TEACHER UNDERSTANDINGS OF EDUCATIONAL NEUROSCIENCE

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Abstract

The present study investigated the understanding of neuroscience and neuromyths within a cohort (N=90) of teachers in the UK and Internationally, using an online questionnaire. The study found no relationship between previously reported predictors of neuromyths and neuromyths acceptance, except for a weak positive correlation that suggests that teachers who are knowledgeable about neuroscience are better at rejecting neuromyths. Although neuromyths were still accepted in line with previous studies, the acceptance rate had decreased slightly for some of the neuromyths, suggesting that efforts to increase communication between teachers and neuroscientists are working.

Introduction

As educators we have an inherent interest in and appreciation of how individuals learn. Teacher training courses traditionally focuses on the psychological theories of learning. In recent years educational neuroscience has made progress in understanding the processes in the brain that underpin learning in the mind. For example, the neurological correlates underpinning dyslexia are understood well enough to allow diagnosis based on brain scanning (Geake, 2009). As evidence from neuroscience has increased, the ability for learning theories to be constrained in light of neurological evidence is growing, empowering educational practitioners to determine which learning theories have the most practical value in a variety of contexts. The fact that some neuroscientific studies have demonstrated empirically that individuals do not learn better when they have information presented to them in their individual preferred learning style highlights one theory highly valued by teachers that has no scientific basis (Howard-Jones *et al.*, 2009). Indeed, quite the opposite is true; neuroimaging studies have demonstrated the effectiveness of “multi-sensory” pedagogies. Learning styles is now identified as a neuromyth (Geake, 2008). Theories of Multiple Intelligences and commercial programs such as Brain Gym still await a demonstration of their effectiveness in terms of neurology.

Misunderstanding and inappropriate generalization of some findings have allowed the development of neuromyths in the teaching community. The term neuromyth was coined by the OECD (2015). These are misconceptions of what conclusions neuroscientific evidence actually allows us to draw. In the interest of constraining learning theories as well eliminating neuromyths from the educational community, better communication needs to be established between teachers, educational researchers and neuroscientists.

This study aims to examine the prevalence of neuromyths amongst a mixed cohort of volunteer participants, all of whom are teachers. The study aims to assess:

- The general neuroscientific knowledge amongst teachers.
- The level of acceptance of identified neuromyths amongst teachers.
- What variables, if any, may predict acceptance of neuromyths amongst teachers.

Literature Review

Attempts to link the findings from neuroscientific research and formal educational practice date back to the 1980s (Bruer, 1997) and since that time, opinions of educational researchers have been divided on the usefulness of neuroscientific research in education (see Bruer, 1997, Geary 1998, Geake & Cooper, 2003, Goswami, 2004). Recent writers are less pessimistic (Goswami, 2006, Varma *et al.,* 2008, Samuels, 2009, Ansari *et al.,* 2011, Howard-Jones *et al.,* 2014, Howard-Jones 2014, Schenk & Cruickshank, 2014).

The last decade has seen the formation of the International Mind, Brain and Education Society (IMBES) along with the Mind, Brain and Education Journal. The Societies aim is to "*facilitate cross-cultural collaboration in biology, education and the cognitive and developmental sciences"* (IMBES, 2015). In addition, there have been two formal reviews of the field, first by the Organisation for Economic Co-Operation and Development (OECD, 2008) and the second by the Royal Society (Royal Society, 2011). All of these developments suggest that the findings from neuroscience and education research are beginning to converge.

Many of the arguments questioning the usefulness of educational neuroscience have focused either on the limitations of the methodologies employed in studying neuroscience or the misleading extrapolations that education professionals (researchers, teachers, civil servants) have made about the results from neuroscientific studies. These so-called "neuromyths" – misconceptions about learner's brains that have been adopted by the education community tend to contain "nuggets" of truth which have been misunderstood or poorly applied (Howard-Jones, 2014).

Bruer (1997) argues that neuroscience only has an explanatory power when viewed through cognitive psychology. His premise is that studying the mind is not necessarily informed by studying the brain. This argument is rebutted by Cruickshank & Schenck (2014) and Howard-Jones (2014) who argue that because the mind is created by the brain it must have biological correlates. The systems of processing in the mind must be reflected by systems in the brain.

