THE CASE OF TEACHERS AND NEUROSCIENCE: HOW DO TEACHERS MEDIATE INFORMATION ABOUT THE BRAIN?

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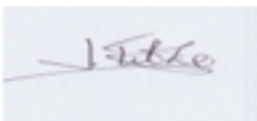
This thesis has not been submitted in support of an application for another degree at this or any other university. It is the result of my own work and includes nothing that is the outcome of work done in collaboration.

Signature:  Word Count: 74,139

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Abstract

A number of researchers both in the U.K. and elsewhere have investigated what teachers know about the brain. However, much less is understood about how teachers acquire and make sense of this knowledge and how it subsequently manifests itself in their practice. This thesis proposes that such an understanding is currently a significant missing component in the interaction between teaching and neuroscience, or teachers and neuroscientists.

This qualitative research presents an analysis of eight semi-structured interviews with five teachers who work in different contexts, as well as exploring data gathered via a survey of 102 teachers from schools across England and Wales. The research has explored a range of relevant literature, in relation to the brain, educational neuroscience and professional learning of teachers, as well as literature relating to the methodological paradigm and methods adopted for the research. Interpretative Phenomenological Analysis (IPA) has supported interpretation of the teachers' experiences of the brain and educational neuroscience. In addition, Cultural Historical Activity Theory (CHAT) has supported examination of the influence of the teachers' working contexts. Data coding facilitated the framing of the codes within seven themes: (i) knowledge and sources, (ii) meaning making, (iii) external pressures and working contexts, (iv) environment and lifestyle, (v) medical and Special Educational Needs and Disabilities (SEND), (vi) products and (vii) child development. These themes capture the teachers' descriptions of how they experience information about the brain and educational neuroscience and ways in which they act upon this knowledge and experience. The themes provide a framework both for further investigation and as areas of experience through which to enhance teachers' knowledge and use of information about the brain and educational neuroscience. What is revealed through the data of the nuances of teachers' thinking about the brain has the potential to contribute to improved understanding between teachers and neuroscientists. This relationship needs to recognise the essential, active role of teachers in translating educational neuroscience research into classroom practice.

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Publications and Presentations Drawing on Elements of this Thesis

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Tibke, J. (2018) How do teachers mediate information about the brain*? Impact (online), The Journal of the Chartered College of Teaching* (February 2012)

Tibke, J. (2016) The Case of Teachers and Neuroscience: have we reached Bruer's bridge yet? *Presented at the Annual BERA Conference, University of Leeds, September 2016*

Tibke, J. (2013) The Case of Teachers and Neuroscience. *Presented at the Postgraduate Research Conference, Lancaster University, July 2013*

Tibke, J. (2012) Beyond the Mozart effect and the neuromyths: how might teachers engage with accurate neuroscientific information? *Doctoral Colloquium presentation, University of Cumbria, July 2012*

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List of Abbreviations

ADHD: Attention Deficit Hyperactive Disorder

ALNCo: Additional Learning Needs Co-ordinator

ASC: Autistic Spectrum Condition

CAVL: Computer-assisted Vocabulary Learning

CCT: Chartered College of Teaching

CfBT: Centre for British Teachers

CHAT: Cultural Historical Activity Theory

CPD: Continuing Professional Development

CRADLE: Centre for Research on Activity, Development and Learning

DSM-V: The Diagnostic and Statistical Manual of Mental Disorders-V

DTI: Diffusion Tensor Imaging

DWR: Developmental Work Research

EBTN: Evidence-based Teachers Network

EEF: Education Endowment Foundation

EEG: Electroencephalogram

fMRI: Functional Magnetic Resonance Imaging

IEE: Institute for Effective Education

IMBES: International Society for Mind, Brain and Education

IPA: Interpretative Phenomenological Analysis

ITT: Initial Teacher Training

MEG: Magnetoencephalography

MFL: Modern Foreign Languages

NSF: The Neuroscience Framework

OECD: Organisation for Economic Co-operation and Development

PET: Positron Emission Tomography

PgCE: Postgraduate Certificate in Education

QTS: Qualified Teacher Status

SATs: Standardised Assessment Tests

SEND: Special Educational Needs and Disabilities

SENDCo: Special Educational Needs and Disabilities Co-ordinator

tDCS: Transcranial Direct Current Stimulation

TMS: Transcranial Magnetic Stimulation

VAK: Visual, Auditory, Kinaesthetic

Chapter 1: Introduction

1.1 Introduction to Chapter 1

This study explores how teachers think about, talk about and act upon their knowledge of the brain and educational neuroscience. Previous studies have concentrated on the extent of teachers' knowledge of the brain and the extent to which teachers subscribe to 'neuromyths'. My purpose is instead to investigate teachers' mediation of this knowledge, to endeavour to understand more about how teachers experience this knowledge, for the purpose of contributing to the development of the interface between teachers and educational neuroscientists. This study is essentially qualitative in nature, drawing data from semi-structured interviews and from an online survey. Although some of the data, particularly the online survey responses, can be quantified, it is the interpretation and cross-reference of all the responses that has enlightened my conclusions and suggestions for further research and actions.

This chapter examines the emergence of educational neuroscience as a discreet discipline and the development of my own interest in educational neuroscience. The problems associated with the allure of neuroscience are then considered, prior to briefly introducing the range of literature that is further explored in chapter two and the overall structure of this thesis.

I come to this research from a teacher and teacher educator background; I am not a neuroscience expert. Since 1982 I have been a classroom teacher, head of department, head of faculty and deputy headteacher in secondary schools in England. Since 2004 I have held roles with universities within programmes for Qualified Teacher Status (QTS) and routes to the Postgraduate Certificate in Education (PGCE), as well as presenting courses for teachers in the UK and overseas. This brief history explains my interest in teacher development, whilst my interest in the brain and educational neuroscience is explained in the rest of this chapter.

1.2 The Emergence of Educational Neuroscience

Knowledge of the human body's most complex component, the brain, continues to expand at an ever-increasing rate. To illustrate, neurosciencenews.com emails updates to its followers daily, frequently reporting on more than ten different neuroscience projects per day. A growing range of informative medical imaging technologies, modelling and mathematical methods have made this expansion possible, though at the same time all these methods also highlight how much more is yet to be discovered and much that is not well understood. In laboratories, extensive research using rodents, birds and sea-dwelling life forms offers further considerations for the human brain, prompting further research. Given that the brain is central to all types of learning, axiomatically it would appear sensible to suggest that this developing knowledge will be of considerable interest to and significance for teachers. The discipline of neuroeducation or educational neuroscience, a young discipline that draws on many longer established fields such as cognitive neuroscience, cognitive psychology and neurobiology, alongside other young disciplines such as neuroethics and neurophilosophy, is based on this premise. Yet in practice, this emerging field is beset by misunderstandings and confusion, along with sensationalised media reports that exaggerate cautious research findings and similar exaggerations that are used to promote commercial learning and teaching products, some examples of which are discussed below, in chapter 1.4 and chapter 2. A proliferation of ‘neuromyths’, a term first used formally in the report of the Organisation for Economic Co-operation and Development (OECD) Symposia on Brain Research (2002), has resulted. Examples of the most notably re-occurring myths include the idea that individuals only use ten per cent of their brain’s capacity, brains (and by implication personality and learning traits) are dominated by either their right or left hemisphere, or that individual brains have a preferred mode of learning, with visual, auditory and kinaesthetic (VAK) being the most frequently cited examples. The ability to untangle what may be of genuine educational use from products or methods that make dubious promises appears to be one that teachers now need to develop more urgently than ever, yet it is rarely the case that educational neuroscience features in initial teacher education programmes or amongst the priorities for teachers’ continuing professional development (CPD). Therefore, teachers frequently find themselves exposed to information about the brain, whether through news media, education products or their own curiosity, with unavoidably limited understanding of the accuracy or relevance of this information for their work. We cannot censor the reading, interests or thoughts of individual teachers and the desire of teachers to find new solutions to the ongoing challenges of, for example, learning needs, behaviour difficulties, student memory, student attention and student motivation, so teachers are a potentially vulnerable audience for the allure of neuroscience and its misuse in promoting educational methods and products. As Howard-Jones et al. (2009) note: ‘little is known about how teachers think about the brain’ (p.2). This is a fundamental issue that this thesis explores, by examining the knowledge and views of a variety of teachers and the insights evident in how these are expressed.

1.3 Starting Point

My initial interest in the brain is a further illustration of the dangers described above. As a musician and music educator, I became aware of the interest evident in the medical world in how the brain processes music, as this also appears to shed light on other aspects of brain function (Rauscher et al., 1993, Rauscher and Shaw, 1998, Stuart, 2008, Warren, 2008). In addition, there is extensive research exploring the use of music in the treatment of neurological conditions (such as Thaut, 2008). It seemed a logical assumption on my part that some of this information would surely be revealing in terms of musical learning and teaching and therefore bound to be of relevance to teachers of music. I set out with great enthusiasm to search for findings that might revolutionise how music is taught and whilst I found things of undoubted interest and potential and was excited to discover plenty of literature based on variations of my hypothesis, I also found that little of the literature is conclusive and much of it is highly complicated. My investigations led to a realisation that the issues and questions arising for the use of knowledge of the brain within music education were not exclusive to music and at this point my investigation broadened, in order to afford me scope to explore understanding of the brain amongst teachers with different professional histories, specialisms and contexts. Having conducted an initial pilot survey with secondary school music teachers, my subsequent data are drawn from teachers across the school curriculum, from the 4-18 age range and in both mainstream and special education contexts. Six questions are central to my investigation:

- what sort of things do teachers know or believe about the brain and from where do they consider this knowledge to have been attained?
- How do they think about and talk about this knowledge?
- how do they use this knowledge?
- how can they become critical consumers of the available information?
- what do they hope or believe neuroscience might or should assist them with in the future?

And most crucially:

- what can dialogue with teachers reveal to us about how we might improve the interface between teachers and neuroscientists, laboratories and classrooms?

1.4 Dangerous Allure

The field of education is not unique in its vulnerability to the allure of neuroscience. In business, for example, there is evidence of the use of neuroscientific information to promote approaches to leadership, the selection of personnel and in both the engaging of potential clients and in winning their subsequent contractual commitment. Companies are emerging in the field of advertising and marketing that use practices claiming to have a basis in neuroscience (‘neuromarketing’) as a means of monitoring consumer response and often promote these as more reliable than methods based on consumers' verbal opinions. There is a clear intention to imply that the neuroscientific basis assures reliability, whereas consumer comments are in some way subjective and less reliable. Researchers have begun to demonstrate that the inclusion of neuroscientific language and imagery, when included in articles, books and websites, tends to convince readers of the validity of the content, whatever the field (McCabe and Castel, 2008, Weisberg et al., 2008). The citing of evidence such as brain images of defendants' brains in legal situations, a practice that has become known as 'neurolaw', has raised ethical questions; how is a decision made that a defendant is not responsible for their own brain? (Satel and Lilienfeld, 2013).

Study of the literature indicates that not all educational commentators are convinced that neuroscience is yet at a point where it can tell us anything that does little more than offer neurobiological confirmation of the efficacy of many of the strategies used by good teachers and many also warn that reference to neuroscience is often oversimplified or reductionist in nature (Bowers, 2016, Bruer, 2006, Sylvan and Christodoulou, 2010).

Busy teachers, amidst competing demands and ever-shifting expectations driven by frequent changes to national policy, have limited access, and limited time, to explore the literature and findings of educational neuroscience. Therefore, the origins and accuracy of what teachers have encountered, along with how this may influence practice, warrants further scrutiny. My study examines teachers' mediation of information about the brain and what they believe they do (or do not do) with this information, through a qualitative exploration based on survey responses (n=102), a series of eight semi-structured interviews with five teachers, three of whom participated in a second interview, during which they offered their thoughts in response to the survey data.

1.5 Literature

As well as literature relating to neuroscience in a range of disciplines and contexts, this investigation is also informed by research that examines teacher knowledge, teacher learning, continuing professional development, learning within organisations and by literature relating to research methods. In addition, online sources that teachers utilise have been reviewed, as these offer quick and easy access for teachers, though their accuracy and reliability are variable. This literature is examined in chapter two, whilst literature relating to methodology and methods is discussed in chapter three.

1.6 Thesis Structure

Following this introductory chapter, chapter 2 consists of a literature review that examines many of the issues and difficulties that have arisen in relation to knowledge of the brain in general and in relation to its use by teachers. The question of how teacher knowledge is developed is also considered and the chapter concludes with an exploration of the question of teacher knowledge of the brain from the perspective of initial teacher education.

Chapter 3 details the methodological position adopted for my research and the methods through which data have been gathered and analysed. The rationale for the use of Interpretative Phenomenological Analysis (IPA) is discussed. The role of Cultural Historical Activity Theory (CHAT) in the early development of my thesis and the eventual decision to limit its role in the analysis of my data are also explained. The final sections of chapter 3 consider researcher assumptions, key ethical questions and the process of gaining ethical approval, the management of matters of potential bias and discussion of the limitations of the project.

Chapter 4 reflects the decision to firstly introduce data without comment, rather than present data, analysis and discussion concurrently. The decision to do this has been taken so that the reader is able to gain a clear picture of the data prior to its analysis and discussion and to afford the reader the opportunity to return to the details of chapter 4 when it is helpful to do so whilst considering the subsequent chapters. This approach is based on the phenomenological concept of 'rich description', which is considered in chapter 3.

In chapter 5 the key themes from the analysis of the data sources are presented and discussed. This discussion is presented through the assimilation of the data into the seven over-arching themes.

The final chapter of this thesis, chapter 6, draws emphasis on what I regard as the most significant findings evolving from this thesis. The implications of these findings in terms of future action and further research and how they connect with other ongoing research is considered.

Chapter 2: Literature Review

2.1 Introduction

Not only is neuroeducation or educational neuroscience a young discipline, it is also one that draws on a wide range of fields. To suggest that cognitive neuroscience, neurobiology, biochemistry and neuro-imaging sit alongside educational psychology, cognitive psychology, theories of potential, motivation and pedagogy, some of which relate to the skills, concepts and knowledge of particular curriculum areas, is to present only a brief selection of related fields. It is important that the multi-disciplinary nature of educational neuroscience is recognised; educational neuroscience does not, nor should not, seek to become a teleological explanation of learning and teaching. Consideration from a range of disciplinary perspectives is central to the avoidance of the educational misapplication of neuroscientific findings, particularly since schools and laboratories are very different places and learning is not simply a biological process. In the context of my study, the nature of teacher knowledge and teacher learning is also of considerable significance.

Rather than attempt to briefly discuss the vast and rapidly expanding literature of the contributory fields of educational neuroscience, the purpose of this review is to examine what the literature appears to suggest are the most important present considerations for educational neuroscience, whatever the discipline of the source and the issues that arise when professionals from other fields, such as teachers and the public in general attempt to engage with information about neuroscience. A preliminary consideration is the need for the continuing building of bridges between the related areas. The review concludes with discussion of definitions of teacher knowledge and aspects of teachers' professional learning and development, including initial teacher training. Examination of literature influential in the design and choice of research methodology, data gathering methods and theoretical perspectives adopted for data analysis is undertaken in chapter 3.

2.2 Bridges and Boundaries

Koizumi (in Battro et al, 2008) points out that cross-disciplinarity does not necessarily build bridges and prefers instead the term *trans-disciplinarity* (p.166), whereby he describes the concept of disciplines working together in the creation of a new field, which he refers to as *brain-science and education*. Koizumi proposes a model for trans-disciplinarity that he describes as 'synthesis over reductionism' (p.167), thus producing new dimensions, beyond the Cartesian reductionism that Koizumi suggests served science and technology effectively up to the twentieth century but less so in the twenty first century. Knox (2016) supports Koizumi's transdisciplinarity proposal, suggesting that it is a way forward that can bypass differences of language and epistemology evident in the individual disciplines. Edelenbosch et al. (2015), present a similar concern, in discussing the boundary between neuroscientists and education practitioners. Working with evidence from 26 semi-structured interviews that explored the role of both groups around this boundary, they suggest that each group displays views about brain-based learning and about the other group that are in conflict. I return to issues of collaboration in chapter 2.5.

In writing *Education and the Brain: A Bridge too Far* (1997), John Bruer came to be considered the most noted sceptical commentator on the possibilities that might emerge from the bridging of neuroscience and education. Bruer posited that cognitive psychology offered better models than neuroscience for educationalists to utilise in the development of learning and teaching strategies. In a reply to Bruer, Iran-Nejad (1998) claims that Bruer chose to consider only a narrow range of neuroscience evidence. He concedes that Bruer's cautions and warnings are worthwhile but unreasonably dismiss the whole field as too complex, drawing a 'definitive, negative conclusion' (p.10) without considering the views, evidence and 'mission of the reform-oriented neuroscience and education movement' (p.10). Both Bruer and Iran-Nejad are agreed that much difficulty lies in how complex neuroscience is communicated to fundamentally significant non-specialists such as teachers and policy makers. However, Iran-Nejad is keen to point to examples of accurate representations in popular science sources, that begin to achieve an effective form of communication that is not just simplification. I discuss this issue further below (chapters 2.3, 2.7). Iran-Nejad also points out that Bruer overlooks what is now referred to as *neuroprognosis*, the use neuroscientific methods to identify potential learning difficulties.

Writing more recently, in the same volume as Koizumi, Bruer updates his position, acknowledging that cognitive neuroscience has progressed to a point whereby it might 'assist in refining educationally relevant cognitive models' (p.44) and citing behavioural, neuropsychological and cognitive neuroscientific studies as the key areas for interactions that can lead to findings of relevance to education. This is in keeping with Bruer's declaration (2006) that whilst neuroscience will grow in relevance to education in the future, the bridges 'will have at least one pier on the island of psychology' (p.109). Bowers (2016) is much less ready to step on to Bruer's bridge. Bowers maintains Bruer's earlier view that neuroscience has nothing to teach us about pedagogy or learning and goes a step further than Bruer in arguing that neuroscience is unlikely to contribute to pedagogy now or in the future. Bowers takes the view that much of what is promoted is irrelevant; seeing a change in a student brain, supposedly as a result of a certain teaching or learning method, is not really important, as what matters is *behavioural* change that demonstrates learning has taken place. This, Bowers insists, is best achieved though the discipline of psychology. Bowers makes his own comments on Bruer's bridge and suggests that it is the wrong analogy. In his view, a one way street is more appropriate, in which the flow is from teachers to neuroscientists, since teachers help bring about changes in the brains of their students which are then of interest to neuroscientists.

A more optimistic outcome, from Beauchamp's and Beauchamp's extensive analysis (2012) of references in neuroeducational literature to bridges, boundaries and various expressions of interaction, is the clarification that the boundaries between disciplines are bridges in themselves, since the intersections represent points of learning, both about work in different fields and about the cultural differences between fields that need to be understood if trans-disciplinarity is to be achieved. Beauchamp's and Beauchamp's analysis was based initially on 482 relevant works, reduced to 86 that contain explicit exploration of aspects of boundary crossing. Their promotion of the notion that the boundaries are represented by on the one hand people and on the other boundary objects or *tools*, such as *artefacts, documents and protocols*, is significant for my investigation, as it alerts me to the potential contributions of these elements. The language here clearly indicates a role for Activity Theory, as suggested above in the introduction and examined further in chapter three.

