The Neuroscience Literacy of Trainee Teachers

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

Graduate School of Education, University of Bristol


Contact Paul Howard-Jones: Graduate School of Education, 35 Berkeley 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.
In 2002, the OECD’s Brain and Learning project drew international attention to the 

unity, 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 

r series “Collaborative Frameworks in 

Neuroscience and Education” brought together over 400 teachers, neuroscientists, 

evaluate programmes of “brain based” learning 

Teacher Development Agency admitted “...we do not specify that neuroscience or
constantly with what is happening in educational research”

p31). Such a “hands off” approach based on encouraging engagement

g 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

to explain their own, or another’s, mind and behaviour
the cause of a state of being (e.g. “now ’m brain dead” as an explanation for a mental

some extent, phrases such as “this menu is confusing my brain” demonstrate how a

now being used to avoid the subject’s role here (e.g. “my brain can’t see it”) and,

direct agency (“My brain made me do it”). The use of the term brain is, of course,

difficult to find examples of common speech that uses “brain” as an agent of either

“my brain wants chocolate”. Such a cognitive semantic analysis suggests the existence of a

don’t know to 95 assertions about the brain
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.

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, in addition to promoting concepts about “repatterning” the
mined 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.
9% saw these behaviours as due to “all genes” and 0 1% as “all environment”. Walker and Plomin

phrases in the media (e.g. “dyslexia gene”), possess a balanced view of the
“I believe it’s about genes, I believe you do see intelligent children from intelligent parents”

“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 decrease….I think it’s genetics…genetics is a very high one and motivation and the environment at home is another one”

“…. 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 young..”

It was also clear, however, that when different teachers discussed “environment”, they
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 with the make up of the family”

“environment” could mean the

“I think maybe in a very enriched environment probably the b

spelling, at the same time doing fun stuff like music, images, sound.”

“I think the brain must be able to change to be honest. You see people who don’t hav

about it. …..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 maybe when you are young…

*Interviewer:*

*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

*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*
the effectiveness of educational solutions and thought more in terms of “coping”, as in

_Interviewer:_

e 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 them in the classroom.”

There appeared to be a type of “all or none” theorising about problems being eit

_Interviewer:_

_Secondary school trainee teacher_ …I suppose yes…if there’s a biological problem, things like diet, drugs. I don’t really like the idea of drugs,
“some of the causes are medical and have to do with the brain and some disorders are due to the environment.”

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 it.”

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

“As a teacher
to try to work it out. It’s not

wouldn’t help.”

teacher, that ‘fixable’ issues to do with the brain revolved around chemical imbalance:

Interviewer:

Secondary school teacher: I guess it would depend if it’s a chemical

Interviewer:

Secondary school teacher: Well…if what’s there in the brain is

it’s a structure in the brain then I would imagine you can’t fix it.

Interviewer:

Primary school teacher:

Interviewer:
There are lots of traditional recipes to neuralize the brain.

Irene: Like what?

Primary school teacher: Like walnut…it has the shape of the brain…and also neurons in your brain or to kind of…moisturize it

“When they have too much sugar in breaks, they come to class very active. If – is a serious issue”

“Sugary food ….after break time they are a bit lively”

Survey of trainee teachers’ neuroscience literacy

around brain function and development might influence teachers’ sense of their own

Method
participants were asked to respond agree, don’t know or disagree.

discussed above, but this time in relation to learner agency. It explored trainees’
assertions was balanced. Respondents were asked to select either “yes”, “no” or “don’t know” as the answer that

\[ \frac{1}{2} \]

percentage contribution of home environment, school environment, genes, and ‘other’

Results
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.

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.

The mean number of correct responses of trainee teachers to the 15 assertions about the brain relating to common neuromyths and misunderstandings 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.

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 social media users (N = 123) to the 16 general assertions and 15 neuromythological assertions about the brain were 9.21 (3.05) and 5.12 (2.21) respectively, compared with 9.04 (2.50) and 5.21 (2.21) for trainees who were not social media users (N = 44). T-tests showed the differences in mean scores for these two groups were not significant.
Neuroscience Literacy

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 assertions about the brain relating to common neuromyths and misunderstanding relevant to education. 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 =

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.

Trainees responded in the “other” category, but all naming influences that might be under home environment (e.g. “social status”, ”community”), or both education and home environment (“experience”).

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”

statement “Learning is not due to the addition of new cells to the brain”. However, the making subjects’

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’.
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

In some instances, trainees’ opinions about 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, a 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 % of trainees considered that “

when they receive information in their preferred learning style”, even though an
showed no benefit of having material presented in one’s preferred learning style. It may be, as agreed 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 coordination 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
rammes such as “Brain Gym”,

. Approaches such as “Brain Gym” also promote the drinking of water as way to support learning. Apart from

Gym” also promote the drinking of water as way to support learning. Apart from
associated with increases in children’s ability to attend

the trainees (49%) disagreed with the statement “Learning problems associated
emediated by education”,

’s knowledge of a pupil’s developmental differences may often diminish their

that “teachers view nature to be at least as important as nurture”. In their survey,

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
and many of which may not even include the teacher’s efforts.

suggest that their “finding that teachers view nature to be at least as important as
of education.”
determinant of outcome does not reduce teachers’ sense of agency,
teachers’ individual comments about how they are making their best teachin
teachers’