Goswami (2006), Geake (2009) and Howard-Jones (2014) provide excellent up to date considerations of the neuromyths that have been adopted by the education community. They cite the ideas that learners are left or right brained; brains are male or female; the existence of brain buttons under the ribs; that there are critical periods for learning; that brains process information from different senses independently and that there are, consequently, individual learning preferences, as examples of neuromyths.

Several authors (OECD, 2008, Geake, 2009, Royal Society, 2011) provide a thorough overview of the key findings from neuroscience generally and how they may apply to educational practice. A key general understanding is that no two human brains are the same. This may seem trite but even identical twins, which are the same genetically, show differences in their brain structure.

Contrary to early ideas of brain development we now know that the brain can adapt, change and therefore learn throughout life even into old age (OECD, 2008). Throughout life new synapses grow and are pruned but this process of pruning and growth is most prevalent at certain sensitive periods, from early childhood to late teens and early twenties. Individual experiences and environments shape individual brains (Royal Society, 2011).

Educational neuroscience has also highlighted the interdependence of intellectual and physical wellbeing and much work has highlighted the importance of emotional wellbeing for learning (OECD, 2008). We now know how stress can inhibit learning because the centres of the brain that deal with emotion affectively inhibit the areas that help to regulate activity across the brain and are used in learning.

Modern theories of learning build firmly upon constructivist ideas (Samuels, 2009), but precisely because there is such a plethora of modern learning theories means that they cannot all be right (Geake, 2009).

At this stage educational neuroscience may not have the resolution to inform specifically about many aspects of classroom pedagogy (e.g. in science teaching) or classroom contexts but it is able to inform us about generalities that may inform curriculum planning on a whole school and regional basis (e.g. sleep patterns and gender differences, developmental differences), as well as serving to identify the psychological theories that may be most robust. The beauty of educational neuroscience is in its potential ability to underpin and constrain psychological theories of learning. Educators are on the cusp of not only being able to identify a psychological intervention that works but also able to explain why it works, thanks to the evidence derived from educational neuroscience. To enable this, we need better communication between the education and neuroscience communities. One of the first steps in this is to identify where miscommunication and misunderstanding has arisen and address these issues, as work by Howard-Jones *et al.* (2009) and Dekker *et al.* (2012) has already begun to do.

Methodology

The methodology for this small-scale research project follows an educational research paradigm 1 as outlined by Taber (2013). In this sense, I hope to determine how literate my participants are with regards to findings from neuroscience in general and neuromyths that relate to education in particular. The method is also designed to allow comparison with previously published results, particularly those of Dekker *et al.* (2012) and Howard-Jones *et al.* (2009). The study aimed to sample a cohort of teachers using a questionnaire to assess:

- The general neuroscientific knowledge amongst teachers.
- The level of acceptance of identified neuromyths amongst teachers.

- What variables, if any, may predict acceptance of neuromyths amongst teachers.

The study used an online questionnaire created through Google Forms and participants were invited to take part voluntarily via email, Twitter and Facebook.

Table 1: General Questions from the survey and the options available to participants.

Question	Possible Responses			
Please indicate your gender:	Participant Defined			
Please indicate your age:				
Please indicate your current level of education:	Undergraduate	PGCE	Masters	PhD
Do you teach in:	Primary	Secondary	Other	
Do you teach in:	Independent	State-maintained		
Do you teach:	National Curriculum	International Curriculum	Both	Other
Are you interested in scientific knowledge about the brain and its influence on learning?	Yes	No	I don't know	
Is knowledge about the brain and its influence on learning important for your teaching practice?				
Please estimate the % effect that genes play on children's ability to learn:	Participant Defined			
Have you ever attended in-service training (CPD) about the brain?	Yes		No	
Have you encountered any of the following educational approaches?	Multiple Intelligences	Learning Styles (e.g.VAK)	Left-brain/Right-Brain	Brain Gym
Do you read popular science magazines or scientific journals?	Yes		No	
Was your original degree a science degree (e.g. BSc)				
Please write the country in which you currently teach or are in training:	Participant Defined			
Please enter your email address if you would like to receive a copy of the results and report in due course.				

Participants were contacted through the author's current professional network of teachers.