2.3 Problems of Terminology

An essential outcome of bridge building is the establishing of shared understanding and terminology between educationalists and scientists. Illes et al. (2010) discuss a number of challenges faced by neuroscientists in their efforts to respond for calls for greater communication of research findings beyond the scientific community and describe this as a necessary 'cultural shift' (p. 64). This shift would lead to greater value being placed on wider scientific communication and they cite the *Society for Neuroscience Science Educator Award* as an illustration of commitment to this end. They acknowledge, however, the potential for misunderstandings, given the complexity of the brain. The prevalence of misunderstandings and neuromyths, some of which are caused by reductionist explanations of complex research and some of which are not misunderstandings but are deliberate misrepresentations (Fischer et al., 2010), is explored in my research.

Even the interface of the words neuroscience and education presents difficulties of definition. Howard-Jones (2008a) comments that scientists sometimes equate learning to memory, or consider learning and the broader ideals of education to be one and the same, whereas definitions of learning from educational contexts are much more complex and are further compounded by the fact that teachers' beliefs about learning not only differ but may not be borne out by their day to day practice or may conflict with local and national policy. Further confusions, he continues, lurk beneath other seemingly straightforward language, such as the use of 'mind' and 'brain', words that are often treated as synonymous, yet refer to abstract and physical phenomena respectively, interdependent but not interchangeable. Having examined viewpoints where neuroscience and education have intersected, through experts from both fields and from psychology, Howard-Jones concludes that there are also issues of differing philosophies to be considered alongside the questions of shared definitions (2010). It is evident in the work of Howard-Jones that he prefers the term 'neuroeducation' to 'educational neuroscience'. However, each could be confusing to teachers without a clear definition. The Neuroscience Framework (NSF) has created Neurolex (neurolex.org/wiki), an attempt to develop a lexicon of consistent neuroscientific terminology, though this does not seek to tackle the philosophical differences to which Howard-Jones refers.

It does not help, as Wall (2014) points out, that commercial organisations introduce terminology of their own devising, such as NeuroNet Learning's 'motor-perceptual learning', or terminology that is now considered part of the history of neuroscience and no longer in use, such as The Brain Balance Center's references to 'functional disconnection syndrome', which has been out of favour since the 1990s (Catani and Ffytche, 2005, p.2224). Wall also notes that NeuroNet Learning (an organisation founded by chiropractors) continues to promote and sell the work of Brain-Gym®, on which I comment below (chapter 2.4). One further point of alarm that Wall also raises is the exploitation of parental anxieties. Some of The Brain Balance Center's programmes for the treatment of developmental conditions such as autism and Attention Deficit Hyperactivity Disorder (ADHD) have a price tag above $5000, yet no research and evidence base for their efficacy. Instead, research is cited that relates to the functions of brain areas that The Brain Center claims its programmes can influence, but none of this research relates directly to the programme treatments. The success of the treatments can only be described in anecdotal evidence, but since children undergoing the treatments are frequently subject to a variety of other types of support, including diet and medication, it is generally not possible to ascribe improvements accurately to any one of these factors. A similar concern has been raised in relation to the methods of Barbara Arrowsmith-Young and the Arrowsmith schools, the work of which is considered below in chapter 2.7.

2.4 Further Problems: Misuse of Findings and Inconsistencies of Analysis

There are several other cautions to be made and problems to consider before we can begin to examine what neuroscience might offer to learning and teaching. The danger of the allure of neuroscientific images and explanations and the sometimes dubious use of these to promote commercial educational products is a major concern. Weisberg et al. (2008), in a study of participants' responses to a variety of explanations of psychological phenomena, demonstrated that the addition of neuroscience, even when 'irrelevant to the logic of the explanation' (p.470) led both non-experts and students of neuroscience to rate information with neuroscience as more satisfying than without. McCabe's and Castel's experiment with explanations of neuroscience (2008) drew similar conclusions. In asking whether neuro-imaging is a breakthrough or a form of Voodoo – the 'new phrenology' (2010, p.714), Diener poses a further question. Diener's article is a response to the reaction to the work of Vul et al., whose *Puzzlingly High Correlations in fMRI Studies of Emotion, Personality and Social Cognition* (2009) was first published under the title *Voodoo Correlations in Social Neuroscience* (2009). Vul and his colleagues questioned the limited detail of analytical techniques employed in fMRI-based studies and the variation of techniques from study to study. They call on authors to undertake re-analysis of the fRMI data, using a consistent, unbiased method far less in danger of inflated correlations 'yielding reassuring looking scattergrams' (p.274). Lisberger (2013) goes a step further in raising concerns about data fraud, how easily this can be done and how difficult it can be to detect. An additional, significant concern for education is that imaging can show activity, but not intention or purpose, or to paraphrase Stanovich's analogy, originally used in reference to measures of intelligence, imaging may show us 'a critical aspect of the engine of the brain, but not the skill of the driver' (2009, p.51).

It is worth noting here that functional magnetic resonance imaging is just one of several imaging methods. All these methods have both strengths and weaknesses and new technological developments are continually being applied to existing methods as well as bringing about new imaging methods. Geake (2009) and Blakemore and Frith (2005) have described these within the literature of learning and educational neuroscience and also consider the possibility of methods emerging that could be used in classrooms rather than in laboratories. This is on the grounds that location and unfamiliarity with the surroundings, such as a hospital or a university, is likely to influence the resultant imaging, but it is not possible to know exactly how. In addition to fMRI, they discuss electroencephalogram (EEG), magnetoencephalogram (MEG), another magnet-based method diffusion tensor imaging (DTI), positron emission tomography (PET) and transcranial magnetic stimulation (TMS). Less familiar is Koizumi's development of optical topography, a method through which Koizumi ambitiously seeks to understand not just how brains might process the concepts of, for example, biology or mathematics, but also concepts such as love and hate (in Battro et al, 2008, p.166).

Offering superfluous neuroscientific explanations or falling under the allure of neuro-imaging, as suggested in the introduction to this thesis, is not limited to education. The NeuroLeadership (sic) Journal is not, as it might sound, a journal for those leading the way in the world of neuroscience. It is for business leaders. Amongst its articles is Prehn's *Create Reframing Mindsets through Framestorm* (2012). The message within the article is that the best business leaders *reframe* situations in order to expand and then analyse the options open to them. This is supported with an array of references to neuroscience and it would be reasonable to suggest that few readers of this journal would be in a position to question these or to further examine these references and in so doing evaluate their specific relevance. Bruer and Bowers would undoubtedly point out that what Prehn says is clearly already supported in psychology and the neuroscience does not add anything new, other than a tone of dubious scientific authority. The article goes on to promote Prehn's own *Framestorm* system. Correspondence with the author confirms that this is a copyrighted, licensed system, for which intended users and promoters must first undertake training, at cost. It is not possible to know how many such subscribers have chosen to pursue the system due to the power of the neuroscientific scaffolding.

Raising concerns about both accuracy and evidence, Goldacre (2006) reports on claims made by the commercial product Brain-Gym®. Brain-Gym® has won followers within education, though some of them have acquired Brain-Gym® strategies from secondary sources rather than through direct Brain-Gym®-approved training or its literature. Goldacre (2006) sought to expose that this product's claims to a scientific basis were founded on non-peer reviewed articles, published in a journal sponsored by the owners of Brain-Gym® itself. As well as describing it as 'bad science', he also refers to 'pseudoscience', a concern echoed by Burton through the term 'psychopedagogy' (2007, p.5). Burton identifies a series of fads in education, in particular the spurious scientific base for learning styles and visual, auditory and kinaesthetic (VAK) strategies, all of which lack of an evidence base in the form of systematic field-testing for the educational benefits claimed. A further challenge to these claims lies in the work of the Evidence Based Teachers Network (EBTN), a component of evidencebasedteaching.co.uk, which bases much of its perspective on the work of Geoff Petty and John Hattie. The EBTN contends that too much educational practice is based on very limited evidence, much of which it describes as sourced from authority (government, school leadership), anecdote or habit. Evidence from neuroscience, along with other educational research, suggests the EBTN, should firstly be scrutinised at a meta data level, in a similar manner to medical research, before finding its way into day-to-day practice, a view that is revisited below, whilst considering calls for research schools (chapter 2.5).

This is a view that is gathering supporters from the classroom and is the basis for the formation of researchED (sic), an organisation originally supported by the Centre for British Teachers (CfBT). researchED purports to demand and seek the evidence base for initiatives promoted in the classroom. An example of researchED questioning how neuroscience has been used in education and business is discussed below, under ‘Brain in the Media”. Tom Bennett, a co-founder of researchED, is a regular critic in the media of much that he considers to be educational pseudoscience, though his concerns are often conflated by polarised views of liberal versus traditional educational practices.

In another illustration of the misuse of neuroscience, Purdy and Morrison (2009) accuse the rationale of the Northern Ireland Revised Curriculum of falling into the trap of using neuroscientific information, not formally tested in educational contexts and in any case over simplified or reductionist, to gain 'scientific credibility' (p.99). Purdy and Morrison re-iterate Goswami's alarm (2006) at the proliferation of and the rapid production of learning packages claiming to be 'brain-based' that are marketed without rigorous trials.

2.5 Evidence and Collaboration

The lack of a reliable evidence base for educational practice is also raised by Fischer et al. (2010). Like the EBTN, they draw attention to the lack of engagement with research in education, when compared to the importance placed on research in medicine and other fields, from meteorology to business. They call for more emphasis on research schools, building on Dewey's vision of laboratory schools but they also recognise the differing assumptions about research evident in medicine and education. Writing with Hinton (2008), Fischer advised that 'dynamic' and 'reciprocal interaction' (p.158) between learning research and practice is required for what is referred to in this article as mind, brain and education. This is now embodied in the title of the International Mind, Brain and Education Society (IMBES). Amongst the benefits of research schools, Hinton and Fischer believe, is the opportunity for educators to influence the direction of research. Though not drawn from a research school context, Geake (2009) and Goswami (2008) have demonstrated that many teachers have extensive ideas about areas of focus for neuroeducational research. Geake categorised 57 examples of such suggestions under the headings *cognition of learning, environment of learning, curriculum and school organisation*.

Though collaboration based in research schools is clearly desirable, the concept brings its own problems and challenges. Kuriloff et al. (2009) examine the experiences of school and university collaborations in neuroeducational research. Difficulties have included disagreement over research areas and priorities, time constraints, gender stereotyping (where analysis through other groupings might be more insightful), resistance where findings contradict teachers' perceptions or strongly challenge the status quo and anxieties about data that participating schools sometimes perceive as potentially damaging. In examining Mind, Brain and Education as the birth of a new field, Schwartz and Gerlach (2011) add complex ethical questions raised by the use of new technology or the possibility of 'experimental interventions providing 'preferential' treatment to some students over others' (p. 71). Both Kuriloff and colleagues and Schwartz and Gerlach offer possible solutions. Kuriloff et al. propose the democratic training model *Participatory Action Research* (PAR), which includes key features of their description of a shared vision built on trusting relationships and agreed standards for rigorous research that promotes the use of appropriate tools of assessment. Schwartz and Gerlach identify vision, relationship, research and assessment as four objectives that are fundamental to the future success of the Research Schools Network. Katzir and Paré-Blagoev (2006) declare that productive collaboration needs to meet two essential conditions: collaborations should be 'guided by the goal of fostering interprofessional interactions that enhance the practice of *each* discipline' (my italics) and they should also 'be based on mutual understanding and respect for the actual and potential contributions of the disciplines' (p.7). Anderson and Della Sala (2011) caution that 'the 'interaction' of neuroscientists and teachers (is) ‘nearly always constituted by the former patronising the latter’ (p.3).

There are examples of research networks in the UK in line with the model of a university in collaboration with one or several schools, as described by Hinton and Fischer (2008) in the case of the Harvard Graduate School of Education and the Ross Independent School, or the example of the University of Pennsylvania’s partnership with nine schools, as described by Kuriloff et al. (2009). A notable example in the UK is the collaborative work between the Centre for Educational Neuroscience (in itself a collaboration of The Institute of Education (now a constituent part of University College, London), Birkbeck College and the research hub at Swiss Cottage School. It is perhaps significant that Swiss Cottage School is a well-established and highly regarded *special* school, though some of the research work in which it is involved finds some dissemination amongst its mainstream partner schools. A number of other universities possess neuroscience teams who work with schools. The work of Paul Howard-Jones and colleagues at the University of Bristol has included research in schools on the significance of the biochemical dopamine and the reward circuitry of the brain for learning activities capitalising on the popularity of what he calls ‘immersive’ gaming (Howard-Jones and Fenton, 2010). However, there is considerable caution about application of neuroscientific findings amongst the UK’s neuroscientific community and a preference for considering implications for the future (Goswami, 2008, Stewart and Williamon, 2008, TLRP, n.d.). More recently, a number of educational neuroscience projects that involve university/school setting collaborations have been funded jointly by The Wellcome Trust and The Education Endowment Foundation (EEF). This funding was announced in October 2014, for the following projects:

Fit to Study: an investigation of correlations between cardiovascular activity and academic achievement, explored through the use of brain imaging and led by Professor Heidi Johansen-Berg of the University of Oxford.

Spaced Learning: described as a 'trial on the effectiveness of repetition and spaced learning, a method of teaching that delivers a unit of work multiple times interspersed with alternative activities'. This is a collaboration between the Hallam Teaching Alliance and Stocksbridge High School.

Learning Counterintuitive Concepts: under the leadership of Professor Denis Mareschal, this study explores the impact of training students to suspend their existing scientific and mathematical beliefs.

GraphoGame Rime: well-known neuroscientist Professor Usha Goswami is leading this exploration of the use of the GraphoGame Rime computer game to deploy 'rhyme analogy' for the development of phonological awareness in learning to read.

Engaging the Brain's Reward System: Professor Paul Howard-Jones is a noted expert in this field and leads this investigation of the impact of chance rewards as a means of engaging learners.

Teen Sleep: Taking as its starting point research into the efficacy of later school start times for teenagers, Professors Colin Espie and Russell Foster of the University of Oxford will investigate the impact of sleep education and later start times. Non-invasive bio-telemetric devices will be employed to gather physiological data.

Via the Wellcome Trust, at the time of the announcement of the funding (9.10.14), schools were invited to apply to participate in the projects. The projects themselves all have a basis in existing, ongoing research and in that sense break no new ground, but they do represent a step towards collaboration, along with significant funding to enable this to happen. Returning to Fischer et al.'s concern (op.cit) that schools do not engage with research, there is now a number of UK schools that have appointed a member of staff with responsibility for the examination and distribution of research and there is a growing call in UK schools for clear, accessible evidence for promoted developments in pedagogy. This may not yet be as participatory as Fischer and his colleagues would wish to see but is at least a step in the right direction. In October 2016 The Research Schools Network, a project in England funded by the Education Endowment Foundation (EEF) and the Institute for Effective Education (IEE), announced the first six successful applicants for research school status. In April 2017 another five schools gained this status. The Research Schools Network website claims that the schools 'will break down barriers between teachers and academics'. Sir Kevan Collins of the EEF states that this is 'so that research doesn't stay in the pages of academic journals'. In both cases, the choice of words clearly raises concerns about the application of some educational research. In a more placatory tone, Professor Bette Chambers of the IEE refers to 'the commitment and enthusiasm of the first five research schools to using research evidence to enhance teaching and learning' (http.wwwresearchschool.org.uk). At this stage, it is not clear to what extent neuroscience may figure in the efforts of the research schools. It is also notable that the focus of the project appears to be the use of evidence from research rather than primary involvement in the research itself.

The research work of the independent Queen Anne's School in Reading, England, is notable for a number of reasons, particularly in that it has taken initiative in inviting researchers at two universities to collaborate with the school to pursue a brain-related research agenda set by the school, under the banner of its *BrainCanDo* project. As well as journal articles reporting on the findings of these projects the school has produced the *BrainCanDo Teacher Handbook* (2018) a guide to the use of information about the brain for pedagogical purposes. This is a readable 42-page guide, containing enough neuroscientific information to be informative and to substantiate the book's suggestions, without straying into what some teachers would consider scientific overload. I use the word 'suggestions' purposefully, since this is the approach the book takes; there are no prescriptive strategies but instead invitations to 'give it a go' that leave the finer details to the teacher and are relevant across the curriculum. Staff at the school are encouraged to share their evaluations of these trials and some have written about them for publication (Beale, 2018; Little, 2018; McNeil, 2018; Müllensiefen et al., 2018). The school has also used educational neuroscience as a perspective through which to evaluate what it perceives as longstanding good practice amongst its staff.

2.6 Neuromyths and Critical Consumerism

Whatever may eventually be brought about by collaborations, one immediate need is for the debunking of what is now a well-catalogued collection of neuromyths (Fischer et al 2010, Goswami 2008, Howard-Jones 2009). These are examined in detail in chapter 2.6.1 and they can be seen in subsequent sections of this thesis; data are included that explore the extent to which teachers participating in my research subscribe to a number of the most prevalent myths. Perhaps of equal significance for this study are the factors that create a climate in which educators can come to keep faith with these myths. Dekker et al. (2012) found that teachers in their study of 242 primary and secondary teachers in the UK and the Netherlands accepted 49% of the neuromyths, with myths used to support commercial products for education given highest credence. Düvel et al. (2017) raise similar concerns in their research with 91 music teachers from German state schools and 125 of their students, who were asked to rate neuroscientific statements relating to the neuroscience of music and the neuroscience of musical learning. Both groups declared 40% of the presented myths to be scientifically accurate. Dekker et al. also found that where teachers scored higher on general knowledge of the brain, they were much less inclined to believe the neuromyths. This provides some support for Sylvan’s and Christodoulou’s view that educators need to become ‘critical consumers’ when considering products that claim to have a neuroscientific basis (2010 p.1). Sylvan and Christodoulou propose a series of questions, a framework and some sources of further guidance that may assist educators in assessing products. A notable caveat is that studies that have produced null findings for so-called brain-based products may not always be put forward for publication in peer-reviewed locations or for publication at all or be rejected as they may perceived as having nothing to contribute. Outside the scope of Sylvan and Christodoulou's work is the question of how guidance and training in their proposed critical consumerism might be brought about. As well as offering some such guidance, my investigation uncovers to what extent training in the use of findings from neuroscience features in the development plans of both individual teachers and their schools.

2.6.1 Neuromyths Further examined

Here I examine some of the persistent myths about the brain, now often referred to as 'neuromyths', since these contribute to confusion about the brain both for teachers and the general public. They are explored in my data, via the 21 statements contained in survey question 7 and as they arise in the course of the eight interviews.

Howard-Jones (2010) describes how neurosurgeon Alan Crockard used the term 'neuromyth' as far back as the 1980s. The term appears to have made its first 'official' appearance in the 2002 OECD report *Understanding the Brain: Towards a New Learning Science*. However, holding faith with misguided ideas about the brain is not simply a twentieth or twenty first century matter. Nineteenth century practitioners of *phrenology* claimed that their 'science' enabled them to assess aspects of personality and mental capacity, details that they accessed via the contours of the skull, which in turn, they believed, informed them about an individual's brain. Dating much further back, around 7000 years, *trepanation* involved the drilling of holes in the skull, in the mistaken belief that this improved brain function and would release undesirable traits or spirits. Jarrett (2015) reports on the alarming existence of a group called the International Trepanation Advocacy Group and he refers to the concerns expressed in the *British Medical Journal* in 2000 at the promotion of self-trepanation.