Plomin’s other finding, that 82% percent of teachers considered knowledge that a
If 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 scales:

- There is a biological limit to what some individuals can achieve in their education
- There is no biological limit to what any 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.
Responses in the “other” category were almost entirely related to the

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

Spearman’s rho
. A follow up study confirmed that teachers’ constructs about

Review of Educational Research, 49
The Learning Brain

Australian Journal of Mental Retardation, 5

Physiology & Behavior, 77

The Psychologist, 11

Learning styles and pedagogy in post-16 learning: A systematic and critical review (Report no.
041543)

Journal of Learning Disabilities, 2
The American Journal of Clinical Nutrition, 78

Nature, 427

Educational Research, 50

British Journal of Educational Psychology, 74

Journal of Child Psychology and Psychiatry, 47

Neuroscience and education: Issues and opportunities

TES Magazine

The Neuroscientist, 8

Remedial and Special Education, 28

Transcript of keynote seminar of the all-party parliamentary group on scientific research in learning and education

"Brain-Science in the Classroom"
Understanding Caffeine: A biobehavioural analysis

Child Development, 53

Cognitive Psychology, 42

Exceptional Children, 54

Journal of Educational Psychology,

98

Proceedings of the National Academy of Sciences

(USA), 97

Lancet, 370

British Journal of Music

Education, 22

The Psychologist, 18

Understanding the Brain: Towards a New Learning Science

Public Understanding of Science, 15

Nature, 414

*Journal of Learning Disabilities, 5*

*American Journal of Regulatory Comparative Physiology, 283*

*Educational Psychology, 25*

*Educational Psychologist, 41*

*Journal of Cognitive Neuroscience, 20*
Trainee teachers (from Herculano-Houzel, 2002) agree/disagree:

<table>
<thead>
<tr>
<th>Agree</th>
<th>Disagree</th>
</tr>
</thead>
</table>

The mind is the result of the action of the spirit, or of the soul, on the brain.

"State of mind" is a reflection of the brain state.

Intuition is a "special sense" that cannot be explained by the brain.
One’s environment can influence hormone production and,

Learning occurs through modification of the brain’s neural

Hormones influence the body’s internal state, and not t
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.

<table>
<thead>
<tr>
<th>Assertion</th>
<th>C</th>
<th>I</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning is not due to the addition of new cells to the brain</td>
<td>52</td>
<td>35</td>
</tr>
<tr>
<td>Brain activity depends entirely on the external environment: with no senses stimulated, we don’t see, hear</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>Emotional brain processes interrupt those brain processes involved with reasoning</td>
<td>69</td>
<td>23</td>
</tr>
<tr>
<td>Cognitive abilities are inherited and cannot be modified by the environment or by life experience</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>We mostly only use 10% of our brains</td>
<td>52</td>
<td>38</td>
</tr>
<tr>
<td>( \text{Trainee teachers} )</td>
<td>( \text{Agree} )</td>
<td>( \text{disagree} )</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-----------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>Children are less attentive after sugary drinks and snacks</td>
<td>63</td>
<td>24</td>
</tr>
<tr>
<td>Omega 3 supplements do not enhance the mental capacity of children in the general population</td>
<td>23</td>
<td>54</td>
</tr>
<tr>
<td>Environments that are rich in stimulus improve the brains of pre-school children</td>
<td>89</td>
<td>10</td>
</tr>
<tr>
<td>Individuals learn better when they receive information in their preferred learning style (e.g. visual, auditory, kinaesthetic)</td>
<td>82</td>
<td>11</td>
</tr>
<tr>
<td>Short bouts of coordination exercises can improve integration of left and right hemispheric brain function</td>
<td>65</td>
<td>31</td>
</tr>
<tr>
<td>Regular drinking of caffeinated soft drinks reduces alertness</td>
<td>33</td>
<td>45</td>
</tr>
<tr>
<td>Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Learning problems associated with developmental differences in brain function cannot be remediated by education</td>
<td>9</td>
<td>41</td>
</tr>
<tr>
<td>There are no critical periods in childhood after which you can’t learn some things, just sensitive periods when it’s easier</td>
<td>55</td>
<td>30</td>
</tr>
<tr>
<td>Vigorous exercise can improve mental function</td>
<td>63</td>
<td>29</td>
</tr>
<tr>
<td>Individual learners show preferences for the mode in which they receive information (e.g. visual, auditory, kinaesthetic)</td>
<td>79</td>
<td>16</td>
</tr>
<tr>
<td>Exercises that rehearse coordination of motor-perception skills can improve literacy skills</td>
<td>35</td>
<td>56</td>
</tr>
<tr>
<td>Production of new connections in the brain can continue into old age</td>
<td>63</td>
<td>25</td>
</tr>
<tr>
<td>Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain</td>
<td>62</td>
<td>31</td>
</tr>
</tbody>
</table>

There are no critical periods in childhood after which you can’t learn some things, just sensitive periods when it’s easier.
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).

<table>
<thead>
<tr>
<th>Assertion</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drinking less than 6-8 glasses of water a day can cause the brain to shrink</td>
<td>I</td>
</tr>
</tbody>
</table>
Fig 1 The mean percentage contribution to educational outcomes that 158 trainee secondary teachers attributed to education, genes, home environment and other.