Data Collection

The survey collected responses between 15th April and 3rd June 2015. The questionnaire contained 45 statements that were concerned with educational neuroscience; 6 of which were subjective statements about the mind and learning 23 of which were general statements about neuroscientific understanding and 16 were concerned with neuromyths that have been identified in the literature. Participants had to indicate Yes, No or I don't know to each of the statements as they were presented. The general statements were designed to assess how neuroscientifically literate participants were while the neuromyths statements were designed to assess participant's acceptance of neuromyths. All the statements appeared in a random order each time the survey was completed.

In addition, participants were asked to complete some general information about themselves. There were thirteen questions that related to gender, age, level of education, school type (independent or state), school level (Primary or Secondary), level of interest in neuroscience, the country they currently worked in etc. Table 1 is a full list of these questions which could be potential predictors of susceptibility to neuromyths. A full list of the questions and summary of responses can be found in the appendix**.**

Ethical Considerations

This research involved the participation adults all of whom are either training or practicing teachers and the ethical guidelines described by the British Educational Research Association (BERA, 2011) were adhered to. Participation in the case-study was completely voluntary and there was no incentive for participants to take the survey. Participant's were able to withdraw from the survey at any time and it was explained to them that the data was being collected as part of a project for a Master's module, although the exact nature of the study was obfuscated – i.e. it was not explicitly stated that the study was investigating the prevalence of neuromythologies amongst teachers. By taking part in the study the volunteers agreed to allow their answers to be used. In addition, the estimated length (15mins) of the survey was clearly stated.

All the data was collected anonymously, although at the end of the questionnaire the participants had the opportunity to leave their email address if they wished, so that they could be sent the results of the study. Results will be made available to all participants via the same channels used to contact them.

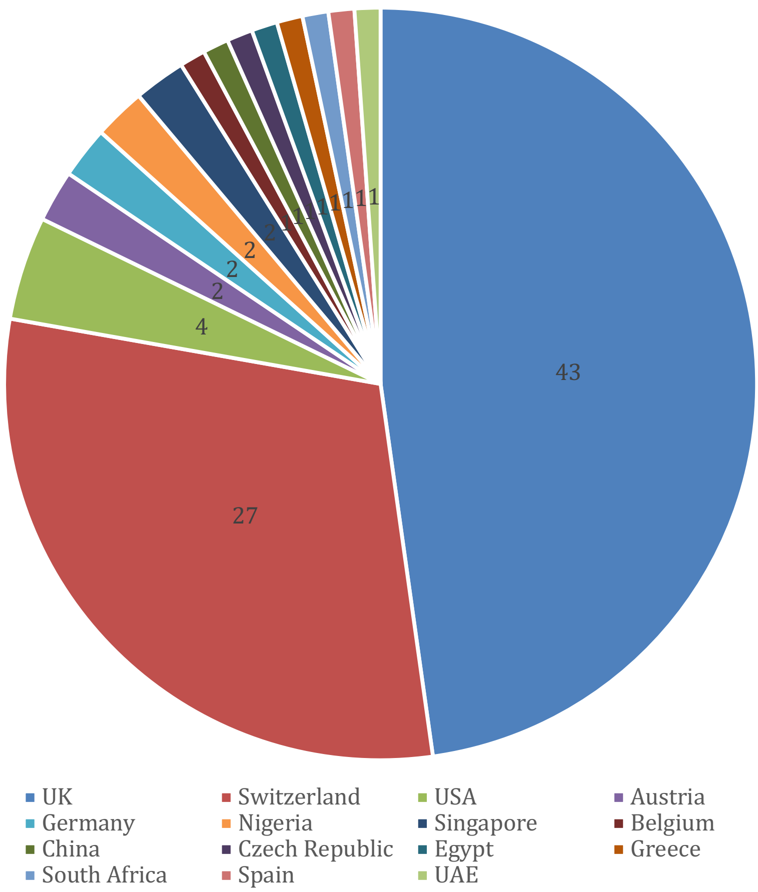
Participants identities were divorced from their answers. At the start of the data analysis, email addresses were removed from the spreadsheet and stored.

The survey used questions that have appeared in previously published studies (Howard-Jones *et al,* 2009 & Dekker *et al,* 2012) and were used with permission from one of the authors of these two studies. Some of the questions were rephrased to make them more accessible to non-native English speakers but not so dramatically as to negatively affect any potential comparison of collected results with those of previous published studies.