Some of the more recently prevalent myths began life with a basis in research, but as discussed in Chapter 1 and so often the case, researchers' tentative findings were sensationalised, reported inaccurately and when the same researchers or others revised these findings this was not reported in the public domain. A good example, discussed below, is the so-called 'Mozart Effect'. Statements relating to neuromyths that are used in my survey are also considered in chapters 2.6.2 to 2.6.4, under the headings true, false and debatable, according to how they are currently viewed in neuroscience literature.

2.6.2 Neuromyths: True

The brain can generate new neurons right into old age

Without information or evidence that suggests otherwise, it is sometimes assumed that the brain inevitably deteriorates in all its functions as we age. Things change, certainly and invasive conditions such as Alzheimer's disease cause ongoing and at present irreparable damage. But it is not the case that the brain ceases to be able to generate new neurons (*neurogenesis*) or create new synaptic connections. Riddle and Lichtenwalner (2007) report that even when the neuroscience community was first presented with evidence of these occurrences, as far back as the 1960s, many persisted with the belief that 'the nerve paths are something fixed and immutable: everything may die, nothing may be regenerated' (Ramon y Cajal, in Riddle and Lichtenwalner, 2007). So it is perhaps not surprising that this view persists amongst teachers.

New neurons are generated in at least three areas of the brain. Most notable amongst these is the hippocampus, which plays a significant role in memory, amongst other things. Though this is to do with the ageing of the brain, it is of consequence for teachers, since they have a major role in the promotion of lifelong learning, which implies that they would wish their pupils to have high expectations of their brains for many years to come.

Recent research suggests that new neurons can be generated in the amygdala, a brain area to which we return below. An incapacity for neurogenesis in the amygdala is amongst several hypotheses relating to autism. Again, caution is required: a recent headline, 'Adult Brains Produce New Cells in Previously Undiscovered Area' (neurosciencenews.com, 15.8.17) refers to research on the brains of adult mice.

Physical exercise can support the efficiency of the brain

Exercise has been shown for many years to be of benefit to our physical bodies, both in a day-to-day sense and in terms of how we function physically in our later years. More recently, much has been made of the positive effects that exercise has on the brain. Ratey and Hagerman (2010) explain that in the past physical activity and brain activity were linked by the need to think smartly in order to survive and in the process be able to learn effective strategies whilst rejecting inferior ones. Ratey and Hagerman point out that our more sedentary lives can disrupt the essential connection between physical activity and brain activity. They also explore extensive evidence of the effects of overcoming this through exercise and refer to the role of exercise in wellbeing, something that Ratey has long promoted in psychiatric practice. Teachers will be interested to note that he has also been an advocate of exercise as an aid to the management of attention deficit hyperactivity disorder (ADHD). This raises a question, of how such an approach can be employed in a classroom populated by pupils both with and without ADHD, though it is often the case that strategies used to support particular educational needs are of benefit to pupils in general. Perhaps the question here is actually one of practicalities and time: how can more regular bouts of exercise be managed and built into a crowded curriculum? In his book *Brain Rules* (2008), neurobiologist John Medina ranks ‘exercise boosts brain power’ as number one of his 12 proposed rules.

Functioning of the brain is affected by emotional experiences

There are few teachers who have not had the experience of a young person in a state of anxiety or rage that made it impossible to reason with them at that point. However, emotional difficulties that can limit learning are not always accompanied by such easily identifiable signs. Schools are starting to recognise this in the growing concern about mental wellbeing.

There are also specific situations when emotional turmoil can reduce the capacities of our pupils. High stakes examinations are an example of a common panic-inducing situation in schools. Zull (2011) describes the role played by various part of the brain in the rapid emergence of such panic. Some of the information being received by the thalamus goes directly to the amygdala, without any monitoring and consideration by the cortex. Zull calls this the ‘lower pathway’ (2011, p. 59), as it generates reflex responses that we might recognise in our pupils as panic, or freezing, or refusal, or even despair. This is the evolutionary response popularly known as ‘fight or flight’, but the lack of anything to fight or run away from leaves our pupils still consumed by the chemicals set in motion by the amygdala and unable to engage with the ‘upper pathway’, whereby incoming information is screened by the cortex before progressing to the amygdala and further, more constructive action. Understanding panic and how it might affect examination performance is surely a useful first step in training pupils to cope with stressful situations such as examinations, and this includes exam- oriented, well-prepared students.

The learning capacity of the brain is affected by sleep

The significance of sleep has received a lot of attention in schools. I think it is fair to say that for a long time schools have promoted sleep as an important part of development. Given the impact of technology on sleep routines and sleep quality, this appears to be a message that schools will need to continue to support. Research such as *Teen Sleep* in the UK (described in chapter 2.5) initially proposed to examine the potential impact of changes to school start and finish times to accommodate what appears to be a slightly different sleeping cycle required by teenagers. In reality this proved impractical and instead the research changed perspective, opting to evaluate the impact of information about sleep delivered in Personal, Social and Health Education (PSHE) lessons. Some schools outside of the project have attempted to make start time adjustments of their own. These have also generally hit upon insurmountable practical issues.

I suggest that in support of their efforts to promote good sleep habits, schools now have a significant body of research on the effects of poor and good sleep, including its specific effects on the brain. The fact that sleep is actually a very busy time for the brain and that a considerable amount of this busy-ness relates to learning might be a good place to begin.

Stickgold and Walker (2007) explain that although the consolidation of memory is a long, complex process that happens over many stages, or as they describe it, ‘a continuing series of biological adjustments that enhance both the efficiency and utility of stored memories over time’ (p. 331), they have no doubt that the various stages of the sleep cycle each play an essential role. They argue that each of these stages is essential in the post-learning, rehearsing and initial encoding phases, i.e. after your lessons. They maintain that this is true of all memory types listed in typical taxonomies of memory (explicit, implicit, declarative, procedural, episodic, semantic).

Other processes of great importance to brain health occur during sleep. Like the body, the brain accumulates waste by-products from its daytime activity. As the brain appeared to have no equivalent to the body’s lymphatic system, the prevailing theory was that the brain recycled its waste and that the key player in this process is cerebrospinal fluid. Recent research (such as Nedergaard and Plog, 2018) has demonstrated that in fact in various mammalian brains there exists what has been called the *glymphatic system*, a term coined from the protective role of glial cells as an equivalent to the lymphatic system. This system largely does its work during sleep. There are several types of glial cells that perform a number of functions and there are more glial cells in the brain than there are neurons. Nedergaard and Plog's work is revealing the extent to which glial cells play a major role in the night time clean-up of our brains. Mo Costandi has suggested that glial cells 'may yet emerge as the real stars of the show" (2013, p. 12).

Mental rehearsal of an action can activate the same brain areas as the action itself

This phenomenon has been utilised most notably in the worlds of sport, music and also for medical purposes where it is, for example, considered a worthwhile adjunct to physiotherapy. Frank et al. (2014) describe how mental practice appears to result in two out- comes. Firstly, 'mental practice to some extent involves the same underlying processes and covert structures as physical practice' (p. 20). Secondly, Frank and his colleagues believe that memory of the physical actions required is reinforced by the mental process. They also note that the mental practice alone can bring about changes within the brain, though they caution that the significance of these is not clear. They make the point persistently that mental practice alone does not suffice but are convinced of its benefits alongside physical practice.

If mental processes can influence physical ones, then the question arises as to whether this happens in reverse. Do our physical selves influence how we think? Explorations in this field come under the banner of *embodied cognition*. Lakoff, (2015) a major figure in this field, has led the way in revealing how much our thoughts, as represented by language, are bound up in physical metaphors. For example, we might describe our mood as up or down, reflecting how we might physically present ourselves as upright when feeling positive and in a more downcast shape when feeling low or 'down'.

Wilson and Golanka (2013) have produced extensive research on embodied cognition and point out that it quickly came to mean several things, starting with the simple idea that 'states of the body modify states of the mind' (2013, p. 1). Wilson and Golanka explain that it is a much more complex and challenging concept:

> Embodiment is the surprisingly radical hypothesis that the brain is not the sole cognitive resource we have available to us to solve problems. Our bodies and their perceptually guided motions through the world do much of the work required to achieve our goals, replacing the need for complex internal mental representations. (2013, p. 1)

This is a demanding concept to frame in terms of educational processes. Ionescu and Vasc (2014) propose that the major implication of embodied cognition for education is a re-think of the Piagetian notion of concrete and abstract. Traditionally, we employ approaches with young children that are dominated by concrete experience and we move on to more abstract thought with older children and adults. Ionescu and Vasc suggest that embodied cognition implies that concrete experience is also needed to develop a deep grasp of abstract concepts and high-order thinking:

It is possible that the abstract ways of teaching (i.e. knowledge not grounded in direct experience) offer fewer chances for learners at any age to thoroughly comprehend concepts, to transfer the learned content, and to maintain this content longer in their memory. (2014, p. 278)

Specialist training can cause identifiable differences in areas of the brain

No two brains are identical. From the outset brains encounter unique environments and individuals' unique experiences and genetic profiles, all of which influence the brain's composition and development. Even in the womb, experiences differ. Our brains constantly reorganise themselves in the light of experience, and neuroscience has recognised that in this sense our brains are 'plastic'. This has been termed 'neuroplasticity' and in educational circles the term has come to be used frequently. We have previously considered this in Chapters 2 and 3.

Imaging technology has made it possible to identify with considerable precision just where training and practice have made identifiable changes to the brains of individuals. Costandi (2013) comments on some entertaining examples, including perhaps one of the most famous, the hippocampi of London taxi drivers.

The cab drivers have to learn, over a number of years, a myriad of route information and street names and construct mental maps that join all this information together to make it useable in their work. The process of creating this specific 'knowledge' as it has long been known has a demonstrable impact on the density of the grey matter in the brains of the taxi drivers. In another example, Costandi remarks on increased grey matter density of the visual cortex that is brought about by a period of three months during which a great deal of time is dedicated to learning to juggle. Costandi's third example is of karate experts, who have been shown to have increased density of the white matter tracts between the cerebellum and the motor cortex. This, Costandi explains, is what 'enables them to pack a more powerful punch' (p. 134).

Examples from other fields abound, such as music. Changes brought about by the repeated physical actions of playing a musical instrument can be tracked to changes in the motor cortex. In the case of experienced players of string instruments, for example, these changes can be tracked to individual fingers. One can reasonably expect that similar matches would be found with many other activities if the necessary neuroimaging was undertaken.

The key point for teachers and their pupils here is that there is a wealth of evidence that the brain changes and develops and can never be described as in its final stage of change or development. Therefore, we can never be certain of precisely what an individual might achieve. It does not follow, sadly, that this means *anyone* can achieve *anything*, but it certainly brings into question a considerable amount of predicting educational outcomes, using attainment to date as a privileged indicator of attainment in the future.

There are structural and biochemical differences between male and female brains

In an era when perceptions and definitions of gender are the subject of debate in educational circles and elsewhere, it seems logical to examine what current knowledge of the brain might contribute to this debate. At the time of writing, the media attention given to the case of Sally and Nigel Rowe, who removed their six-year-old son from school because another boy had attended school wearing a skirt, has brought gender into further focus (bbc.co.uk/news/uk-england- hampshire-41224146, accessed 12.9.17).

Historically, explorations of the brain from a gender perspective have concentrated on brain volume and frequently studies have not had access to enough brains to draw robust conclusions. Stuart Ritchie, at Edinburgh University, has been able to overcome this with assistance from UK Biobank. Ritchie and his team worked with 2750 women and 2466 men, aged between 44 and 77 (Ritchie et al., 2017). They found the cerebral cortex of women to be thicker than those of the men, whilst the men displayed greater volume in other brain areas. However, when overall brain size was factored into this comparison, the researchers found that the raw data were misleading, as with this factor considered there were 10 areas where the women displayed larger relative volume compared to 14 where the men did. Below, I briefly consider whether information like this is of any significance to educators and their pupils. Before doing so, I add one more example to our discussion. In 2015, *New Scientist* ran the following headline:

Scans Prove There's no Such Thing as a 'Male' or 'Female' Brain.

The article bearing this headline (Hamzelou, 2015), reports on the research of Daphna Joel at Tel Aviv University. Joel did not have access to quite as many scanned brains as Ritchie, though 1400 is still one of the larger samples for research of this nature. Joel's sample did have a much wider age range (13–

85) however. Looking at 29 brain regions that are regarded as having size differences between those classing themselves as male or female, Joel and her team found that very few of the sample could be classed as having an entirely male or female brain, if these areas of size differences are used as a definition. As Hamzelou described the findings:

> this means that, averaged across many people, sex differences in brain structure do exist, but an individual brain is likely to be just that: individual, with a mix of features. ‘There are not two types of brain’, says Joel.

Joel is not alone in disputing the idea that gender is not binary and Hamzelou draws attention to a number of other researchers whose work in this field is highly significant.

Many of these researchers now argue that our perceptions of gender are much more based on stereotypes, environment and culture and the arguments around this are challenging for teachers. Academic performance in science and mathematics, for example, which is often deemed to be better amongst boys than girls, at least in the UK, seems to be much more a consequence of conformity to cultural stereotypes than anything to do with a gender-based ‘preference’ or aptitude within the brain.

There is an argument that gender information is often demanded where it is not a necessity or is a complete irrelevance. The tensions emerging around the Rowe family and similar issues in other parts of the UK, certainly imply that schools will need to further consider the gender dimensions of their operational and strategic policies. Whether schools can or should aim in the future to function free of binary perceptions of gender is set to be a major area of debate and another area in which educators will encounter neuroscientific research.

The brain responds in a similar way to things that we find pleasant

This phenomenon appears to be a source of fascination for news media such as the *Daily Mail*. Since 2016 its reports on activities and substances that cause the same response in the brain as cocaine has included music, fast food, energy drinks (when mixed with alcohol) and Facebook. *Mail Online* (23.6.17) reproduced an article written by Andrew Brown for *The Conversation* with the title edited to state that 'eating only low-carb foods can have similar effect on the brain as ECSTACY'. As one might expect, there is research behind each of these reports that presents its findings in a rather more understated way.

Even though our subjective experiences of differing forms of pleasure seem distinctive and different to us, different sources of pleasure draw a similar response from neurotransmitters such as dopamine and serotonin, which then become active in regular circuits. Activity is notably visible in an area at the front of the brain, the orbitofrontal cortex, along with other areas in the circuit, such as the nucleus accumbens and the ventral tegmentum. This activity can be seen for different pleasure stimuli. This is a simple explanation of the *Daily Mail*'s concern that so many things, even essential things, appear to make our brains respond as if we were using cocaine.

However, the phases of pleasure and the actions of the pleasure circuitry really need to be considered as separate entities and several neuroscientists have described this as a sequence of wanting, liking and learning. This is actually essential to our survival, for example in the case of food. It is essential that we have a desire or a want for food, that we find a healthy variety of foods that we like and that we learn where to find these foods and to recognise when we have eaten enough of them. There is also a psychiatric dimension to pleasure and the inability to experience pleasure or perceive anything as pleasurable is a marker of many psychiatric conditions.

What is missing from the alarmist accounts of this process is how some substances, most notably chemical substances that are abused, misalign the phases of the pleasure response. Regular drug use tends to unbalance the process of wanting and liking, resulting in the disappearance of the liking in favour of simply satisfying the wanting.

Things become increasingly complicated, when we factor in research that suggests that there are ‘hotspots’ in areas of the brain, including those mentioned above, that can increase or decrease the sensations of wanting and liking, which would seem to account for individual differences in response. Aspects of environment are also another influential factor, as any parent or teacher who has attempted to support a young person trying to resist peer pressure will know.

The role of dopamine is undergoing reconsideration, since it appears not in fact to promote pleasure but instead plays a role in wanting and in the anticipation of reward.

Kringelbach has led extensive research in this field. He can be seen explaining this in an entertaining and inspiring presentation in 2015, captured on YouTube under the title *The joyful mind: the neuroscience of pleasure and happiness with Morten Kringelbach.* This and associated research has the potential to greatly inform work with addiction and depression and even, as some suggest, an emerging science of happiness.

For a period from birth, we have the capacity to learn any language

Influential linguist Stephen Krashen has been pointing out since the 1970s that our first language is *acquired* rather than learned (for example, Krashen 1977). Zull (2011) refers to the role of *statistical learning* in this acquisition, pointing out that of the many sounds that a baby hears, the repeatedly heard words spoken by its parents begin to emerge from the seeming randomness of all the other sounds. The sounds of these words then begin to have meaning and begin to assemble into patterns. Krashen has been influential in the development of second language learning and much of his pedagogy is based on the concept of language acquisition.

Krashen is not alone in pursuing our capacity to acquire whatever language(s) we are regularly exposed to in our early months and years as a basis for how we might learn other languages. Mackey (2014) describes Morgan-Short's research, which seeks to demonstrate that immersive learning of a second language is more effective than learning by being introduced to the rules of the target language . Mackey explains how electro- physiology was used to examine brain processes during these two approaches to learning. In this research, an artificial language was learned. The participants learning through immersion showed similar brain activity to that found when using their first language. Moreover, Mackey reports that despite there being no subsequent opportunities to practise this artificial language, six months later the immersive learners had retained much more than the group who had learned the language in a grammar-based manner. In the context of schools and their curricula and timetables, it is difficult to recreate the immersive language environment of this research, or of a baby's early months. Other language researchers working with medical imaging have suggested that language learning has benefits for our brains beyond the learning of additional languages.

2.6.3 Neuromyths: False

Information is processed in the same way by everyone's brain

Individual brains differ in all kinds of ways and there can be little doubt that no two brains are the same or undertake any function in precisely the same way. Recently, the research group Brain Somatic Mosaicism Network (BSMN) has demonstrated that not even two neurons within the same brain are alike and the group is now researching the possible implications of this finding of single cell genetic diversity for fields such as psychiatry (McConnell et al., 2017).

There is a huge volume of research and writing confirming that no two brains are identical and that since brain development is experience-dependent the differences between all our brains, at a physiological level, are likely to continually increase. However, this is not to imply that educators must therefore attempt to cater for a myriad of brain differences of which they cannot possibly have manageable information. This has been a source of considerable related debate in the UK, in the guises of individual learning styles and personalised learning.

It does seem sensible for teachers to recognise that individuals receive information and instructions in different ways and will respond in slightly different ways to the learning activities they are then expected to undertake. It is another matter entirely for teachers to attempt to pre-empt these differing responses. Rather, it would seem prudent to be ever conscious of the fact that these differences can be one of the sources of confusion and error and that a variety of approaches is significant in the accessing of new learning. Perhaps this is as far as we can realistically take the growing knowledge of individual brain difference, as far as the classroom is concerned, with the exception of clearly diagnosed instances of additional learning needs. Cognitive scientist Daniel Willingham's comment that 'children are more alike than different in terms of how they think and learn' (2009, p. 147) should be used to balance the debate rather than close it.

