Holcomb, 2002).

Perhaps, however, the most worrying result of our survey is that (only) just less than half of the trainees (49%) disagreed with the statement "Learning problems associated with developmental differences in brain function cannot be remediated by education", with 41% undecided and 9% of the opinion that this was true. This suggests that a teacher's knowledge of a pupil's developmental differences may often diminish their belief in the potential for positive change, as if some biological barrier has been exposed. Current perspectives in developmental cognitive neuroscience avoid predictive mechanisms of biological cause and effect, emphasise the complexity of interrelation between biological systems and environments such as those provided by education, and highlight the enduring possibility of mitigation. Further insights into respondents belief in biologically determined outcomes arises from their estimates of the percentage contribution to educational outcomes that could be attributed to education, genes and home environment. Our sample of trainee teachers considered, on average, that only 25% of educational outcome was due to genetic issues. This contrasts considerably with the findings of Walker and Plomin (2005) who concluded that "teachers view nature to be at least as important as nurture". In their survey, Walker and Plomin presented 667 primary school teachers with a list of five broad categories of behavioural traits: personality, intelligence, behaviour problems, learning difficulties, and mental illness. Respondents were asked about the extent to which each trait was influenced by genes (nature) or the environment (nurture). The percentage of teachers who reported genetics were at least as important as environment were 87%, 94%, 43%, 94%, and 91%, respectively. However, we suggest that Walker and Plomin's participants may have been confused by what was meant by the term “environment”, which can have a range of disparate meanings in education, most of which are narrower than its meaning within the field of genetics, and many of which may not even include the teacher’s efforts. The difference between our results and those of Walker and Plomin may illustrate an important challenge likely to be involved with most interdisciplinary studies at the interface of neuroscience/genetics and education. In such investigations, the same language and terms may be used in diverse ways by the different disciplines involved, influencing the data collected and its interpretation in unexpected ways. Walker and Plomin suggest that their “finding that teachers view nature to be at least as important as nurture does not imply teachers, whose job is to educate children and nurture their potential, believe that their efforts have no impact – or they would not be in the field of education.” In supporting their argument, that a belief in genetics as the key determinant of outcome does not reduce teachers’ sense of agency, they point to teachers’ individual comments about how they are making their best teaching efforts irrespective of their nature/nurture perspective, and to teachers’ requests for more information to help facilitate earlier intervention. In order to understand this issue further, we looked more carefully at the responses of the small minority in our study (N=12, or 8%) that did believe genetics was at least or more important than home environment and education put together, and in particular how they responded to our question regarding biological determinism. For this small sample, equal numbers (N=4, or 33%) agreed, disagreed and were undecided about whether learning problems associated with developmental differences in brain function cannot be remediated by education. This was in contrast to the rest of the group, of whom only 6% agreed, 40% were undecided, and 51% disagreed. In this light, Walker and Plomin’s other finding, that 82% percent of teachers considered knowledge that a pupil had a genetically influenced learning difficulty would cause them to change their teaching strategies, takes on a potentially more ominous significance. An alternative interpretation might be that, if such knowledge reduces a teacher's sense of agency, the changes in teaching strategy they refer to may reflect diminished expectations of academic progress.

There was a clear association between scores for general knowledge about the brain and for a correct understanding of concepts associated with common classroom neuromyths. This suggests that having a basic knowledge of brain function may provide some protection against the most prevalent of misconceptions currently influencing educational thinking and classroom practice.

Follow up survey on genetic beliefs and biological limits to achievement

A smaller second survey was devised to further investigate whether genetic beliefs were related to a reduced sense of teachers' agency. This survey was carried out in 2009 with a new group of trainee secondary school teachers approximately halfway through their training (N=166, 103 females, 58 males, 5 unspecified). As before, these trainee teachers were asked to estimate the mean % contribution to educational outcomes that they would attribute to education, genes, home environment and "other". It then asked them to rate their agreement with 2 statements on 5-point Likert scale:

> There is a biological limit to what <u>some</u> individuals can achieve in their education

> There is no biological limit to what <u>any</u> individual can achieve in their education

Mean percentage attributions of educational achievement to education, genes, home environment and "other" were (with standard deviations in parentheses) were 36.8

(12.1), 21.1 (10.9), 41.1 (13.4), 1.5 (5.1). This was a similar set of figures to those obtained in the previous survey for this question, confirming that genetic influence is viewed by trainee teachers as a lesser influence than either educational or home environment. Responses in the "other" category were almost entirely related to the influence of friends and peers, a social environmental factor that cannot be considered as directly genetic.