Data Analysis
Results from the survey were downloaded to an excel spreadsheet and all analysis was undertaken using Excel 2016 for Mac. After removal of email addresses, descriptive statistics were used to gain an understanding of the profiles of the participants (age, gender, level of education etc.). The results of these are displayed in figure 1 and table 2.

The percentage of correct and incorrect answers were calculated for each participant and for each statement. Independent t-tests and analysis of variance were used to examine differences in percentage of correct responses to neuromyths and, separately, general statements (dependent variables) between different groups (independent variable: e.g. gender, country, level of education). Finally, two regression analyses were performed to look at the predictors of correct responses to neuromyth statements and agreement with neuroscientific statements.

Figure 1: Number of Particpants by country



Findings

Profile of sample

In total there were responses (N=90) to the survey from teachers located in 15 countries. Most responses were from teachers in the UK (N=43) and Switzerland (N=27). Of the

Table 2: Participant characteristics

	%		%
Education level:		**School type**	
Undergraduate	13	independent	93
PGCE	23	state	7
Masters	56	**Curriculums taught**	
PhD	6	National	41
School level		International	32
Primary	9	Both	27
Secondary	82	**Interested in educational neuroscience**	92
Other	8	**Think neuroscience important for T&L**	77
Encountered in career		**Attended educational neuroscience in-service CPD**	34
Multiple Intelligences	76	**Science Degree**	40
Learning styles	87	**Read science magazines/Journals**	48
Left/Right brain learners	49		
Brain gym	50		

respondents, 53% were female and 44% were male; two participants declined to give their gender. The mean given age was 42 years (s.d.=9) although three participants placed erroneous numbers (e.g. 0, 65+ etc.) that were excluded from this calculation. The participants' characteristics are summarized in table 2. Most teachers (56%) were educated to Masters Level and taught in Secondary (82%) Independent (93%) schools. A large proportion (87%) had encountered the idea of learning styles, while 76% had encountered the theory of Multiple Intelligences. Most (92%) teachers expressed an interest in educational neuroscience but less (77%) thought it was important for their teaching and learning. 40% of the teachers held science degrees as their first degree. The mean estimate of the effect genes have on an individuals' ability to learn was 47% (s.d.=23).

Neuroscientific Understanding and Acceptance of Neuromyths

The mean score on the general statements and neuromyths statements were 74% (s.d.=10) and 44% (s.d.=14) correct respectively. Indicating that despite generally strong general knowledge of neuroscience assertions, acceptance of neuromyths was still high amongst teachers. There was a significant difference in the scores ($t(89)=22.41$, $p =< 0.001$).

Table 3: Results for 16 neuromyth assertions ranked by number of incorrect responses. Those in italics are true statements.

Neuromyth	%		
	Correct	Incorrect	I don't know
Environments that are rich in stimulus improve the brains of pre-school children.	4	84	11
Individuals learn better when they receive information in their preferred learning style (e.g. visual, auditory, kinaesthetic).	26	64	10
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners.	18	57	26
The left and right hemisphere of the brain always work together.	22	49	29
Children are less attentive after sugary drinks and snacks.	23	43	33
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills.	6	42	52
Omega 3 supplements enhance the mental capacity of children in the general population.	18	32	50
Regular drinking of caffeinated soft drinks reduces alertness.	19	30	51
We only use 10% of our brains.	38	23	39
Drinking less than 6-8 glasses of water a day can cause your brain to shrink.	44	19	37
There are no critical periods in childhood after which you cannot learn somethings, just sensitive periods when it is easier.	69	18	13
Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired.	68	17	16
Learning problems associated with developmental differences in brain function cannot be remediated by education.	79	7	14
Vigorous exercise can improve mental function.	76	7	18
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain.	76	2	22
Production of new connections in the brain can continue into old age.	92	2	6