Each side of the brain is exclusively responsible for different types of mental activity

Even with a very brief online search, it is easy to find representations of 'the dichotomous brain', depicting the alleged key functions of the misnamed right brain and left brain. Images abound, often depicting the right hemisphere of the brain as creative and impulsive, and the left hemisphere as logical and rational. Fanciful depictions often rep- resent the left as, for example, a filing cabinet and the right as a drawing of flowers. Online tests featured on social media that claim to assess whether your brain is left or right dominated continue to attract participants. I suspect some participants do tests like this sim- ply for entertainment and are sceptical about the results, but such tests help to keep the dichotomous brain idea alive, as do some websites that seek to simplify the brain.

There are dangers for teachers in subscribing to this outdated conception of the brain, particularly in its use to generate stereotypes that potentially inhibit a teacher's perception of an individual student's potential and abilities. The reality is far more complex than the simple right brain–left brain model. Space does not permit a full exploration of the locations and networks of specific brain functions and the continual updating of theories about these. We can, however, briefly consider how neuroscientific thinking has shifted, away from the notion of separate functions located right or left to a more integrated model of how our brains function.

The brain does indeed have two hemispheres, but what is less commonly pointed out by the popular dichotomous brain games and articles is that the two hemispheres are joined together by the corpus callosum. The corpus callosum contains millions of connections between each hemisphere. Neuroscience is now more concerned with how this area and some other connections allow the hemispheres to work together. How the brain functions through networks has replaced the previous pursuance of the idea that the brain is a collection of specialised areas, functioning independently. As far back as 2003, Stephan et al. demonstrated that the two hemispheres vary in engagement, dependent on the task. This is significantly different to ascribing logic or creativity exclusively to one hemisphere.

Scientific evidence shows that listening to the music of Mozart can improve long-term brain function

When Rauscher, Shaw and Ky (1993) tentatively suggested that their research with a specific composition of Mozart's (his Concerto for Two Pianos, in D major) appeared to show that the music could temporarily positively affect individuals' ability on a set of spatial reasoning tasks, they could not have predicted how widely and wildly their initial findings would be reported.

British radio station Classic FM released a CD entitled *Mozart for Babies*, capturing the alleged newfound discovery that, as Philip Sheppard's book title puts it, *Music Makes Your Child Smarter* (2005). Therapist Don Campbell took out a registered trademark for the term *The Mozart Effect*. I should state here that I am a huge supporter of the value of music and its immense significance to us as a species. However, when we examine the work of Francie Rauscher and her colleagues, we find a slightly different account.

The effect that the three researchers uncovered initially appeared to show an increase in a very specific ability: spatial reasoning. What was rather less reported was that the effect was very short- lived, in some cases merely a matter of seconds. The participants were all college students in America, so there was no evidence here of effects on the brains of babies or the school-aged population. Furthermore, in subsequent research that attracted rather less media attention, Rauscher and Shaw (1998) pointed out that the 'effect' was not evident with all participants, others appeared to be affected by different music such as J. S. Bach or pop music and in yet other cases the music made no difference. Again we are left with the conclusion that tentative, exploratory research findings were sensationalised out of proportion.

Remembering a phone number to use once and remembering a past experience use the same type of memory

There has been increased interest in recent years amongst educators in the processes of memory formation. At the same time, neuroscience research has drawn into question some of our previously established understanding of memory formation.

Many teachers have been aware of students who do not cope well with multiple or complex instructions and we have a better understanding now of the role of working or short-term memory in this problem. Working memory is often referred to as the brain's notepad or post-it note. Willingham (2009) advises that if you ever pick up a bottle out of which a genie appears and offers to grant your wishes, ask for increased working memory. Educators are also realising that poor working memory sometimes plays a role in a number of difficulties, including poor behaviour caused by frustration, and also that poor working memory does not necessarily indicate poor levels of other learning traits, even though it undoubtedly poses an additional challenge for both teacher and student.

Working memory is a revised explanation of the over-simplified dual process model of memory. In the latter, information to which any of our senses pay attention would move to our short-term memory and if we then continued to work with this information, it may subsequently find its way into our long-term memory. Current thinking is more complex. Working memory is now described as a three-component model, wherein a control centre (within an area of the prefrontal cortex) manages two other areas. The first of these is the phonological loop, located within the parietal and temporal lobes and concerned with language, whilst the other is the visuo- spatial sketchpad, which concerns itself with visual information and locations and functions through the occipital, parietal and frontal lobes of the brain's right hemisphere.

Long-term memory is much more distributed than previously thought. Much emphasis has been placed on the role of the hippocampus in memory storage, but more recent evidence reveals that a number of areas of the brain are involved in memory encoding, storage and retrieval.

Current explanations of memory, then, have moved some distance away from the analogy of the brain as a computer, with a fixed area for memory storage. Instead, we can see that memory, including different aspects of the same piece of information, is distributed around the brain and retrieval involves a network of areas working together. Medina (2008) suggests that evidence from stroke victims who have suffered damage to an area of the brain, resulting in them recognising consonants but not vowels, is a good illustration of how information is broken up and stored in different places. He offers an example of one stroke sufferer's attempt to write a sentence. She writes, but leaves the vowels out of each word.

Medina makes two other points about memory that are worthy of consideration for educators. He suggests that 'the more elaborately we encode information at the moment of learning, the stronger the memory' (2008, p. 110). This seems logical, since this offers many more 'hooks' for retrieval. Secondly, Medina suggests that 'retrieval may be best improved by replicating the conditions surrounding the initial coding' (p. 113). This is not always possible for our students, but it does perhaps shed light on why some students understand a mathematical calculation in a maths classroom but not a science classroom, or fail to recall information in an examination hall that they appeared to be sure of in a classroom.

Memory is not, as Medina acknowledges, simply dependent on a ‘moment of learning’. He describes the experiments of Ebbinghaus (1885), which are the foundation of the ‘spaced learning’ or ‘spaced practice’ methods favoured by many schools, that recognise the need to reinforce memory over a period of time. Many schools have considered the ‘forgetting curve’ proposed by Ebbinghaus, which portrays the relationship between retention, retrieval and spaced practice.

Some schools have also explored computer programs that claim to increase working memory capacity. This field has been investigated at length by Tracy Packiam Alloway, formerly at the University of Strathclyde and now the University of North Florida. She suggests that working memory is a better predictor of learning potential than previous test scores and estimates that the working memory of one in ten children is poor (tracyalloway.com). Her work has done much to draw attention to the significance of working memory. Alloway is the creator of the working memory training program, *Jungle Memory*. A similar program is marketed by Pearson, under the name *Cogmed*. Each of these programs does bring about improvements in working memory in the context of the activities of the program, or when undertaking similar computer tasks – what is referred to as *near transfer*. What is less well evidenced is whether the training can have an effect on unrelated tasks – far transfer – and positively influence educational participation and outcomes. In their meta-analysis of working memory training studies, Melby- Lervåg and Hulme (2013) reach a strong conclusion:

> The absence of transfer to tasks that are unlike the training tasks shows that there is no evidence these programmes are suitable as methods of treatment for children with develop- mental cognitive disorders or as ways of effecting general improvements in adults' or children's cognitive skills or scholastic attainments. (p. 283)

Concentrating on one difficult task is more effective than multi-tasking

Like right and left brain or the 10% of the brain myths, the skill of multi-tasking and the greater capacity for this ascribed to women has become commonplace language in the UK.

Challenging tasks require our complete attention, otherwise we make mistakes, miss things out, lose the thread and so forth. Earlier in this century there seemed to be considerable credence given to the new-found skill of multi-tasking, particularly in certain types of employment, where one might expect to type a report, check emails and plan a schedule seemingly simultaneously, even adding regular check-ins on social media to the task list. But what actually happens is that attention is frequently switched from one task to another, often with negative effects on the completion of each task and a drain on time and energy created by the need to refocus at each task switch. The business world started to grasp this, with business journals and magazines reporting on not just the inefficiency of multi-tasking, but also on research that suggested it was not good for brain health and yet more research that multi-tasking can impair cognitive function. In 'Multi-tasking Damages Your Brain and Career, New Studies Suggest' (8.10.14), Forbes.com referred to three studies discussed below.

Loh and Kanai's investigation (2014) pointed out correlation (but not necessarily causation) between decreased grey matter in the anterior cingulate cortex, a brain area involved in cognitive and emotional control, amongst 75 people who multi-task with several media devices. A Stanford University study raised concerns as far back as 2009 (Ophir et al., 2009). This study found that the regular multi-taskers were actually worse at switching from one task to another, a problem that the researchers suggested was due to their inability to block out irrelevant information. Also referred to by Forbes was an even older often-cited in-house study conducted for Hewlett Packard by Glenn Wilson of the University of London's Institute of Psychiatry. The study showed individuals performing IQ tests at 15 points lower because they did the tests whilst multi-tasking. Wilson has been somewhat frustrated by the misreporting of this study, from which no published report emerged. His comments on the study can be seen on his website (www.drglennwilson.com/info- mania_experiment_for_HP.doc). He has not returned to this field of investigation since 2005.

Research continues to investigate multi-tasking and interruptions, as well as the ongoing research exploring the neural differences in the brains of a very small number of people who appear able to multi- task without any deterioration of the quality of any of the tasks undertaken. Daniel Goleman, well known to many teachers for his work on emotional intelligence, has written more recently about the challenges faced by our pupils in coping with multiple stimuli. His book's title, *Focus* (2013), identifies the capacity that Goleman describes as the essential key to success in the information age.

Multiple Intelligences (MI) can be shown via brain scans

Howard Gardner's Theory of Multiple Intelligences (MI) is familiar to many teachers, or at least the categories that it proposes: spatial, linguistic, logical-mathematical, bodily-kinaesthetic, musical, inter- personal, intra-personal and naturalistic. The last of these was added to the original seven. Gardner has maintained that there are most probably others. MI has proved to be a useful theory for educators, in that it seeks to recognise different 'intelligences', celebrating children's different aptitudes and seeking to capitalise on these in the classroom. However, Gardner is eager to dissociate MI from its beleaguered cousin, Learning Styles, even though many commentators have made this connection.

If MI is useful as a theory, then does it matter whether its existence can be supported by neuroscience? At one stage, Gardner appeared to accept that no neurobiological evidence supported MI, even though neuroscience was cited as one of the sources of the original theory. He also accepted that in the school curriculum as it stands in much of the world, linguistic and mathematical intelligences hold pole position. However, more recently there has been renewed support for the idea of visible evidence. In 2017, Shearer and Karanian reviewed extensive literature on projects seeking to ascertain the neural correlates of each Multiple Intelligence, in an effort to establish whether each one does indeed have a consistent architecture within the brain. For example, in the case of interpersonal intelligence, they found that 38.74% of the literature cited the prefrontal cortex but only one citation (0.9%) existed for the cerebellum. Shearer and Karanian conclude that there is neuroscientific evidence for MI and also state that this evidence correlates well with Gardner's original proposed sites of brain activity for each intelligence. They do acknowledge that it remains a difficult step to go from here to viewing MI as the bridge between neuroscience and education. One is left with the view that if it is helpful for teachers and positive for pupils, then it remains at least a useful theory.

In general, we only use 10% of our brain

As Jarrett observes:

> some myths run out of steam, go out of fashion, or exist only on the fringes of popular belief. But others show remarkable zombie-like endurance, managing to march on through mounting contradictory evidence. It's these stubborn and popular beliefs that are often picked up by self-appointed gurus or evangelists looking to bolster their quack courses or campaigns. The staying power of some of these classic myths is also helped along by their seductive appeal – they extol facts that would be great news if only they were true. (2015, p. 51)

The final false statement considered here must plead guilty to every dimension of Jarrett's description. There is indeed an allure in the idea that as yet each of us has huge untapped reserves. Like most of the myths, the 10%

myth has misinterpretations and baseless suggestions mixed up in its evolution.

Many writers have pointed out that influential psychologist William James suggested that we have greater mental energy than we might realise. In 'The Energies of Men' (1907) he wrote of 'sources of strength not habitually tapped at all'. It appears that others saw fit to ascribe various proportions to this unused potential, whilst brain surgery exploring techniques to reduce seizures in epileptic individuals, which appeared at one stage to have uncovered inactive areas of brain tissue, added a further layer of scientific credibility. There can surely be few who would seriously refute what is eminently clear now, however, that with the exception of existing damage, we use all of our brain, not all at the same time, but there is nothing that evolution has chosen to leave there for no purpose.

2.6.4 Debatable

The brain sometimes 'prunes' or deletes neural connections

We know that this does happen, but there is good reason to include it under the heading 'debatable. The phrase 'use it or lose it' is commonly used in reference to functioning of the brain as well as physical capacities. In the case of the brain, this is usually in reference to cognitive function and sometimes in reference to memory. There is some truth in this advice, since it is possible for synapses and axons to fade if they are not called into action, but it is also true that some synaptic pruning is actually necessary and desirable.

In its early development the brain creates more connections than it will need and then removes and reorganises them. Considering that even after this period of development, which is generally considered to last until late childhood, there remains something like 80–90 billion neurons, between which there is something in the region of a trillion connections, it is not surprising that some deletion and re-arranging occurs. Another period of major deletion and rearranging occurs during adolescence.

These early years of synaptic density gave rise to the concept of ‘critical periods’, periods that represent a key time for certain types of learning. In the past this then led many educators to believe that if certain things were not learned by a certain age, then they were unlikely to be learned at all. It is true that this is a good time for the learning of some things, but the idea of ‘critical’ periods has changed places with ‘sensitive’ periods. The implication is that learning is possible at all periods and though this may make some learning more difficult, it is also the case that this period is not a prime one for some types of learning. This is important for many reasons, both for adults and children and particularly children who have suffered deprivation in their early years. The damage that such children suffer is, to some extent and with the right opportunities and support, reversible and this seems an important aspect of the morale of those who teach these children.

Thomas and Knowland (2009) believe that the sensitive periods of brain development could play a larger role in the planning of the school curriculum. Sarah-Jayne Blakemore’s work has brought a developing brain dimension to questions of adolescence, moving the debate on from seeing this period as one of just problematic hormones. Blakemore's research is extensive. More recently, she has written for a wider audience, in the readable and personal book *Inventing Ourselves: The Secret Life of the Teenage Brain* (2018). Though not specifically aimed at teachers, the book explores many of the aspects of teenage behaviour with which teachers of that age group are regularly pre-occupied.

Mental ability is inherited

Not only is this issue more complex than 'nature versus nurture', it is also a potentially loaded and heated one:

> Both for the environmentalist and for the believer in blended inheritance, one of the most puzzling phenomena is the appearance, not only of extremely dull children in the families of the well-to-do professional classes, but also of extremely bright children in families where the personal, cultural and economic conditions of the parents would, one might imagine, condemn every child to failure on either count. (p. 139)

So wrote Sir Cyril Burt in *The Eugenics Review* in 1957. Burt's thoughts display how socially, politically and economically loaded and presumptuous discussions of ability can become. But there is also something positive to be taken from his words, even if they would rightly fail any contemporary test of sensitivity and correctness. What appears to confound Burt is that neither genetics nor environment can function as a reliable indicator of the broad trait referred to as mental ability. We understand now that not only are they both significant, they interact. Genes interact with and are affected by environment.

Behavioural geneticists Kathryn Ashbury and Robert Plomin (2014) describe this under three types of genotype–environment correlation that would have helped Burt with his conundrum. They identify three types of correlation:

Passive: unstimulating, low aspiration, low-achieving parents, pass this on genetically and via the home environment

Evocative: child's genetic propensities are evident in behaviours, picked up and utilised by teachers, by offering more opportunities to develop particular skills and interests

Active: child is active in pursuing activity and people that align with genetic propensities

It appears that it is difficult to be conclusive; both environment and genetic inheritance play a part. What seems crucial for teachers to consider is that neither factor exists independently and neither of them can predict the future. Many schools, along with influential individuals like Dame Alison Peacock, chief executive of the Chartered College in Teaching, are increasingly recognising that test results should not be treated as proxy for future attainment, but rather as an indication of attainment at a certain point. This is a key aspect of Peacock's work with Swann, Hart and Drummond, Learning without Limits (2012). Teachers should, and many do, challenge themselves about the assumptions it is easy to make on the basis of a child's family history and environment. To some extent, when these factors are not supportive, other things can still prove influential. Ashbury and Plomin explain that a key principle of behavioural genetics research is that 'continuity is genetic and change is environmental' (2014, p. 26). Their application of this principle to educational performance offers a thought-provoking end piece to this brief discussion: 'any large, uncharacteristic fluctuation in performance over time, in either direction, is likely to be the result of experience rather than genes – think inspirational teacher, extensive practice, traumatic loss, or bad company' (p. 26).

2.7 Sources for the Public and for Teachers

Teachers' *accurate* general knowledge of the brain, which as we have seen above can improve their selection of strategies and materials of supposed neuroscientific origin, may be helpfully supported by the more reliable sector of the popular science market, though this pre-supposes that teachers can identify what *is* reliable. Geake (2011) raises a point that challenges my suggestion: 'without being rooted in education, neuroscientific data and interpretations are unlikely to be embraced by the education profession' (p.43). Geake suggests that such interest will only occur if the data in question has arisen in researching questions that have arisen from education in the first place. However, there are worthwhile examples of popular press books about the brain, such as Medina's *Brain Rules* (2008), *The Learning Brain* (Blakemore and Frith, 2005) and Ratey's *User's Guide to the Brain* (2001). Accessible discussions of the brain also preface the examination of classroom strategies in Wolfe's *Brain Matters* (2001) and Tokuhama-Espinosa's *Mind, Brain and Education Science* (2011), though it could be argued that much of the content of these two examples replicates information available from many sources, hence not all of each book lives up to their respective claims to ‘translate research into classroom practice’ or to provide ‘a comprehensive guide to the new brain-based teaching’.

Precisely what Wolfe, Tokuhama-Espinosa and others offer that can be put into action in the classroom deserves further examination. What teachers who choose to examine this type of literature gain from doing so may depend on what teachers are looking for and on how long they are willing to spend on the search. If they seek quick fixes, ideas, strategies for immediate use or ‘tips and tricks’, they may find little that is new or not already strongly evidenced and supported by educational and cognitive psychology, as previously suggested by Bruer and more recently by Bowers. For example, when Schenk advises ‘connect with your learner by sharing something you find valuable’ or ‘introduce yourself and have others introduce themselves’ (2011, p.165) as motivation strategies, it is fair to remark than one hardly needs neuroscientific evidence in order to grasp the usefulness of these suggestions. Of much more value in Schenk’s book, is discussion of how the adolescent brain is not the same as the adult brain, or discussion of implications of neuroscience for the future, though again it could be argued that worthwhile as such discussions are, they tell us little about classroom practice. In the longer term, these are the considerations to which neuroscience can most helpfully contribute, rather than checklists of strategies that may appear to have an air of infallibility due to their alleged scientific basis. Tokuhama-Espinosa writes that ‘using MBE (mind brain education) science, we can now explain neurologically in many cases why the things great teachers do work’ (2011, p. 205). Even if one accepts this, it does not offer anything new for busy teachers. Tokuhama-Espinosa offers 21 neuroscientifically-grounded ‘principles that great teachers follow’ but draws short of suggesting learning and teaching activities based on these principles.