Trainees' responses to the two statements were scored for their belief in a biological limit to a learner's achievement, i.e. level of agreement with the first (1 to 4 points) and level of disagreement with the second (1 to 4 points). This produced a score out of 8 for each participant (mean = 4.41, SD = 1.86). Spearman rank correlation analysis revealed a statistically significant association between the percentage of educational outcome trainees attributed to genetic factors and their beliefs in a biological limit to what a learner can achieve (Spearman's rho = 0.22, $p = 0.005$).

Conclusions

This study has revealed that most respondents in a sample of trainees towards the end of a 1-year PGCE course had already come into contact with brain-based ideas in their short period of training, despite these forming no part of the formal college-based part of the course. Moreover, a large number of trainees already possessed a range of misunderstandings about the brain, many of which can be found in educational resources, practices and programmes being successfully marketed within UK schools. Higher levels of general knowledge about the brain were associated with increased resistance to such ideas, suggesting that the inclusion of some basic neuroscience in initial teacher training may help inoculate trainees against common educational neuromyths and the poor practice associated with them. Contrary to findings of a study of primary school teachers, most trainees considered genetic issues to be less important than either education or home environment as factors influencing educational outcomes. The minority who placed great emphasis on the role of genetics in educational outcome were characterised by a reduced confidence that learning problems associated with developmental differences could benefit from educational attempts at remediation. A follow up study confirmed that teachers' constructs about development are linked to their sense of agency, with beliefs in strong genetic influence associated with stronger notions of biologically-defined limits on pupil achievement.

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	Trainee teachers			Public with graduate education (from Hurculano-Houzel, 2002)		
	agree	d.k.	Disagree	Agree	d.k.	disagree
The mind is the result of the action of the spirit, or of the soul, on the brain	15	49	36	18	51	31
"State of mind" is a reflection of the brain state in a given moment	48	40	12	48	27	25
If there are ways to study brain activity, the mind can be studied through them	22	56	22	50	34	16
The mind is a product of the working of the brain	43	45	11	72	22	6
Without a brain, consciousness is not possible	77	12	11	82	8	10
Intuition is a "special sense" that cannot be explained by the brain	24	44	32	25	39	36
Individuals are not responsible for behaviour associated with a developmental difference in brain function	14	55	31			

Table 1 Responses of trainee teachers to assertions of subjective opinion about the mind-brain relationship and learner agency, the former shown with responses of the graduate sample of the public studied by Hurculano-Houzel (2002) for comparison.

	Trainee teachers			Public (from Hurculano-Houzel, 2002)		
	Agree	d.k.	disagree	agree	d.k.	disagree
One's environment can influence hormone production and, in turn, personality (C)	61	30	8	64		
We use our brains 24 hours a day (C)	89	5	6	92		
To learn how to do something, it is necessary to pay attention to it (C).	43	13	43	73		
Learning occurs through modification of the brain's neural connections(C)	50	44	6		30	
Performance in activities such as playing the piano improves as a function of hours spent practising (C)	78	12	10	82		
It is with the brain, and not the heart, that we experience happiness, anger, and fear (C)	76	11	13	97		
Hormones influence the body's internal state, and not their personality (I)	25	34	42	24		
Memory is stored in the brain much like as in a computer. That is, each memory goes into a tiny piece of the brain (I)	36	38	26	41		
Memory is stored in networks of cells distributed throughout the brain (C)	50	42	8	60		
Keeping a phone number in memory until dialling, recalling recent events & distant experiences, all use the same memory system (I)	12	45	44	49		
When we sleep, the brain shuts down (I)	0	7	93			80