Table 4: Predictors of Neuromyths

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95.0%*	*Upper 95.0%*
Intercept	5.001451218	12.234239	0.408807709	0.683845773	-19.37040265	29.37330509
Gen% Correct	0.632596131	0.144499123	4.377854458	3.82507E-05	0.344739116	0.920453146
Education	1.745020622	1.844616866	0.946007083	0.347182897	-1.929644611	5.419685855
Interested	-12.65655367	6.056361045	-2.089795105	0.040026732	-24.72144355	-0.591663784
Important	4.850068635	3.92344522	1.236175953	0.220250706	-2.965835039	12.66597231
In-service training	-5.379281977	3.190574315	-1.685991752	0.095953585	-11.73523194	0.976667987
Multiple Intelligences	-1.079422854	3.42399773	-0.315252211	0.753445657	-7.900376106	5.741530399
Learning styles	1.571655814	4.644776183	0.338370624	0.736029325	-7.681212824	10.82452445
Hemisphere	-3.436633738	3.104447893	-1.107003196	0.271830457	-9.621011073	2.747743596
Gym	-0.047930699	2.852351758	-0.016803923	0.986637663	-5.730106779	5.634245381
Read	1.252340158	3.119596287	0.401443021	0.689235548	-4.962214324	7.46689464
science degree	-1.999789944	3.160915393	-0.632661649	0.528878829	-8.296656306	4.297076419
Country	0.359033546	1.835066531	0.195651514	0.845412049	-3.296606444	4.014673536
Gender	-5.065024284	2.828172624	-1.790917655	0.077341347	-10.69903306	0.568984491
Age	-0.090160999	0.112869228	-0.798809389	0.426923357	-0.315008032	0.134686034

Table 3 shows the results for the 16 neuromyths ranked by percentage of incorrect responses. Examining the highest ranked neuromyth – the assertion that "*Environments that are rich in stimulus improve the brains of pre-school children*" – shows that 84% of teachers in the sample were incorrect in their response to this statement i.e. they agreed with the statement. Based on the the percentage of teachers who therefore think that this statement is true, this is the most prevalent neuromyth in this sample (For an explanation of why this statement is false see Bruer (2012) and Bruer & Greenough (2001)).

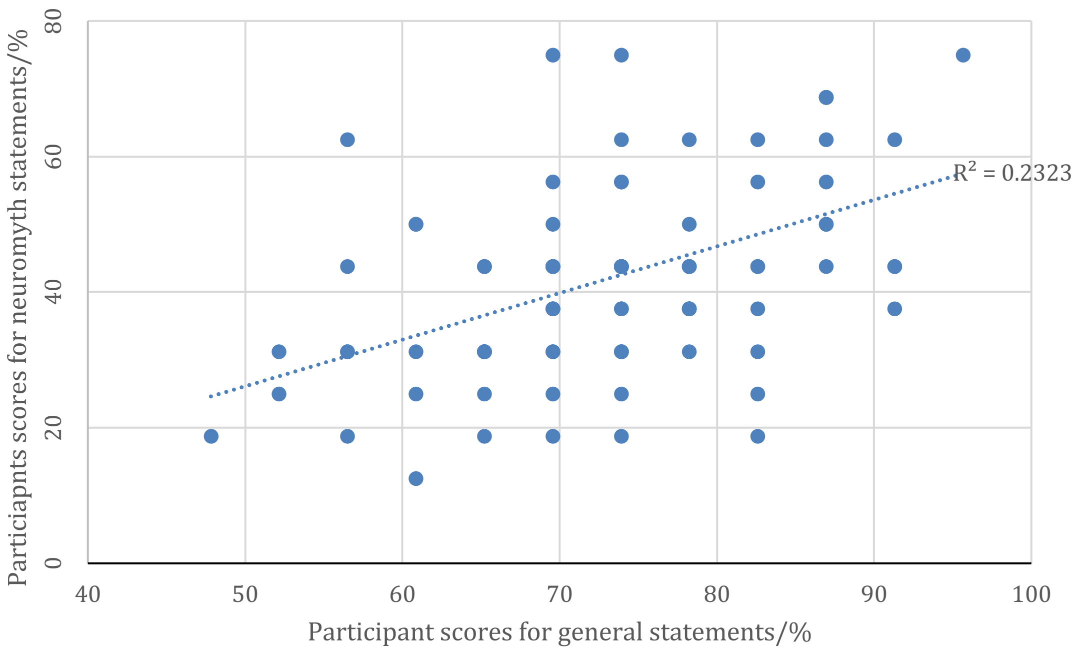
Likewise, for the fourth highest ranked neuromyth and the first in italics (a true statement) – *"The left and the right hemisphere of the brain always work together"* – 49% of the teachers in the sample thought that this statement was false and disagreed with it. This response was incorrect.