Wolfe, however, is willing to commit to suggestions of this nature. She offers a chapter entitled ‘A Toolkit of Brain-Compatible Strategies’ (2002, p. 170-191). There can be little question that the strategies may well be useful when deployed appropriately, though it is rather unlikely that any effective strategies for learning and teaching are not ‘brain-compatible’. Perhaps the most valuable section of Wolfe’s book is the preface, in which she raises important questions and considerations. She promotes caution amongst those interested in bringing learning from neuroscience into the classroom, since ‘educators have a history of jumping on bandwagons’ (p. v). She rightly points out that there is a great deal we do not know about the brain, but it would be ‘foolish to wait until all the research is in’ (p. v) before considering how the research might influence classroom practice. In any case, we will never reach such a position and could not possibly know if we had. It is to Wolfe’s credit that she advises that her book ‘contains more caveats than definitive answers’ (p. viii).

Both Wolfe and Tokuhama-Espinosa propose that teachers need a basic understanding of brain function and anatomy, in order to understand neuroscientific literature relating to learning and teaching and they both suggest that this understanding should in turn support the essential criticality that can protect teachers from fads and bandwagons. Tokuhama-Espinosa makes an interesting case for teachers having knowledge of neuroanatomy that helps them understand why children might have difficulties with different tasks that appear to require similar skills. She uses the example of aspects of language, citing the work of Argyris et al. (2007) and Kacinik and Chiarello (2007). Their work reveals that spelling and the use of metaphors, for example, involve different neural networks and Tokuhama-Espinosa suggests that awareness of this can help teachers understand why the same child can be good at one aspect of language and less good at another. The implication is that greater understanding can inform interventions and teaching strategies. Tokuhama-Espinosa's book contains other thought-provoking breakdowns of the mental functions involved in key learning skills such as reading, mathematics and creativity (see, for example, her discussion of reading, p.180-188).

Another sub-section of popular publications about the brain places emphasis on the stories of individuals, in the manner so effective in neurologist Oliver Sacks's '*The Man who Mistook his Wife for a Hat'* (1971) and many of his subsequent works. Examples that have caught the attention of educators include Doidge's '*The Brain that Changes Itself*' (2007) and on a similar theme (and with a foreword by Doidge), Arrowsmith-Young's '*The Woman who Changed her Brain*' (2012). What is noteworthy in Arrowsmith-Young's case is that this book is autobiographical and she has gone on to develop an educational approach that has achieved success in her own special schools, initially in Canada and since in seven countries. Indeed, given the contribution of neuroscience to approaches to, for example, dyslexia, (Shaywitz and Shaywitz, 2008, Shaywitz et al. 1998), it may be the case that if educational neuroscience can offer *specifics* then it may initially do so more effectively with *specific* learning difficulties. That said, the case of Arrowsmith-Young and the Arrowsmith programme raises a number of questions. The programme is predicated on 19 cognitive deficits that Arrowsmith-Young has identified, based on her own experiences and strongly influenced by the work of Alexandr Luria on the effects of different sites of brain damage on brain function, as well as Rosenzweig's work on neuroplasticity. Arrowsmith-Young firmly believes that in many cases of learning difficulty, remediation is possible, yet most often in schools the emphasis is instead on the development of compensatory methods. Her book describes many cases of notable success, for both adults and children. It does not, however, present any data accounting for less successful students of the programme. Amanda Hooton (2017) reports the comments of Dr. Tim Hannan, a clinical psychologist and neuropsychologist who is head of the school of psychology at Charles Sturt University in New South Wales, Victoria: 'after 35 years, there is still not a single, controlled clinical trial, adopting stringent methods, published in a peer-reviewed journal, to show the efficacy of the Arrowsmith Program'. Hooton also relays the views of other sceptics, who suggest that it is difficult to be certain that it is the program that brings about the changes, that since parents invest so much in the program they assign all improvements to it and that some children respond well due to the changed environment or through feeling that they are part of something 'special', rather like the Hawthorne Effect. Many of the Arrowsmith Programme exercises are computer-based. There is continued disagreement that such 'brain training' activities can elicit far transfer, rather than simply enable students to be better at things that are similar to the computer tasks. In their meta-analysis of studies of computer-based working memory training programmes, Melby-Lervåg and Hulme (2013) reach a strong conclusion:

> The absence of transfer to tasks that are unlike the training tasks shows that there is no evidence these programmes are suitable as methods of treatment for children with developmental cognitive disorders or as ways of effecting general improvements in adults' or children's cognitive skills or scholastic attainments (p.283)

Also autobiographical as well as highly influential, is the writing of Temple Grandin, who has suggested that she perhaps possesses the most famous autistic brain in the world (2014a). Now Professor of Animal Science at Colorado State University, Grandin's work has been 'translated' into strategies and interventions with autistic children in mainstream and special school settings in the UK. The books *The Way I See It*, *a personal look at autism and Asperger's'* (2008), the Grandin-edited *Different…Not Less*: *inspiring stories of achievement and successful employment from adults with autism, Asperger's and ADHD* (2012) and *Unwritten Rules of Social Relationships* (2004, with Sean Barron) have been the basis of many strategies, whilst Grandin's more recent *The Autistic Brain* (2014a, with Richard Panek) offers an up to date review of what neuro-imaging and genetics can tell us about autism, along with Grandin's well-grounded views on how we might rethink how we view autism, its diagnosis and its labels. She emphasises that diagnosis for autism is still a relatively vague procedure, that no consistent genetic variations have been established for autism and that in her view there is an over-emphasis on working with social and communication issues with autistic children, at the expense of time spent on managing sensory difficulties that are often a catalyst of their more problematic behaviour traits. Grandin also reconsiders her own work on thinking in pictures, having come to the realisation that though this is a trait of her own it is not as common amongst autistic people as she had previously assumed. Even so, for teachers working with pupils with any degree of autism, Grandin's discussions of thinking in pictures are thought-provoking, especially as she explains that this is also how her memory works. This may, of course be relevant to other, non-autistic pupils as well. In Thinking in Pictures (1995/2006) Grandin illustrates this point through her own struggles with algebra: 'there was nothing for me to picture. If I have no picture, I have no thought' (p.29). Everything in Grandin's memory, including words, is converted into a picture or a mental video. She posits this as a key aspect of her ability to empathise with animals, as they also think in pictures, not language.

Grandin has featured in the work of other writers, in explorations of themes such as neurodiversity and what it means to be a human being. The former issue is of particular significance to teachers as well as to society at large. Writing in *Health Care Analysis*, Jaarsma and Welin (2012) examine the claims of the neurodiversity movement, a movement that seeks to re-evaluate neurological conditions as variations of neurological development rather than disabilities. The movement takes the view that neuro-diverse groups have a just case for rights and acceptance. Jaarsma and Welin see neurodiversity as a ‘controversial concept’ (abstract). They contrast Grandin’s view that autism is a part of who she is and that for her and many others it is a factor in the individual contributions they have made, with the view expressed by Donna Williams that autism is a prison that hides her true self from the world. Jaarsma and Welin are concerned that the neurodiversity viewpoint overlooks the added complication of low and high functioning autism. They make a distinction between these in describing the former as a disability and the latter as a condition, though they also argue that statistically autism can be seen as a normal variation, given the extent to which it is found in the population. They point out, as does the neurodiversity movement, that homosexuality was at one time classified as a psychiatric disorder.

Grandin has expressed concern about the effects of being classified as autistic and Jaarsma and Welin pursue this issue. It does not help, they suggest, that the current edition (2013) of *The Diagnostic and Statistical Manual of Mental Disorders* (DSM-V) classifies low and high functioning autism as one condition (high functioning autism/Asperger’s Syndrome was a separate classification in the fourth edition). Even if accepted as part of normal human variation, Jaarsma and Welin suggest that low functioning autistic individuals continue to need additional care and the all-encompassing definition does not help support this. Grandin herself has been critical of the DSM definitions, though she in turn has been criticised for writing about the high functioning experience of autism with little reference to the different experience of low functioning autism. It has been suggested that this can create misplaced optimism. Part of the problem here is not autism itself but societal response to it. Inclusive schools are perhaps in the vanguard of challenging this, as they have an opportunity to promote awareness of both the rights and the vulnerabilities of autistic individuals.

Bergenmar et al. (2015) also warn of the dangers of viewing autism in terms of missing cognitive and social skills – a deficit model. They suggest that the deficit viewpoint could easily be turned on its head. That is to say, it could equally be argued that the deficit lies with 'neurotypical' people being unable to understand the ways in which autistic individuals differ from themselves or to empathise with affective differences.

There is a number of other writers in North America who have been influential in experimentation with learning and teaching methods purported to have their origins in neuroscience. In 1995, Eric Jenson displayed considerable faith in the anticipated impact of what he and others termed 'brain-based learning' (in fact the title of his 1995 book): 'there is an explosion in brain research that threatens the existing paradigms in learning and teaching' (preface). Amongst these 'threats' is the proposition that research has suggested that the brain was not designed for formal learning at all, rather for survival learning. Jenson takes this to the level of a case for completely reforming school structures, suggesting we should 'design schooling around how the brain learns best' (preface), inadvertently giving us an example of language that presents a disembodied view of the brain. This is a phenomenon discussed by Satel and Lilienfield (2013), who examine cases where 'neurolaw' has been deployed, for instance using research that has demonstrated that adolescent brains reach maturity later than previously thought, as the basis of a legal defence of a seventeen year old charged with murder. As mentioned above in the case of leadership, there is now, according to Satel and Lilienfield, a volume of research in the field of neurolaw that 'is exploding' (p. 100). Legrenzi and Umiltà present a variety of other examples, such as neuro-politics, neuro-theology and neuro-economics, in the aptly titled *Neuromania* (2011).

Returning to Jenson, it is interesting to look at his 'brain-based' view on some issues that have continued to raise debate amongst educators. His term 'capability beliefs' (p.71) echoes the work of Carol Dweck and the powerful influence upon individuals of what they believe their abilities to be, whilst Jenson also sweeps away the individual learning styles debate, declaring that they are irrelevant 'when we consider the variety with which the brain works' (p.129). In describing them as 'intellectual poison' (p. 234), Jenson enters the debate wherein the behaviourist principles of rewards and sanctions are challenged. Like the books of Wolfe and Tokuhama-Espinosa discussed above, Jenson generally opts to discuss the brain and then the classroom, so at times the precise connection between classroom practice that he advocates and brain-based research is unclear and yet again we are left with advice that frequently already exists, supported in particular by cognitive psychology and thus a question mark as to whether the neuroscience is actually contributing anything other than an additional source of confirmation for the advice.

This is an issue taken up by cognitive psychologist Daniel Willingham (2008). He takes the view that when the flow of information and analysis is from common psychology-examined behaviours to neuroscience, this contributes little, whereas when the flow is in the opposite direction and neuroscience tells us things about behaviours that psychology may not have identified or classified, then this has currency for the development of learning and teaching. Byrnes (2001) however takes the view that findings from neuroscience that are deemed useful for education should be consistent with findings in cognitive and other fields of psychology.

Willingham's book *Why Don't Students like School?* (2009) is one that has won the interest of teachers, wherein Willingham takes teachers' questions and offers answers from the perspective of a cognitive scientist. Willingham examines concerns such as memory, attention, thinking and children's (alleged) differing learning styles. He is willing to challenge commonly accepted principles, suggesting for instance that trying to make lesson content relevant to pupils' interests is misguided and may well be counter-productive, as it may lead learners' thoughts away from the lesson and instead onto the very interests that were meant to gain attention for the lesson content. He contests that it is the teacher's ability to make potentially dull content of interest, through its presentation, the construction of tasks and the teacher's classroom persona, that is most significant. He also points out that the extensive research on learning styles has failed to conclusively demonstrate the need for teachers to attempt to identify or accommodate different learning styles. He refers to the following as a 'cognitive principle': 'children are more alike than different in how they think and learn' (p. 147). Willingham does slip into the confusing issue raised above (chapter 2.5) of using the words 'brain' and 'mind' interchangeably. He does so right at the start, where he describes the brain and then states that 'the mind is at last yielding its secrets' and 'it would seem that greater knowledge of the mind would yield important benefits to education' (p.1).

Whilst educational neuroscience has concentrated on using knowledge of the brain to understand the processes of learning and teaching and has understandably been particularly interested in what is happening in the brains of learners, just what is happening the brains of teachers in the act of teaching has also been the subject of investigation. This is the theme of Vanessa Rodriguez's *The Teaching Brain* (2014, with Michelle Fitzpatrick). Rodriguez recognises that teaching is an activity that is not solely the field of professional teachers and proposes that teaching is in fact an evolutionary, social cognitive ability. However, Rodriguez limits comment on neurological findings, taking the view that we do not yet understand enough of the brain's complexities to then deploy them in our understanding of the teaching brain. Although Rodriguez does redefine how we might think about teaching and does utilise models such as Kurt Fischer's Skill Complexity Scale (p.135), the book might more appropriately have been entitled 'The Teaching Mind'.

A series of articles in *Mind, Brain and Education* does take up the challenge of examining neurological information about the brain in the act of teaching. In the first edition dedicated to the teaching brain (March 2013), emphasis is placed on teaching as an act of synchronised interaction, through which teachers become adept at recognising the learning state of each student and are able to interact with individuals whilst ‘adjusting to bring the room to a united rhythm’ (Kent, p.13).

2.8 The Brain Online

Brain information available from online sources requires consideration, since there is a large and continually growing quantity of it, some of which is more readily available to teachers than academic sources and *some* of them are the most up to date in terms of recent research findings (though issues of validity and accuracy exist in this domain as elsewhere). Given the ease of access to online sources, it is reasonable to suggest that the Internet may well increasingly be the primary source of information for teachers. There is certainly a fast growing collection of teacher continuing professional development (CPD) materials online, the most popular of which is the Twitter feed of @teachertoolkit, whose blog and feed declares itself ‘The Most Followed Teacher on Twitter in the UK’. The teacher behind Teacher Toolkit is Ross Morrison McGill, a secondary school deputy headteacher, though it now employs a number of staff and freelance contributors. Teacher Toolkit has ventured into the field of cognition on occasion. In his blog of 17th October 2015, ‘The Cognitive Revolution in Teaching’, McGill makes an interesting point about the drive for consistent evidence for classroom methods, suggesting that it may work against the validity of teachers’ intuition. However, the blog is riddled with questionable statements: ‘cognitive-ism (sic) is a rejection of psycho-analytic approaches, which trying (sic) to understand the mind in terms of myth, and behaviourist approaches, which try to understand the mind in terms of behaviour only'. It is not clear in this brief blog why cognition is discussed at all, since the key point is clearly about the evidence versus intuition question. What is of concern here is the fact that what is presented to the teaching profession by its most followed online provider needs to be accurate and up to date.

Other Twitter commentators make it their business to seek out inaccuracies and misuses of neuroscience. Amongst these are @theneurocritic, @skeptosaurus, @neuroskeptic and @neurobollocks. It is of concern to me that teachers looking for ideas from the many teachers visible on Twitter are perhaps unlikely to balance neuroscientific claims against the challenges presented by observers such as the Twitter commentators listed above. An illustration of the important role undertaken by these tweeters is illustrated by @neuroskeptic's response to an article in The Daily Telegraph (1.3.16) that ran the headline 'Scientists discover how to upload knowledge to your brain'. This article purports to report on research undertaken by Choe et al. (2016). Neuroskeptic uses Twitter to draw readers to his response to this article, which is entitled 'No, We Can't "Upload Knowledge to Your Brain"' (6.3.16). @neuroskeptic points out that transcranial direct current stimulation (tDCS) was used to *stimulate* the brains of participants, not to 'upload' anything. Though the participants attempted tasks that are used in the training of pilots, The Telegraph's claim that the researchers 'studied the electric signals in the brain of a trained pilot and then fed the data into novice subjects as they learned to pilot an aeroplane' is, as @neuroskeptic describes it, 'journalistic fiction’. In fact, it is both misleading and dangerous fiction, given the enthusiasm that exists for direct current stimulation equipment that is available online and the willingness of some individuals to make such devices themselves. @neurobollocks has warned about these dangers (2014).

There are additional reliable online sources and on Twitter these include @BrainSciencenew, @neuropsychblog, @KnowingNeurons, @BritishNeuro and @SimpleNeurosci. Most of these also offer websites, alongside other reliable sites such as those of the DANA Foundation, senseaboutscience.com and brainfacts.org, which is a ‘public information initiative’ of The Kavli Foundation, Gatesby and The Society for Neuroscience. The content of these sites is properly seated in research and therefore avoids offering ‘tips and tricks’ for the classroom or elsewhere. A brief analysis of the titles of neuroscience news reports on these sites demonstrates the caution with which research findings are approached, with the prevalence of the words ‘may’, and ‘could’:

‘a key mechanism that could improve brain function’ (Neuroscience news, 18.2.16)

‘common antibiotic may be linked to temporary mental confusion’ (Neuroscience News, 18.2.16, reporting an article published in the online edition of *Neurology*, 17.2.16)

Often, the caution reflects the need for more research, especially when the research under discussion is not based on human brains:

‘adult neurogenesis may be increased by sustained aerobic findings’ (Neuroscience News, 8.2.16, reporting on research undertaken with rats at the University of Jyväskylä, Finland).

2.9.1 Teacher Knowledge, Teacher Learning and Continuing Professional Development

Given that I examine teachers’ learning via their engagement with educational neuroscience or other encounters with information about the brain, I include here an examination of some key aspects of teacher education and development, including Initial Teacher Training (ITT) in chapter 2.9.2. As the literature of teacher and professional training and continuing development is vast, this exploration focuses on themes, frameworks and perspectives that have significance in the context of my research.

Just what teacher knowledge *is*, has been a subject of debate at least dating back to Aristotle. This review considers some key contributions to the framing of a definition of teacher knowledge. Ben-Peretz (2011) considers several definitions of teacher knowledge, through an analysis of nine articles published in *Teaching and Teacher Education*, between 1988 and 2009. Her analysis indicates that there has been an expansion and broadening of what is meant by teacher knowledge and it seems prudent to add here Shulman’s earlier observation (1986) that it has also grown in complexity. Taking the earliest analysed article as a starting point (Grossman and Richert, 1988), in figure 2.1 below (p.75) I attempt to map the evolution of this expansion and complexity. Presented thus, it appears that much of the expansion and complexity is created through the addition of issues of knowledge sources and knowledge development, individual knowledge and values and either a broadening perception or an explicit identifying of the moral duties or roles of teachers. Ben-Peretz points out that all these contributors are of western origins and use a shared educational language, which indicates there is more to consider in an extended review, across a wider global and cultural landscape. Shifts in education policy since 2009 would undoubtedly add further layers to this representation, certainly in the UK, such as accountability and the use of school-level data. I point this out since it is relevant to the working contexts of the teachers who have contributed to my data.

On a smaller scale, the workplace itself is a central factor in teacher knowledge and development. Eraut (2007) explores learning within the workplace context, in this instance through nurses, graduate engineers and trainee chartered accountants. He describes beneficial aspects of observing others at work, though amongst these are words and phrases that demonstrate the challenges of identifying workplace learning. These include ‘embedded knowledge’, ‘implicit knowledge’, ‘’clues to the use of knowledge that must have been previously learnt’ and ‘allowing complexity to be appreciated, even if it was not fully explained to, or fully understood by, the observer’ (p.404). Eraut makes his own reference to the difficulties, in discussing ‘cultural knowledge, which has not been codified’ (p.405).