Learning is not due to the addition of new cells to the brain (C*)	52	35	13	82		
Brain activity depends entirely on the external environment: with no senses stimulated, we don't see, hear or feel anything (I)	11	22	66	33		
Emotional brain processes interrupt those brain processes involved with reasoning (I)	69	23	8	70		
Cognitive abilities are inherited and cannot be modified by the environment or by life experience (I)	3	10	87			91
We mostly only use 10% of our brains(I)	52	38	10	48		

Table 2 Responses of trainee teachers to a selection of the general assertions (C=correct assertion, I=incorrect assertion) about the brain intended to assess levels of neuroscience literacy. Results of the Hurculano-Houzel survey of those members of public who had been educated at graduate level are provided for comparison (Hurculano-Houzel, 2002), with blank cells where results were not reported.

*see text for discussion of the correctness, or otherwise, of this assertion

	Trainee teachers		
	Agree	d.k.	disagree
Children are less attentive after sugary drinks and snacks (I)	63	24	13
Omega 3 supplements do not enhance the mental capacity of children in the general population (C)	23	54	23
Environments that are rich in stimulus improve the brains of pre-school children (I)	89	10	1
Individuals learn better when they receive information in their preferred learning style (e.g. visual, auditory, kinaesthetic) (I)	82	11	7
Short bouts of co-ordination exercises can improve integration of left and right hemispheric brain function (I)	65	31	4
Regular drinking of caffeinated soft drinks reduces alertness (C)	33	45	22
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners (I)	60	35	5
Learning problems associated with developmental differences in brain function cannot be remediated by education (I)	9	41	49
There are no critical periods in childhood after which you can't learn some things, just sensitive periods when it's easier (C)	55	30	15
Vigorous exercise can improve mental function (C)	63	29	8
Individual learners show preferences for the mode in which they receive information (e.g. visual, auditory, kinaesthetic) (C)	79	16	5
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills(I)	35	56	9
Production of new connections in the brain can continue into old age (C)	63	25	12
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain (C)	62	31	6

Drinking less than 6-8 glasses of water a day can cause the brain to shrink (I)	18	39	43

Table 3.3 Responses of trainee teachers to a selection of assertions drawn from educational neuromyths (C=correct assertion based on scientific evidence, I=incorrect assertion, or an assertion for which there is no scientific evidence).

FIGURES

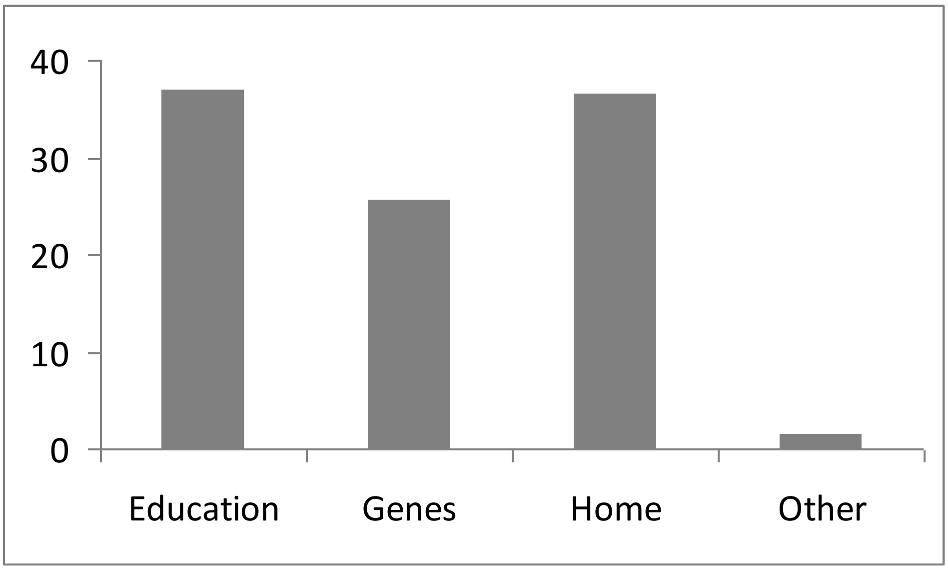

Fig 1 The mean percentage contribution to educational outcomes that 158 trainee secondary teachers attributed to education, genes, home environment and other.