The sample performed better (M=74% correct, s.d.=10) against statements designed to assess general neuroscience knowledge. Of the remaining 28 statements, there were four where more than a quarter of the sample were incorrect. Only one general statement received more than 40% incorrect responses. This was the statement: *"To learn how to do something, it is necessary to pay attention to it."* 48% of the respondents disagreed with this statement.

Predictors of Neuromyths

Because such a large proportion of the sample were secondary teachers working in independent schools, I was unable to statistically compare primary vs secondary or state vs independent school as predictors of neuromyths or of general neuroscientific knowledge. The same reasoning also applied to comparing interested vs not interested in educational neuroscience. ANOVA tests revealed no effect of level of education (independent variable) on neuromyth acceptance ($F(3)=1.002$, $p=0.395$) or general knowledge ($F(3)=1.176, p=0.323$). Independent t-tests revealed no difference between teachers from Switzerland vs UK on neuromyths acceptance ($t(68)=0.815, p=0.208$) and also general knowledge ($t(68)=0.475, p=0.318$). Regarding gender, no difference was found for general knowledge ($t(88)=1.232, p=0.111$) or in correct responses to neuromyth assertions ($t(88)=2.574, p=0.006$). Nor was any difference found whether participants held a science degree or not in their general knowledge ($t(88)=2.277, p=0.012$) or in their responses to neuromyths ($t(88)=2.14, p=0.014$).

Figure 2: Relationship between scores for general statements and scores for responses to neuromyths



A linear regression revealed a weak positive correlation between neuromyth rejection and level of general knowledge (β=0.63, see table 4 and figure 2), indicating that teachers who had good general knowledge of neuroscience, had some ability to identify and discriminate against neuromyths. No other factors predicted belief in neuromyths. The model explained a small amount of variance (R^2 = 0.29).

Figure 2 shows the simple linear regression for the correlation between participants scores on general knowledge and neuromyths statements.

Discussion

A cohort of 90 teachers who were drawn loosely from the author's own professional network, answered a questionnaire that assessed their agreement to statements about the brain and learning. While this number of participants is by no means as large as some other published studies – (Howard-Jones *et al.,* 2009: N = 158, Dekker *et al.*, 2012: N=242, Tardif, 2015: N=283), it is still a large enough sample for some useful comparisons to be drawn.

Neuroscience Knowledge

This study found that the general neuroscientific knowledge amongst the 90 teachers was very good with a mean score of 74% (s.d. = 10). The only statement that elicited a concerning response was *"To learn how to do something, it is necessary to pay attention to it."*. 50% of the cohort either rejected or selected "I don't know" to this assertion. This reflects a similar response found in the Howard-

Jones *et al.* (2009) study where only 43% of teachers agreed with this statement. Potential ambiguity of the statement aside, the authors of that study, highlight that this could be evidence of a new neuromyth arising from work with artificial grammars as they state:

"*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*".

The authors go on to emphasize that implicit learning does not equate to learning without attention and it is worrying that this is an idea that is adopted by a large proportion of individuals whose role is to help others learn.

Prevalence of Neuromyths

Overall the results in table 3 indicate that many teachers in this sample still believe in ideas relating to learning styles and hemispheric dominance of the brain as the statements that relate to those ideas have the greatest acceptance within the sample.

The study found that the most common neuromyth in terms of teacher agreement (84%) was that stimulus rich environments improve the brains of pre-school children. Howard-Jones *et al.* (2009) found 89% of respondents agreed with this statement. Interestingly, in Dekker *et al.*'s (2012) study which compared and contrasted neuromyths amongst teachers in Dorset, UK and the areas surrounding Amsterdam, NL, it was found that 95% of UK teachers agreed with this statement, while only 56% of the Dutch teachers agreed with this statement. In both these studies this was also the neuromyth that had the highest level of support amongst UK teachers.

This myth is thought to arise from published studies from the 1940's of brain development in rats that compared the development of rats in normal laboratory conditions (empty cages) against rats which had objects and obstacles in their cages. As Bruer (2012) notes, not only is it invalid to extrapolate wildly from rats to humans, but the normal environments of wild rats are much more diverse than a laboratory cage, hence these studies were actually measuring deprivation not stimulation.