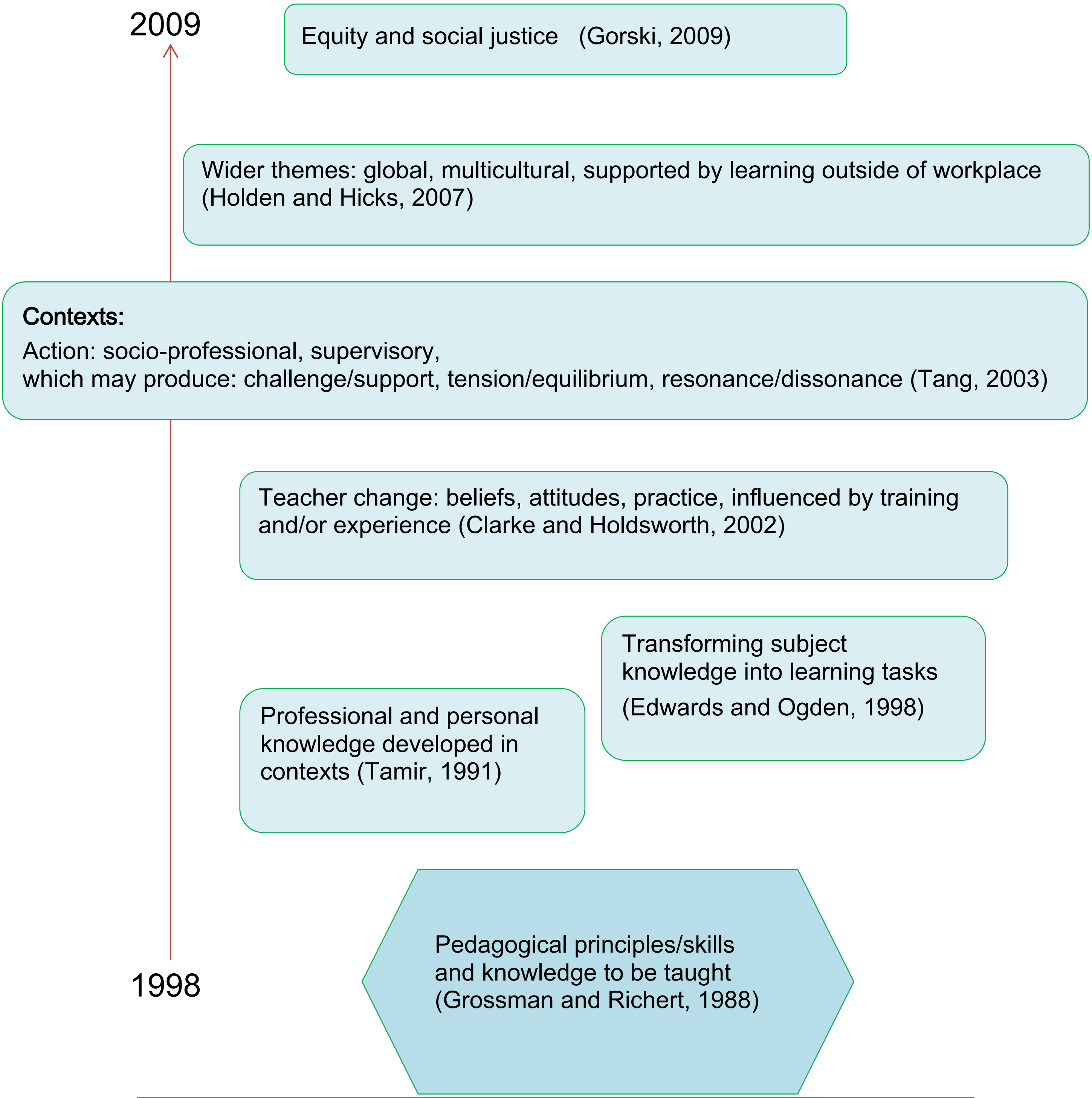

Figure 2.1 Features/influences on teacher knowledge, adapted from Ben-

Eraut also attempts to tabulate the modes of cognition employed by professional learners, tracking how these differ with timescale. Fullan (1993) chooses to place at least equal emphasis on professional behaviour, pointing out that ‘people behave their way into new visions and ideas, not just think their way into them' (p.13). Fullan also argues that this takes time and here there may well be contradictions between individual professional behaviour and the urgent agendas of schools and governments.

Contradictions of this nature, in Harland's and Kinder's explanation, are a matter of 'value congruence' (1997, p.77) and they quote Fullan's observation that 'structural changes are easier to bring about than normative ones' (1991, p. xiii), a viewpoint Fullan later reaffirmed in stating that 'educational change is technically simple but socially complex' (2007, p. 84). Harland and Kinder make a further point that the outcomes of continuing professional development (CPD) are likely to differ, depending on whether the CPD is voluntarily undertaken or an imposed requirement. Harland and Kinder construct a typology of CPD outcomes and tabulate these into a hierarchy, though they also 'tentatively' (p.77) propose that for CPD to be most effective all nine outcomes need to be present. Both the typology of outcomes and the hierarchy offer an additional tool for the examination of the long-term impact of CPD. Table 2.1 is based on Harland and Kinder's original proposal, re-ordered to display what they propose are the most effective outcomes in priority order.

Impact on Practice	INSET Input
First order	Value congruence, knowledge and skills
Second order	Motivation, affective, institutional
Third order	Provisionary, information, new awareness

Table 2.1: A hierarchy of INSET inputs and outcomes, based on Harland and Kinder (1997, pp.76-77)

2.9.2 Initial Teacher Training

Although the Standards for Teachers in England (2012, revised June 2013) require that teachers must ‘be able to use and evaluate distinctive teaching approaches’ (p.8) there is no requirement that these are considered in the light of neuroscientific evidence. *The Carter Review* (2014), a review of initial teacher training in England, has suggested that there is a case for the formal re-introduction of child development within teacher training programmes: ‘Recommendation 1e: child and adolescent development should be included within a framework for ITT content’ (p.9). It is likely that approaches to this will draw on updated knowledge of the development of the brain, such as Blakemore’s work on the adolescent brain (for example, Blakemore, 2018, Blakemore and Choudbury, 2006 and Führmann, Knoll and Blakemore 2015). In addition, the *Carter Review* also proposes that trainees need to be taught

> the core skills of how to access, interpret and use research to inform classroom practice. It is important that trainees understand how to interpret educational theory and research in a critical way, so they are able to deal with contested issues’ (p.8)

Howard-Jones et al. (2009) has examined understanding of the brain amongst trainee teachers in England. They concluded that ‘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’ (p.2). These ideas, Howard-Jones et al. declare, are similar to the misconceptions shared by the general public. This is perhaps not surprising, given that training programmes in 2009 (and subsequently) have placed their greatest emphasis on trainee's production of evidence to demonstrate that they have met the standards for teachers.

Blakemore can be seen explaining aspects of her work on the adolescent brain, in her 2012 TedTalks presentation, *The Mysterious Workings of the Adolescent Brain.* This 13-minute format has potential for introducing trainee teachers to relevant aspects of brain development and has been well received when viewed by student teachers in sessions taught by me. In an equally accessible example, writing in *Beyond Future Horizons* (2008b), Howard-Jones suggests several ways in which neuroscience may feature in educational practices by 2025 and he also offers predictions of further possibilities beyond 2025. These include:

- contribution from cognitive neuroscience to the teaching of mathematics in the early years
- echoing Blakemore's work, the possibility that adolescents will be better understood and approaches to their education adjusted accordingly,
- drawing on his own work, a greater understanding of how reward circuits in the brain influence motivation
- the use of neuroscience in the diagnosis of learning difficulties (and in the design of interventions, though as Mostert and Crockett pointed out as far back as 2000, there is a history of unsubstantiated interventions raising false hope, a danger of which trainee teachers should be informed)
- greater capacity for the training of certain cognitive functions and in particular working memory, a function for which Tracy Packiam-Alloway

has published books (2010, 2014) and marketed training software (Jungle Memory™, *Cogmed*, sold through Pearson Education Ltd)

- understanding of children's mental health being further informed by neuroscience
- better use of neuroscientific evidence to support exercise within the curriculum
- the use of drugs that promote cognitive function (and Howard-Jones also predicts that the government will struggle to adopt a clear policy for this)
- similarly to the Carter Review, the proposal that by 2025 psychology and neuroscience will play a role in teacher training
- a clearer remit for a discipline he prefers to call neuro-educational research.

These are well-founded suggestions that might usefully play a role themselves in bringing about the 'framework for ITT content' (op. cit.) proposed by the Carter Review.

Beyond 2025, Howard-Jones cites possibilities of educational roles for genetic profiling and brain-computer interfacing. He has suggested elsewhere (2010) that there is a growing need for a new type of education professional, possessing expertise in neuroscience and education. This echoes Goswami's similar call (2006, 2009).

2.9.3 Chapter Summary

This chapter has examined the wide range of literature that is relevant to the potential role and influence of knowledge of the brain and educational neuroscience research for the work of teachers, as well as examining teacher training and development from a number of perspectives. The chapter reflects the complexity of the situation and the challenges this presents to teachers in attempting to gain an up to date understanding of the rapidly developing field, amidst other competing demands upon their professional time and energy.

Chapter 3: Methodology and Methods

3.1 Introduction

This chapter explains the evolution of the methodological position adopted for my research, before then explaining the data gathering and analysis methods employed and the rationale for these methods. In addition, cultural historical activity theory (CHAT) is discussed, along with a review of some of its literature, as although not used as a sole analytical lens CHAT played a significant part in the early framing of my thinking about data and analysis. The use of thematic analysis, in the form of interpretative phenomenological analysis (IPA) and factors influencing the use of this are then considered. The chapter concludes by reviewing ethical matters, bias and limitations, both as planned for at the outset and as these factors were observed throughout the research.

3.2.1 The Quantitative/Qualitative Question

A mixed methodology, in the manner Creswell (2009) has described as a 'dominant-less dominant' methodology (p.184), was initially proposed for my research. In this instance, the dominant mode of analysis would be qualitative, with some quantitative methods simultaneously employed that may (or may not) identify trends across teachers, types of schools or across a variety of demographic groupings. It was anticipated that as datasets grew, the study would methodologically evolve in a manner defined by Tashakkori and Teddlie (1998) as a *multilevel* use of mixed methods. This seemed appropriate since aggregated data would become available through the amalgamation of responses from teachers with varying roles and levels of responsibility within a large sample of schools, which may be analysed across a number of parameters, such as curriculum areas, school roles and hierarchies, age and gender and could also be analysed at varying stages of data collection. Statistical inferences drawn from this analysis would in turn need to be considered from a qualitative, interpretative perspective.

This mixed-methodology approach has been reconsidered, as I came to realise that in seeking to understand the lived experience of teachers' engagement with and experiences of educational neuroscience my intentions were of an almost entirely qualitative nature. This realisation avoids a danger that has been described by Yanow and Schwartz-Shea (2006) thus: 'small "n" studies that apply large "n" tools' (p.xvi-xvii). Though it has been useful to quantitatively summarise my survey data with descriptive statistics and to undertake a similar exercise with the coding of my interview data, this does not mean that the research is essentially of mixed *methodology*. This shift in perception of the adopted methodology led to a further realisation that it was necessary to design an approach fit for purpose, seated in sound research principles, rather than expect to be able to work with a prescribed research design or model. To do the latter risks what Holloway and Todres (2003) describe as 'methodolotry' (p.347) and the evolving process is in keeping with the notion of qualitative research design as an emergent process, as suggested by Creswell (2007).

3.2.2 Research Design

Knowledge, opinions, ideas, concerns and day-to-day practice of a sample of teachers in relation to educational neuroscience constitute key data and these have been gathered through a survey and individual interviews. Coded analysis of discussions and interviews, utilising Atlas.ti, working with both interview audio and transcripts and the survey responses supported the identification of key themes that then underwent further interpretation and analysis.

An initial pilot survey was conducted through an online survey tool (Bristol Online Surveys), since this gave participants convenient access and allowed some initial data analysis to be instantly undertaken electronically. The pilot survey also afforded an opportunity to trial questions and specifically asked participants to comment on the survey itself. This provided useful indicators of potential points of confusion that were then taken into consideration in creating the survey that was subsequently completed by a larger sample of teachers. Foddy's guidance (1993/1999) assisted in the avoidance of misleading questions, for example through questions that imply answers, patterns of questions that imply or lead participants towards answers or single questions that actually pose two questions.

3.2.3 Data Gathering 1: Survey

The final version of the survey, which was made available via Bristol Online Surveys (BOS) is visible within the survey responses presented in chapter 4.

This was circulated via teacher contacts, which eventually resulted in 102 responses.

The survey's initial questions (1-7) provide some contextual data, relating to teaching phase (primary/secondary), subject orientation in the case of secondary school teachers, school setting, participant gender and age group and a final question that explores whether the neuroscience of education has played any part at any stage in the professional development of the participating teachers in the preceding five years, either as a personal interest or as something promoted in their school.

The survey then asks participants to respond to a series of statements about the brain (questions 7.1 – 7.25). My purpose here was to set teachers thinking about what they know about the brain prior to asking about their own practice and to explore to what extent this sample of teachers continues to keep faith with some of the more common neuromyths. Each statement is presented plainly, without neuroscientific complications or terminology and without any additional scenario or context. This approach serves two purposes. Firstly, it helps reduce potential participant anxiety about the survey being highly scientific, which could leave participants feeling self-critical of their knowledge and understanding. This could then have an effect later in the survey, as participants might then feel that their thoughts and comments for later questions might be less important, given their limited knowledge. Secondly, avoiding presenting the questions in a contextualised manner allows participants to respond from a personal viewpoint. Though responses will inevitably be based on personal experiences and working contexts, consciously or otherwise, they are at least free of the complication of comparison to a hypothetical context.

With the lead authors' permission, this section of the survey draws partly on that of Howard-Jones et al. (2009). Rather than create an entirely different set of statements for this section of the survey, it seems prudent to achieve some consistency with other related research and to then have the opportunity to review differences in findings. Several such differences are considered in chapter five, within my analysis of survey responses (for example in chapter 5.4.4). It is important to state, however, that Howard-Jones et al. sought to examine teachers' knowledge, whereas my intention is to explore teachers' thinking, dialogue and actions in relation to this knowledge. Therefore, the next section of the survey moves on from Lickert scale, knowledge-based questions to a series of questions that offer the opportunity to describe actions taken in the light of knowledge of the brain (question eight). Question nine then asks about teaching situations that, in the opinions of participants, would benefit from a greater understanding of neuroscientific processes. In terms of the survey's overall structure, the intention of questions eight and nine, having situated participants' thinking in general questions relating to the brain during question seven, is to then allow participants to offer more prosaic descriptions of their question responses, creating the opportunity for individual answers that are rich for analysis, revealing knowledge, viewpoints, concerns and aspirations, contained within linguistic choices that are also revealing and informative. It was not possible for participants to 're-arrange' this step-by-step procedure, as the online survey programme guided them through the questions in numerical order only; a participant would not have been able to choose to answer the questions in a different order.

Questions 10.1- 10.5 explore participants' experiences of and views about several practices that have been promoted in schools on the basis of neuroscientific authority (learning styles, Brain-Gym®, brain training, VAK (visual, auditory, kinaesthetic), Multiple Intelligences).

The final question asks participants to consider how they perceive the balance of several factors that influence educational outcomes (genes, school experience, environment beyond school, other). The purpose of this question was to gauge opinion about and reaction to the issue of genetics, since this also requires some neuroscientific understanding and the field of behavioural genetics is set to play increasing significance in education (Ashbury and Plomin, 2014).

Whilst the survey responses constitute a dataset of interest in itself, this dataset also served a particularly significant role as stimulus for the second round of interviews, undertaken with the two most experienced interviewees in terms of their work in education and also undertaken with the most recently trained of the five interviewees. During these three interviews the interviewees were asked to consider the survey data and comment freely. Their commentary was influential in the co-ordination of codes into key themes, as well as offering triangulation.

3.2.4 Data Gathering 2: Interviews

Whilst the survey generated responses from a large number of teachers, a series of semi-structured interviews was designed, in order to explore more deeply the opinions about and experiences of information about the brain amongst a selection of teachers and to hear directly how this sample expressed their views. This was the main purpose of interviews 1 to 5, the questions for which can be seen in appendix one. Data is drawn from the interview responses of five teachers, each of whom works in a different context (though there is no intention to imply that each individual context is a 'typical' example of each context; the significance is in the fact that they are different).

No time limits were set for the length of the interviews and responses to the questions were explored further as appropriate. The initial question asked the teachers to consider the origins of whatever knowledge they have of the brain, regardless of how extensive they considered that knowledge to be. The second question then sought to examine in what ways the teachers felt this knowledge influenced their classroom practice, whilst the third question searched for evidence of the impact of these brain knowledge-influenced practices. Question four attempts to delve more deeply into why the teachers believe these practices might have had the impact that they describe.

Questions five turns to the wider context of participants' schools, asking how or whether the neuroscience of learning fits into the culture and practice of their individual schools. Question six seeks views on whether it is helpful for children to have some understanding of learning and the brain.

Finally, Question seven invites the teachers to share their views about what they believe neuroscience might most usefully assist them with.

The second series of interviews then explored the response of three of the interviewees to the survey data, as well as exploring changes in their own thinking about the brain as a result of participating in this research. In total eight interviews took place, each of which is presented in chapter four.

In designing and conducting the series of interviews, I have been conscious of the danger that has been described by David Silverman as 'manufactured data' (2013, p. 32). Silverman questions the need for the use of interviews in many cases and instead suggests that the data that is sought is often available through other pre-existing means. He goes on to suggest that responses from interviewees to questions that they had not previously considered may produce immediate answers that are not a reliable reflection of the interviewee's views, thoughts or beliefs. Therefore, there is a risk that the process itself is 'manufacturing' data. In the context of my research, there is little that might be examined as an alternative to gathering responses via interview. Using the example of hospital staff, Silverman suggests that much of what a researcher might seek may be gathered more successfully through observation of the staff at work, rather than through interviews. Classroom observation of participating teachers was considered at the data gathering design stage, but eventually disregarded through concerns that echo those of Silverman: my presence as an observer would inevitably influence the actions of the teacher, who would be conscious of my interest in the use of approaches drawing on neuroscience and my presence would also affect the actions of his/her pupils. Observation in schools brings with it a number of ethical and practical considerations. These are not insurmountable, but I concluded that such an approach might only yield a limited amount of the data I sought and that the voices of individual teachers themselves, given time to reflect upon and discuss the questions raised in as natural and conversational manner as possible, would be more productive. This is logical and more reliable, since it gives teachers an opportunity to state their views first hand and for me to consider both what they say and how they say it, rather than trying to glean this by watching them at work. Since my aim is to further understand how teachers think and *talk* about the brain and educational neuroscience, it is surely sensible to afford them the opportunity *to* talk. Silverman acknowledges that ‘the main strength of qualitative data is its ability to study phenomena which are simply unavailable elsewhere’ (op.cit. p.83), which I believe to be apt in the context of my data gathering.