64% of teachers in the present study thought that individuals learn better when receiving information in their preferred learning style. This can be contrasted to 79% for Howard-Jones *et al.*(2009), UK:93% and NL: 96% in Dekker *et al.*'s (2012) study and 96% in Tardif *et al.*'s (2015) study of Francophone teachers in Vaud, Switzerland. For the first two studies respectively this was also the second most accepted myth as it is in this study. 87% of teachers in this study also indicated that they had been exposed to the idea of learning styles at schools in their teaching career. While it is true that individuals may have preferences for the modality in which they receive information, the neuroscientific studies carried out to date suggest that multi-sensory teaching helps more learning take place in the brain. This is because the brain's sensory systems are not isolated from each other but communicate *across* the hemispheres (Geake, 2008).

Tardif *et al.* (2015) found that 85% of respondents agreed that some people use one hemisphere more than the other and Dekker *et al.* (2012) found that 90% of teachers believed that differences in dominance could help explain individual differences among learners. This study found that 57% of teachers agreed with the same statement, while 49% disagreed with the statement that the "left and right hemispheres always work together". While some functions (like speech) are lateralised to one hemisphere, it is not correct that when one hemisphere is working the other is not. Blood flow to and metabolic activity in regions of the brain never completely stop until death!

Predictors of Neuromyths

Despite a high score on the general knowledge statements (M=74%), the acceptance of neuromyths was still prevalent (M=42%). The relatively low mean of 42% indicates that there is still confusion amongst the teachers in this sample surrounding neuromyths despite relatively good understanding of the brain. This would seem to to support Dekker *et al.*'s (2012) conclusion that greater knowledge about the brain and neuroscience actually makes teachers more susceptible to believing in neuromyths. This study also found a weak correlation between the score on general knowledge section and the neuromyth section of the survey, similar to the Dekker *et al.* (2012) study. However, counter intuitively, this correlation suggested that possession of a good score on the general section predicted an individual more likely to perform better with the neuromyth statements. Despite a low mean score on the neuromyths statements, individuals who scored highest in the general section, tended to also score higher than average in the neuromyth section. Dekker *et al.* (2012) do not make it clear how their regression was calculated, whilst also reporting a positive correlation but interpreting it negatively.

With regards to the predictors of neuromyth susceptibility amongst teachers, this study could find no evidence that age, gender, interest in science, or possessing a science degree either made teachers more or less susceptible to adopting neuromyths. This study could not repeat Dekker *et al.*'s (2012) finding that the country a teacher is from predicts their level of general neuroscientific knowledge. That study found that Dutch teachers were more likely to score highly on the general knowledge type statements. On one hand this may due to the relatively small sample size of this study but it could also be argued that Dekker *et al.*'s (2012) study only sampled from one County in the UK which could be said to be unrepresentative of the entire country.

Limitations

It should be noted that the vast majority of the teachers sampled were secondary practitioners from independent schools and although this was not by design (the author contacted several groups of teachers from both independent and state-maintained schools), it will impact the generalizability of any conclusions. In addition, although 16 countries are represented in the sample, it is likely that most of the respondents from outside the UK (particularly Switzerland) were teachers who trained in UK, or other Anglophone countries. These teachers would be likely to share cultural biases, again narrowing the ability to extrapolate from these findings. The results described above match closely both those of the Howard-Jones *et al.'*s (2009) study of teachers and trainee teachers in the UK, and Dekker *et al.*'s (2012) sample of UK teachers support the case that the results from this study represent neuromyths amongst (mainly) UK teachers.

Conclusion

In conclusion this study has found that neuroscientific knowledge amongst teachers is fairly robust, with many teachers demonstrating an understanding of neuroscience concepts. The study has also demonstrated that neuromyths are alive and well amongst the cohort sampled. The neuromyths that have been identified as the most accepted amongst teachers in this study, are also borne out as the most accepted in at least two other similar studies since 2009. However, this study has found a lower level of acceptance in some neuromyths cases, particularly with regards to those statements regarding learning styles and hemispheric dominance. This suggests that teachers are becoming more aware of these misconceptions, although further studies would need to be undertaken to corroborate this statement. Tardif *et al.*'s (2015) study of francophone teachers in Switzerland would appear to buck this trend. As most of the published neuromyths studies have been conducted in English, this could be due to factors which may slow the dissemination and communication of idea's and finding across language barriers, resulting in non-English speaking teachers continuing to hold false pedagogical ideas.