Where interviews are used, Silverman advocates that the setting of the interview is important and should be reported. Full details of the interview settings are supplied in chapter 4. I took the decision that the interviews should take place in comfortable and familiar surroundings of the interviewees’ choosing and was fortunate in being able to meet with four of the interviewees in their own homes. Interview participant one was interviewed in a classroom in which she undertakes some of her teaching. Prompted by Silverman again, I was eager that responses to my questions in the first sequence of interviews would come in the form of pre-existing experiences, thoughts and concerns, rather than be 'new thoughts' *generated* through pondering on my questions. The second sequence of interviews differed, since here I sought the responses of three interviewees to the compiled survey responses, which they had not previously seen. This offered effective triangulation and the three participants reacted to the survey data in ways I did not anticipate and in different ways to each other. A final challenge from Silverman drew focus on the need to examine not just *views* offered by the participants but also the *actions* that they have taken as a result of these views. The significance of individual actions is a key factor in Cultural Historical Activity Theory and this is discussed below (chapter 3.3).

3.2.5 The Selecting of Survey and Interview Participants

Some guidance for the selection or sampling of participants in qualitative research advises that those selected should be individuals who are well informed about the research area (for example, Sargeant, 2012). This seemingly obvious guidance, often described as *purposive* or *purposeful* sampling is in fact less relevant in the case of my research, since teachers who are well informed about educational neuroscience and the brain are very much a minority within the profession. Such an approach would also require a means through which to assess levels of knowledge, a requirement that would most likely deter participants. In any case, allowing a variety of teachers to opt to participate has allowed a range of critical and insightful comments to be made and queries to be raised by teachers who confess little knowledge of educational neuroscience. These comments and queries are highly valuable to my investigation, as is evident in chapter five. The participants in my research do however comply with Smith's and Pietkiewicz's description of a purposeful participant sample (2014), in that they form a group for whom the issue under investigation is relevant and significant.

The opportunity to undertake the survey was made available to any teachers who wished to do so and these teachers were encouraged to ask teacher colleagues and associates to complete the survey. This is a key point, as my research is not an investigation of teacher expertise but of teachers' thinking and articulation of the field. The brief contextual information required in the survey, described in chapters 3.2.3 and 4.2.1, builds in the opportunity for this information to be considered during analysis. The starting point for the distribution of the survey was teacher contacts of my own, be they former colleagues or teachers from schools with which I have worked for teacher training and development purposes. I was able to begin the distribution across a range of schools, primary, secondary and in the special school sector and the summarised contextual information confirms that the wider distribution continued in this manner. Something that is less easily tracked is the circumstances and frame of mind in which individual participants completed the survey and how these factors might affect some responses.

The welcome page of the survey, having thanked participants for giving up time to undertake the survey then explains that their responses are anonymous, as there is no means by which the researcher can track them back to any individual. The welcome page also clarifies that no scientific knowledge is assumed and nor is the survey meant to be a test of any such knowledge, but rather an exploration of what for the participating teachers is familiar, less familiar and of further interest.

The interview participants are a convenience sample in the sense that they were all able to make some time available to be interviewed, in locations accessible to me, after each having reviewed the participant information (appendix 4). However, I set out to recruit a group of interviewees from different school contexts and with differing experiences of working as teachers, to include experience in primary, secondary and special schools in England and Wales. In this sense, it may be argued that the group of interviewees is a *quota* sample. This quota was achieved, though as previously stated this does not mean imply that each teacher's responses are regarded as representative of their school context. What is relevant and analysed in chapter five is that the differing contexts and experiences are influential in generating a variety of responses. These responses reflect both shared concerns and individual concerns and together present what Coyle (2006) refers to as 'sufficient discourse' (p.247) to relay variety and variation.

3.2.6 Codes and Themes

All data were examined through a coding process, as proposed by Saldaña (2009). Codes were then analysed for sub-themes, which were drawn into seven over-arching themes. These seven themes were then traced back to the codes, in order to retain the origins of each theme within the data. The themes form the basis of discussion of the findings. As the coding and identification of themes are part of data analysis, they are described further in chapter five.

3.3 Theoretical Perspectives: Introduction

In the development of theoretical perspectives through which to consider the data gathered for this thesis, two have been influential. These are Cultural Historical Activity Theory (CHAT) and Interpretative Phenomenological Analysis (IPA). The origins, development and suitability of CHAT and IPA are reviewed in chapters 3.3 and 3.4.

3.3.1 Cultural Historical Activity Theory: Introduction

As indicated in chapter 1, cultural historical activity theory (CHAT) has played a significant role in the early stages of the design of this research. Initially, it was my intention to undertake the analysis of the data entirely from a CHAT perspective. At that stage, CHAT appeared to offer a suitable framework through which to analyse the thoughts and actions of individual teachers in relation to neuroscience and in addition a framework through which to analyse the various factors, internally and externally, locally and nationally, influencing the participating teachers. These factors, in turn, would reveal tensions and contradictions that individual teachers would be managing in different ways. There is no doubt that CHAT has remained an influential element in the analysis of the data. For this reason, below I put forward my understanding of CHAT through its origins, phases of development, key principles and a brief review of some of CHAT's significant literature. Following this, I explain further how CHAT remains an aspect of my analysis but not the sole perspective.

3.3.2 Origins

The origins of Cultural Historical Activity Theory (CHAT) lie in the work of twentieth century Russian psychologists Lev Vygotsky, Alexander Luria and Alexei Leont'ev, who are commonly referred to as 'the Russian School'. The term 'Cultural Historical Activity Theory' itself was first used by Cole (1996), hence the use of the term activity theory below, in reference to sources preceding 1995. Antecedents can be traced further, to the work of Karl Marx, which contributed to the Russian school's drive for an approach to psychology that challenged the prevalence of psychoanalysis and behaviourism. Activity theorists in the USA often cite Dewey's work on social constructivism as an influence (for example, Garrison,1995, 2001 and Glassman, 2001), though Dewey was less interested in the role of tools and objectives (which are described below).

CHAT has continued to develop from these earlier foundations, progressing through three 'generations' and with the most recent development being 'Developmental Work Research' (DWR), led by Yrjö Engeström at the University of Helsinki. Each of these phases of development is briefly considered below, along with the key principles, terminology and applications of activity theory. I also examine its validity as one tool of analysis for my own research.

3.3.3 Phases of Development and Key Principles

The Russian school took the view that individual responses to and interactions with one's environment are not simply driven by innate, personal reactions but instead are influenced by cultural factors and by the tools used to interact with the environment. In turn, the actions of individuals influence culture and tools. In this sense, the individual is a mediator. In activity theory's first generation, this has been represented as in figure 3.1, a simple representation as proposed by Vygotsky.

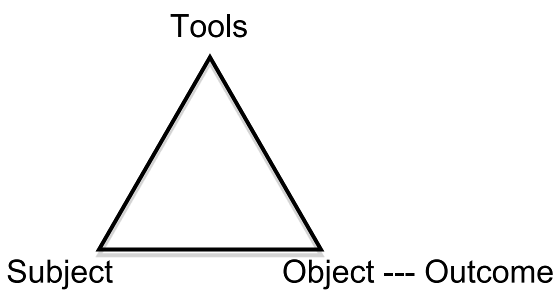

Figure 3.1: first generation activity theory representation

Vygotsky placed great emphasis on language as the most significant psychological tool, given its role both in interaction and in personal thought. Vygotsky described this in his 'genetic law of cultural development' (1941/1997, p.105). To this, Luria added the significance of written language, logical and mathematical operations, on the basis of their impact on how people categorise the environment.

A key contribution of Leont'ev to the development of activity theory was the concept that a distinction needed to be made between the action of individuals, the actions of groups and the actions of individuals within groups. This led to a reformulation of figure 3.1 above, into a second generation of activity theory, as represented in figure 3.2.

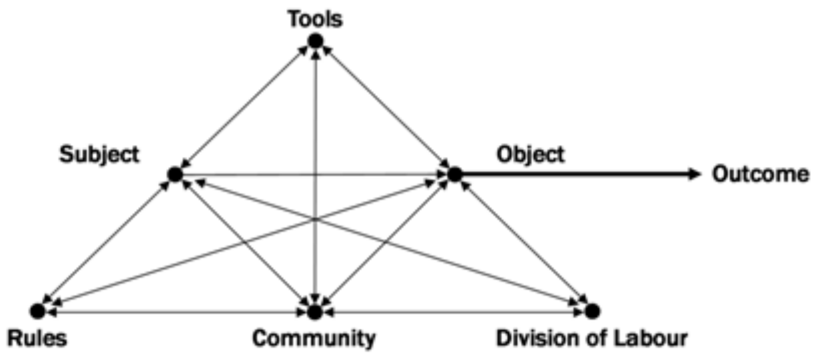

Figure 3.2: second generation activity theory (Engeström, 1987)

Leont'ev, drawing on Marx's work on labour power and the division of labour, brought the concepts of activity theory to the work place, pointing out that activity takes place within organisations at individual and collective levels. Leont'ev made a distinction between activity, action and operation, which will be defined below, in chapter 3.4.4.

Third generation activity theory has sought to widen analysis to include missing aspects of second generation activity theory, such as cultural diversity and the interaction of activity systems (see figure 3.3).

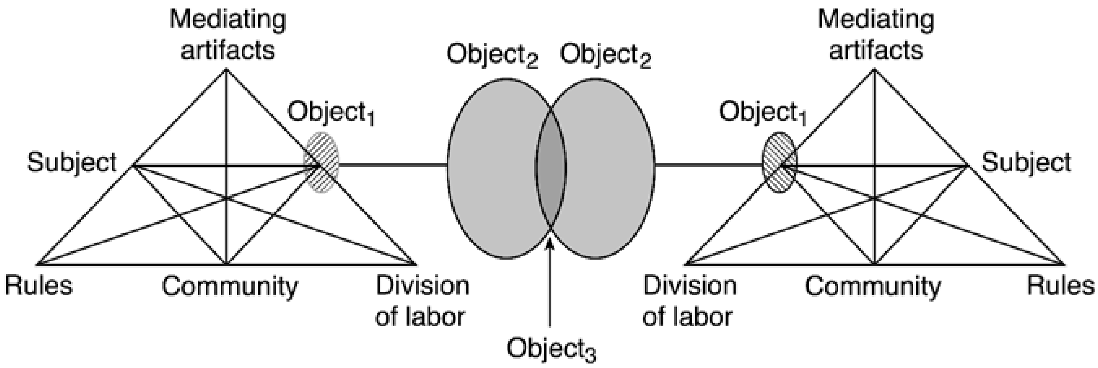

Figure 3.3: third generation activity theory (Engeström, 1999)

With colleagues at the Centre for Research on Activity, Development and Learning (CRADLE), Engeström has introduced a further phase of activity theory, known as Developmental Work Research (DWR). DWR seeks to work with organisations and institutions in using activity theory analyses to improve working practices. CRADLE describes this as 'reciprocal interaction between theory and practice… in close collaboration with work organisations, educational institutions and organisations pursuing investigative developmental consulting' (http://www.helsinki.fi/cradle/info.htm).
DWR is also interested in how new skills are learned in the workplace.

3.3.4 The Language of Cultural Historical Activity Theory

Here I discuss the regular terminology of CHAT, largely in the order that it has emerged via the models above.

The *subjec*t referred to in an activity theory analysis is the individual whose activity is under consideration. The artefacts through which this individual interacts with a specified context, be they hardware, software, language, dialogue, thought patterns, written documents or routines and procedures, constitute *tools*. The *object* or *objective* captures whatever the subject is attempting to achieve. This may also be an *outcome*, though outcome may also mean the intended result of different, collective objects.

Second generation activity theory introduces three significant terms. Firstly, *rules* can refer to formally, informally and even tacitly established procedures or expectations that have a degree of governance over how a subject approaches and carries out their activities. Secondly, *community* requires us to consider the different players and their roles within the context under consideration, recognising that these have significance for the subject. Finally, *division of labour* explores how labour power is deployed, how outcomes may be broken down into activity needed to achieve the outcome and how these activities are then disseminated amongst available labour sources.

Additionally, activity theory often utilises a variety of additional terminology. *Contradiction* is often employed where activities may appear to work against each other in achieving an outcome or where existing 'old' rules may mitigate against the introduction of new activities, the use of new tools or new divisions of labour. Where contradictions exist, there is likely to also be *tensions.* Activity Theory proposes that learning and changes to practice are often generated through the existence and resolution of contradictions and tensions. *Bridges* and *boundaries* are relevant to the intersection of activities, describing how interacting activity systems or even entirely independent fields or disciplines work in collaboration, successfully or otherwise. Beauchamp and Beauchamp (2012) introduce the term *boundaries as bridges*, in their efforts to describe something deeper than cross-disciplinarity, which Koizumi (in Battro et al, 2008) has referred to as trans-disciplinarity (as noted above, in chapter 2.2).

Leont'ev used the word *action* to refer to individual actions, *activity* to represent collective, individual actions and *operation,* the overall purpose of an organisation.

3.3.5. A Brief Review of the Literature of Cultural Historical Activity Theory

This review commences with a consideration of Engeström's discussion of expansive learning at work (2001), which is based on his own theory of expansive learning, before then considering other relevant examples of the use of CHAT in contexts relevant to my investigation.

Engeström builds four questions concerning professional learning and proposes five principles and then proceeds to develop his 1987 human activity system model into a modelling of the interacting of activity systems. The four questions can be summarised as 'who learns, why, what and how?' (See Engeström, 2001, p.133), whilst the attendant five principles are as follows:

- an activity system is a unit of analysis, that is collective, mediated, tool-oriented and networked

- an activity system is a mutli-layered, multi-voiced community, with individual and collective histories, tools, artifacts and conventions
- transformation takes place over lengthy periods of time (historicity)
- contradictions are a source of development
- reconceptualisation of objects and motives can result in activity systems undergoing expansive transformations

(adapted from Engeström, 2001, p.135-136)

The use of these questions, principles and models within my research is considered below in chapter 3.6.3.

Roth and Lee (2010), in exploring CHAT's relationship with pedagogy, highlight how actions become unconscious operations integrated into practice, something that is evident in the work and development of teachers. Interestingly, Roth and Lee point out that actions can have different meanings or consequences within different activity systems and they thus make the case for the use of activity as a *unit* of analysis, ensuring that cultural and historical factors are considered, rather than considering *elements,* without reference to a wider framework or the significance of the interaction of individuals. To do the latter, they suggest, is to contribute to 'the problem with much classroom research' (p.4).

Daniels and Warmington (2007) in discussing both Engeström and Vygotsky, reflect on evidence that practitioners can be 'happy to construct new models and tools for changing their work', yet '…reluctant to proceed with their implementation' (p.389). This can be viewed as a possible contradiction in the apparent engagement of some teachers in training and development activity that subsequently has little or no impact on their practice.

Edwards (2005) describes how practice is many workplaces is enacted across organisations and institutions, requiring ‘relational agency’ or ‘multi –agency collaboration’ (p. 168). This is increasingly relevant to teacher education, as new approaches to the training of teachers in England require a new style of partnership, between schools and between schools and Higher Education institutions, in addition to the drive for inter-agency working between education, health and social services for the well -being and development of young people. This provides a further illustration of the need to understand the development of the work of teachers as drawn across a variety of needs, demands and interactions, for which activity theory provides both frameworks and perspectives for analysis.

3.3.6 This Thesis and Cultural Historical Activity Theory

My research analyses survey responses of 102 teachers and the interview responses of five teachers, each of whom works in a different context (though as previously stated there is no intention to imply that each individual context is a ‘typical’ example of each context; the significance is in the fact that they are different).

CHAT requires the analysis of a number of dimensions and interactions that I believe are purposeful and informative in gaining insight into how the development activities of individual teachers contribute to and conflict with several activity systems. Engeström's second generation activity theory model (1987) presents an initial framework for highlighting the interplay of a range of factors that can be examined. This is visible in figure 3.4 below (p. 69), where examples of these factors have been sketched on to the model. Considered through the five principles proposed by Engeström, it is evident that the sketch 1. contains units of analysis that are collective, mediated, object-oriented and networked, 2. features multi-voiced layers, individual histories, systems, rules and conventions, 3. explores history to examine how transformation occurs over time, 4. identifies contradictions and structural tensions, the resolutions of which drive change and 5. reveals transformations that have created an expanded reconceptualisation or vision. Alongside Engeström's four questions (who learns, why, what and how?) there is much scope here for deep analysis and for working towards third generation activity theory, allowing study of the third space created through the intersection of activity systems. These dimensions have been used to support the use of interpretative phenomenological analysis (IPA).

As described above, in the initial stages I proposed that a CHAT lens would be the sole perspective for the analysis of my data. CHAT does offer a framework through which wider contexts and influences can be explored and a host of relevant further questions uncovered. CHAT considers individuals to be an unsatisfactory unit of analysis when devoid of the wider context and deeper individual dimensions. The early, CHAT-orientated development of my research plan served an important purpose in alerting me to the need to consider context and has provided guidance about how context can be explored. It has also been influential in the design of survey and interview questions.

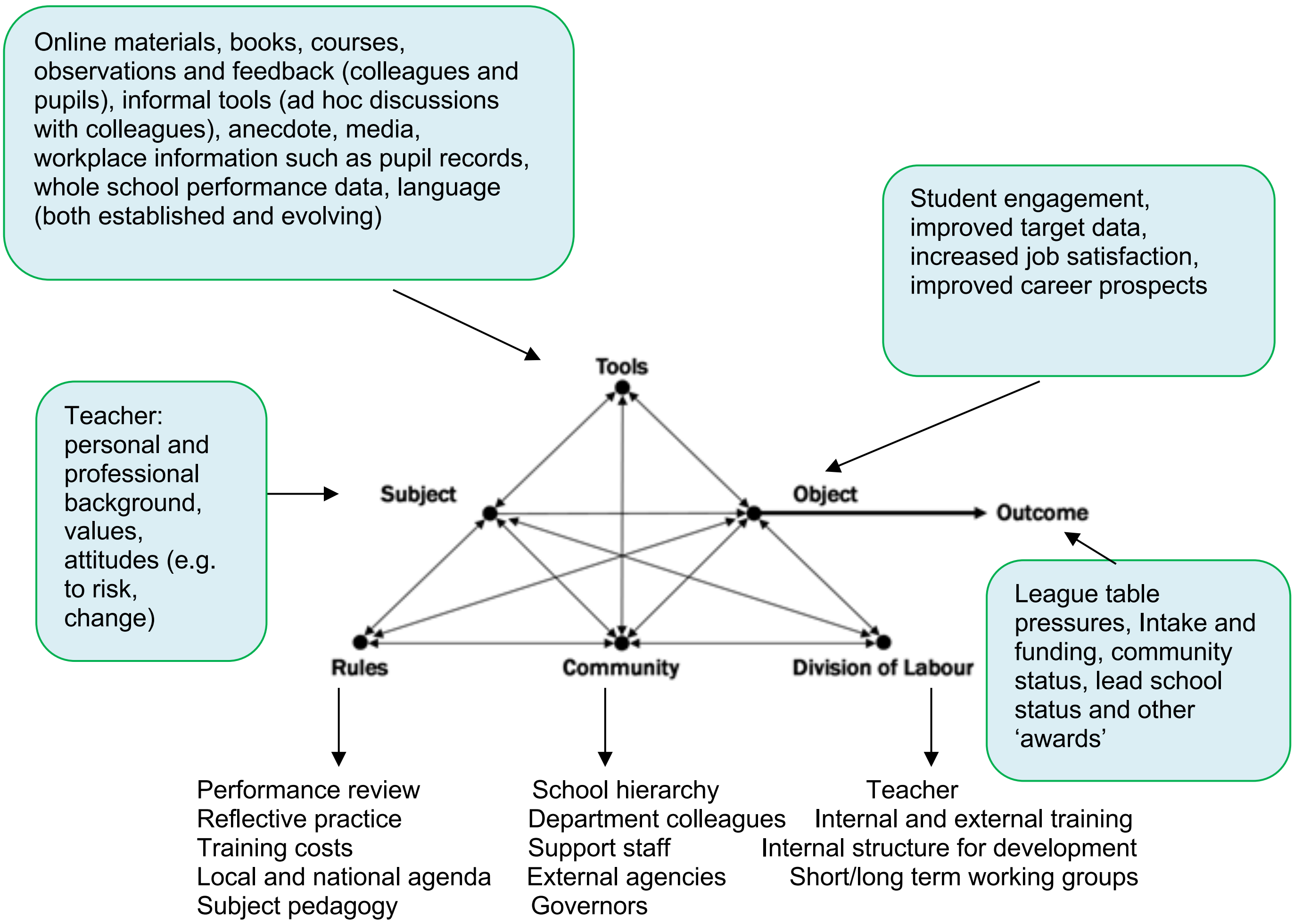

Figure 3.4: a second generation activity theory sketch, adapted from Engeström (1987)

However, I began to find that an entirely CHAT-led analysis was creating an over-emphasis on contextual influences and detracting from the focus I wish to give to the individual voices of participants; CHAT was potentially changing my question, from how *teachers* mediate information about the brain to how a *variety of local and national factors* influence how teachers mediate information about the brain. These factors are undoubtedly significant and are part of the analysis but it has been necessary to balance this with the voices of the teachers as revealed in their articulation of views and experiences. To not do so undermines the personal agency, autonomy and individuality of the teachers' responses and their own descriptions of their experiences. CHAT has, therefore, been subsumed into a wider thematic analysis, utilising interpretative phenomenological analysis (IPA). The theoretical underpinnings of this wider analytical basis are discussed in chapter 3.5.