Since the term neuromyth was coined by the OECD (2015), there have been many calls to address the growing concern regarding teachers' misconceptions about the claims that neuroscience makes about learning. Neuroscience has by no means completely resolved the mechanisms of learning in the brain and the study is still very much in it's infancy. However, the plethora of neuromyths existing in the face of such an early scientific exploration of learning in the brain, is cause for concern. Surely as new insights are developed from the empirical study of learning, the number of neuromyths is likely to grow unless communication between the neuroscience and education communities is further encouraged, along with much more rigorous training in scientific methods in general and neuroscience in particular is made available to new and practicing teachers.

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Appendix

Question	% Correct	Incorrect	I don't know
When we sleep, the brain shuts down. (F)	98	1	1
Emotions impact learning. (T)	98	0	2
Mental capacity is hereditary and cannot be affected by the environment. (F)	94	1	4
Cognitive abilities are inherited and cannot be modified by the environment or by life experience. (F)	92	4	3
Production of new connections in the brain can continue into old age. (T)	92	2	6
Brain development has finished by the time that children reach secondary school. (F)	89	3	8
We use our brains 24 hours a day. (T)	88	9	3
The environment can influence hormone production and therefore personality. (T)	87	3	10
Individual learners show preferences for the mode in which they receive information. (T)	86	7	8
Happiness, anger and fear are experienced by the brain, not the heart. (T)	80	14	6
Keeping a phone number in memory until dialling, recalling recent events and distant experiences, all use the same memory system. (F)	80	3	17
Without a brain, consciousness is not possible. (T)	79	11	10
Learning problems associated with developmental differences in brain function cannot be remediated by education. (F)	79	7	14
Learning occurs through changes in the connections between brain cells. (T)	79	3	18
Normal human brain development involves the birth and death of brain cells. (T)	78	10	12

Brain activity depends entirely on the external environment: with no senses stimulated, we don't see, hear or feel anything. (F)	77	9	14
Vigorous exercise can improve mental function. (T)	76	7	18
Extended rehearsal of some mental processes can change the shape and structure of some parts of the brain. (T)	76	2	22
Emotions disrupt logical thinking. (T)	74	21	4
The mind can be studied by studying the activity of the brain. (T)	72	13	14
Memory is stored in networks of cells distributed throughout the brain. (T)	71	7	22
There are no critical periods in childhood after which you cannot learn somethings, just sensitive periods when it is easier. (T)	69	18	13
The brains of boys and girls develop at the same rate. (F)	69	6	26
Children must acquire their native language before a second language is learned. If they do not do so neither language will be fully acquired. (F)	68	17	16
The mind is a product of the brain. (T)	68	13	19
Hormones influence the internal state of our bodies, not our personality. (F)	67	23	10
The body clock shifts during adolescence, causing pupils to be tired during the first lessons of the day. (T)	63	4	32
"State of mind" reflects "the brain state" in a given moment. (T)	60	24	16
Academic achievement can be affected by skipping breakfast. (T)	60	23	17
To learn how to do something, it is necessary to pay attention to it. (T)	50	48	2
When a brain region is damaged other parts of the brain can take up its function. (T)	50	21	29
Your mind results from the action of the spirit/soul on the brain. (F)	48	23	29

Drinking less than 6-8 glasses of water a day can cause your brain to shrink. (F)	44	19	37
The brain stores memory like a computer: each memory goes into a tiny piece of the brain. (F)	43	33	23
We only use 10% of our brains. (F)	38	23	39
Individuals are responsible for behaviour associated with a developmental difference in brain function. (T)	37	33	30
Individuals learn better when they receive information in their preferred learning style (e.g. visual, auditory, kinaesthetic). (F)	26	64	10
Children are less attentive after sugary drinks and snacks. (F)	23	43	33
The left and right hemisphere of the brain always work together. (T)	22	49	29
Boys have bigger brains than girls. (T)	19	36	46
Regular drinking of caffeinated soft drinks reduces alertness. (T)	19	30	51
Differences in hemispheric dominance (left brain, right brain) can help explain individual differences amongst learners. (F)	18	57	26
Omega 3 supplements enhance the mental capacity of children in the general population. (F)	18	32	50
Exercises that rehearse co-ordination of motor-perception skills can improve literacy skills. (F)	6	42	52
Environments that are rich in stimulus improve the brains of pre-school children.(F)	4	84	11