To further illustrate the dimensions and frameworks that CHAT offers, below I consider an example with a teacher as the subject. The teacher brings a range of pre-existing views and experiences to his/her working context. Some of these views will have an impact on how the teacher responds to the question of the relevance of knowledge of the brain and educational neuroscience in the classroom. For example, the teacher may have views about research and its role in the classroom, they may have had good and/or bad experiences of the introduction of research-based practice, they may be sceptical or may be enthusiastic about what neuroscience may offer, they may simply feel too busy at the time to explore information from neuroscience. The teacher's confidence with science in general may also influence their willingness to engage with this information. This biography is bound to influence the teacher's ongoing practice. However, a CHAT analysis will look beyond the teacher, to include wider contextual elements that affect how the teacher works and develops professionally. The teacher's individual activity, within a CHAT analysis, would be considered in terms of both how it contributes to the teacher's personal objectives and how it contributes to the objectives of the teams in which the teacher functions and the objective of the institution or organisation.

The teacher's actions will also be governed by rules within the work context, as well as the teacher's personal interpretation of these rules and the interpretation of any team, such as a department or faculty, of which the teacher may be part. There may be contradictions in the enactment of these rules, between teacher and team/department colleagues, between department, between departments and school leadership and so forth. Teams/departments can be viewed as interacting activity systems, as can all divisions within the community. There may be further contradictions where use of new tools is not well supported by adherence to old rules.

I refer above to a number of potential elements of the teacher's work community, such as team/department colleagues, other departments/teams and school leadership, which operate at different levels frequently described as senior and middle. This indicates the existence of hierarchies within the community. Account should be taken of a wider community, which may be an education authority, an academy trust, inter-school collaborations within those communities or beyond them, school governing bodies and external agencies that regularly supply services to individual schools. Beyond this community is the over-arching presence national government and international developments in education in general and in the case of this thesis research about the brain and educational neuroscience in particular.

In terms of objects and outcomes, there may be a variety of each, some shared willingly within the community and some that are a concern of, or even privately sought by the teacher. How well individual and/or team objects support intended whole school outcomes may be a further source of tensions and contradictions.

The tools through which the teacher carries out their work will clearly have an impact on working practice and outcomes. In the case of the use of neuroscience in support of the work of teachers and the learning of students, the tools are expanding rapidly and haphazardly, so these may be introduced through the teacher's own encounters with articles and books promoting allegedly neuroscience-based practices or these may be promoted by other sections of the school community. These may also be acquired through dialogue with other teachers and may also come in the form of software promoted by school leadership.

In summary, CHAT has informed the analysis of my data, influencing how the working contexts of the participating teachers are understood and the coding and identification of themes through which to further examine the data.

3.3.7 Widening the Theoretical Perspective

Having concluded that CHAT alone would not provide a complete working framework through which to explore my data for the reasons explained in chapter 3.3.6., a number of other approaches were considered, before deciding to adopt a thematic analysis approach, guided by interpretative phenomenological analysis. Here I briefly explain which other approaches were considered and not adopted. I am aware that although these approaches were not adopted, my investigations of each of them will have influenced my own views of my research. I return to the question of the significance of researcher values in chapter 3.4.1.

A *case study* approach, focused on each interview participant, was explored. However, this approach would require further sources of data, such as documents, observations, reports, letters, emails and so forth, in order to explore each case in depth. These sources might reveal little, if anything, about the teachers' engagement with and mediation of neuroscience.

Similarly, an *ethnographic* approach was rejected as to observe and be amongst teachers on a day to day basis would likely only very occasionally yield data about their mediation of knowledge of the brain and neuroscience.

A *grounded theory* approach was ultimately rejected as my intention has been to develop strands of understanding of how teachers mediate information about the brain and educational neuroscience, rather than to produce a theory about how this occurs. The interview sample would need to be larger for this approach and an attempt to distil a theory would have run the risk of narrowing discussion, rather than drawing attention to any number of factors that are relevant to teachers' mediation of information about the brain and educational neuroscience.

Whilst CHAT acknowledges the relevance of individual biographies, in this case of teachers, I concluded that a *narrative analysis* approach might over-emphasise biography and introduce chronology requirements that might ultimately prove superfluous.

Conversational Analysis has some significance, in that I have examined how teachers express their thoughts about the brain, their choice of words and their use of analogy, for example. However, there are dangers of pursuing this approach further. Silverman raises concern, whilst commenting on problems that can occur when researchers work exclusively with interview data: 'blinded by a vision of people's 'deep interiors', they remorselessly focus on accessing the inside of people's heads' (2013, p.41). This has alerted me to the need to take care to avoid lapsing into a psycho-analytic approach and instead to ensure that my coding, themes and interpretations are based on either clearly articulated data (i.e. semantic) or underlying ideas, assumptions or theories of the participants (i.e. latent). Previously, in chapter 3.2.2., I have responded to Silverman's challenge that too much emphasis is often placed on interview data despite the ready availability of other more suitable data.

3.3.8 Thematic Analysis

Thematic analysis looks for themes or patterns across data sets. Braun and Clarke (2006) point out that most forms of qualitative analysis are to a large extent thematic and that thematic analysis is a 'theoretically flexible approach' (2006, p.2). I have found this helpful, in that it has encouraged me continue to pursue Creswell's idea of emergent design, appropriate for the research in question. However, it has still been necessary to draw on some more precise guidelines. To fail to do so could render my findings open to Antaki et al.'s criticism (2003) that thematic analysis can be misused as an 'anything goes' approach. Antaki et al. also describe several problems that can emerge within attempts to analyse interview data, for example where the spotting of features is regarded as analysis, where data are used to support the researcher's views or where data from a small sample are treated as generisable.

Additional guidance and rigour has been provided by Interpretative Phenomenological Analysis (IPA). In chapter 3.6 I explain the suitability of IPA as well as the guidance it offers and the considerations it raises.

3.3.9 Interpretative Phenomenological Analysis (IPA)

Pietkiewisz's and Smith's description of IPA (2014) helps clarify its suitability for the aims of my research: 'with IPA, we aim at producing an in-depth examination of certain phenomena, and not generating a theory to be generalised over the whole population' (p.4). They suggest that the aim of IPA is instead to generate 'rich and detailed descriptions of how individuals experience phenomena under investigation' (p.4). In the case of my research, the aim has been to generate descriptions of how teachers experience information about the brain and educational neuroscience, in order to further understand teachers' difficulties with and hopes for educational neuroscience.

IPA takes a naturalist epistemological position, drawing on the experiences and language of participants. It also embraces a constructivist viewpoint, in that it recognises a socially constructed dimension within the articulations of participants. For this reason, Braun and Clarke (2006) advise that coding and analysis should not overlook context. As Pietkiewisz and Smith point out, there is 'no such thing as an uninterpreted phenomenon' (2014, p.8), hence their suggestion that given the further interpretations of the researcher the process might be described as a 'double hermeneutic' (p.7). It is an inductive procedure, wherein themes are determined from the semantic or explicit content of the data and through latent or interpretative examination of the data. I recognise that the researcher cannot play an entirely neutral role in this process and this is considered in chapter 3.4.1.

Two questions posed by Moustakas in his guidance for phenomenological research (1994) also help capture the aims of my data gathering process. Moustakas firstly asks what is the participants' articulation of their experience of the phenomenon and secondly what has affected how participants experience the phenomenon. To this I have added a third question, as advised by Silverman (2013), who asks what have participants actually done as a consequence of their experience of the phenomenon.

Ultimately, the IPA approach is intended to leave readers feeling, as Polkinghorne puts it, that 'I understand better what it is like for someone to experience that' (1989, p.46).

3.4.1 The Role of the Researcher in Interpretative Phenomenological Analysis

It is important when using IPA to recognise that the researcher cannot adopt a passive or neutral position. It is the researcher who decides what is of interest within the data and subsequently what becomes the key themes that are explored. Indeed, although themes are inducted from the data, it is the researcher who devises the questions that are posed to participants and these questions inevitably reflect interests of the researcher, which in turn will be evident in the data. Ely et al. (1997) take a clear view of the notion that themes simply 'emerge' from the data, stating that thematic analysis

> can be misinterpreted to mean that themes 'reside' in the data, and if we just look hard enough they will 'emerge' like Venus on the half shelf. If themes 'reside' anywhere, they reside in our heads from our thinking about our data and creating links as we understand them (pp.205-206)

Nor can the researcher view their role as simply 'giving voice' to participants, since the researcher makes selections from the data in order to support the researcher's lines of inquiry and arguments. It is important, therefore, that the researcher recognises what it is that he or she seeks to know more about and is thus able to see the active nature of the researcher role. Similarly, in using semi-structured interviews the researcher becomes an instrument of the data gathering process, engaging in conversation with each interview participant. This can require prompts, suggestions and the introduction of new information as the conversation progresses. It is important to ensure that the participant is not led by the researcher. In reality, it was possible to make the interviews feel very conversational, in order to afford the participants as much scope as possible to share their thoughts.

In his considerations of the role of existing beliefs in understanding phenomena, phenomenologist Edmund Husserl, often considered to be the founder of the phenomenological movement, proposed the concept of *epoché* (cessation), or *bracketing* of personal beliefs (for example in *Ideas*, 1913). In practice, this appears to be very difficult to achieve and in any case, according to Tufford and Newman (2010) a process of which the cognitive mechanisms are not well understood. Husserl's student and colleague, Martin Heidegger moved away from the idea that such a pure, descriptive phenomenology was possible, which led to his conception of interpretative or hermeneutic phenomenology, in which understanding of phenomena is seated in individual interpretation, in turn influenced by social constructions (as he proposed in *Being and Time*, 1927).

There is no need here, however, to become further entangled in debate about the merits of Husserl's and Heidegger's approaches to phenomenology. My purpose in drawing attention to this debate is to acknowledge that the challenge of separating the researcher's beliefs, interests and assumptions from his or her interpretations of the data has been an ongoing one for phenomenology.

3.4.2 Researcher Assumptions

A number of assumptions, applicable to qualitative research and in contrast to many of the assumptions of quantitative research, are described below. Assumptions can fall into two broad categories – philosophical and methodological. Drawing on Creswell (1994), Guba and Lincoln (1981) and Merriam (1998), assumptions for my research are outlined below in table 3.1.

Assumption	Qualitative Viewpoint
Ontological	Multiple realities exist, as may be seen in the differing views and perceptions of participants.
Epistemological	Interaction between researcher and participants is inevitable.
Axiological	Values and biases of the researcher and participants will be of significance.
Rhetorical	Interactions between researcher and participants may be relatively informal, conversational, will allow for personal voices and will take interest in the use of words and phrases.
Methodological	Research design is emerging, with inductive categorisation developing during the process. Participant contexts are considered significant. The researcher seeks to explore the processes and meaning making experienced by participants.

	The researcher inevitably mediates these through his or her own experiences and is a key instrument of data collection. Findings are richly descriptive and are intended to develop understanding and further hypotheses. There is no assumption that the findings are generisable.

Table 3.1: researcher assumptions for qualitative research

In relation to the specific focus of my research, I make the assumption that there are aspects of knowledge of the brain and the debates of educational neuroscience of which teachers can usefully be aware and that are likely to take on more significance over time. However, my view of how this may come about is open and willing to be guided by the distillation of views expressed by teachers participating in my research and in subsequent research into this issue.

3.4.3 Limitations

My research shares some of the common limitations identified in qualitative research. The sample is relatively small, since research of this nature needs to focus closely on a small number of individuals. The survey responses do increase participation and give me access to the knowledge and views of a wider cross-section of teachers, though not to the extent that findings can be generalised across the whole of the teaching population in England or the United Kingdom.

Availability of interview participants and time restraints have an impact on the use of this method of data gathering. Interview participants were generous with their time and engaged in extensive dialogue, though in every case had time allowed there is likely to be more that might have been discussed. This has generated further lines of inquiry, some of which are considered in chapter six. Time has also been significant in that some practices, at least in some schools have changed over the period during which my research has been undertaken. Fewer schools now require teachers to identify planning for so-called visual, auditory and kinaesthetic learners (VAK), though this was widespread practice when my data gathering began. Teachers raise this as something they perceive to be an aspect of knowledge of the brain influencing the understanding of learning. This view would most likely be less evident if the same data gathering procedure was undertaken now. Willig (2008) points out that researchers should expect to receive different answers to reframed versions of a question. Similarly, the same question asked at a different time is likely to elicit different answers. Participants' references to VAK, however, remain relevant, since they form part of the background to their subsequent learning about teaching and the brain and in some cases remain influential on current practice.

The presence of the researcher can affect participants' responses. It was important to try to put participants at ease, particularly about the extent of their knowledge. It was made clear both in interviews and in the survey that the data gathering was not intended as any kind of 'test' of knowledge of the brain, though some participants may still have felt as if it was. This issue is considered further in chapter 3.5.1.

Participants' responses can also be affected by self-reporting, memory and attributions that may not be accurate but cannot be verified. In the case of my research, attribution is a potential problem when participants have been asked about sources of knowledge of the brain and memory has also posed difficulties when participants have struggled to recall such information.

The presentation of qualitative data and findings can present problems of confidentiality and anonymity. In the case of my research, it is not possible to know who the survey respondents are. An attempt to work this out could conceivably be made from the demographic data for individual participants, however that data is held securely and only available to the researcher. The interview participants are given pseudonyms and whilst contextual details of their respective schools are described, no school names or locations are disclosed.

3.5.1 Ethical Considerations and Ethical Approval

Confirmation of ethical approval for my research can be seen in appendix two.

Two key sources of guidance on ethical matters have been The British Education Research Association (BERA) Guidelines for Ethical Research (2011, updated in 2018) and the British Psychological Society (BPS) Code of Human Research Ethics (2014).

The privacy of individuals has been protected through anonymity for survey participants. For the interviews, participants have been given pseudonyms and contextual details have been written with care to avoid features that might render the individuals or their schools identifiable.

Participants have a right to know the purpose of the research to which they are contributing. This was presented to survey participants in the introduction to the survey, along with clarification of their right to withdraw their responses in whole or part at any stage. Interview participants received an information sheet and signed a participant consent form (see appendices three and four). Interview participants have also had the opportunity to view the transcripts and the rich descriptions of the interviews, to ensure that their comments have been represented as they intended to convey them. Interview participants' consent has been re-affirmed as the research has progressed.

Although no aspect of my research can be considered to pose a risk to participants within the definitions of risk offered by BERA and BPS, there is still a risk of undermining participants' professional knowledge, if data gathering is undertaken in a manner that may imply that this knowledge should be greater than it appears to be. I took a decision to raise this directly and clarify that my interest is in what teachers have to say about the brain and educational neuroscience, regardless of how highly or otherwise they rate their knowledge of these; all views and comments have relevance to my investigation. Efforts were made to approach this with sensitivity and to recognise that knowledge of the brain and educational neuroscience are not in themselves indicators of a teacher's professional effectiveness.

All data has been stored electronically, protected by passcodes that are known only to me. The only exception to this is the paper copies of the interview transcripts, which I have annotated as part of the analytical process. These copies are held in locked storage of which I am the only keyholder.

Finally, no participants have been offered any form of incentive to become involved in this research.

3.5.2 Bias

Reference has already been made to the influence of the researcher's personal views, beliefs and values and the difficulty in separating these from those of the research participants within qualitative research (chapter 3.3.9, chapter 3..4.1). Potentially, this may lead to bias, defined as differing treatment of groups or individuals that may be unfair, or distorted treatment of data. Problems of bias can occur at any stage of the research process and across all types of research design.

In the case of the research presented in this thesis, several potential areas are key considerations for the potential of bias. The first of these is in the selection of participants for both data sources – interviews and survey. The survey was made available initially to teachers who I have either worked with, have met in other professional circumstances or have met outside of a professional context. Though these teachers may be aware of some of my views about some of the survey questions, they were also encouraged to pass on the survey details to other colleagues and I was also sometimes given contact details of other teachers, whom my contacts thought might be willing to complete the survey. The survey was also made available through social media. Ultimately, it is not possible nor desirable to know exactly which teachers completed the survey; survey responses are entirely anonymous and any potential bias in my initial choices is likely to have been countered by the wider distribution of the survey.

In designing the survey and the interview questions, I have been aware that personal bias and beliefs can be communicated through these. Therefore, the questions have been posed in such a way that a range of answers are possible. In the later stages of the survey and throughout the interviews, there has been opportunity for participants to further expand their comments and the right to withdraw any aspect or the total of any individual's contribution to the data has been raised throughout the data gathering process. Participants were also made aware that they may withdraw part or all of their contribution at any stage, not just while data gathering was on-going.

Bias can be supported by the selection of which data are given emphasis. It may be tempting to ignore responses that do not support the researcher's views or conclusions or that do not support emerging patterns during analysis. This has, in fact, had something of a reciprocal effect, in that some of my own opinions and beliefs about the role of knowledge of the brain and educational neuroscience in the professional thinking and day to day activity of teachers have been reconsidered as a result of aspects of the data.

Qualitative research is vulnerable to accusations of bias when the analytical methods are not made clear (Morse et al., 2002). In this chapter, I have attempted to identify the evolution of the analytical approach adopted and in applying the approach have attempted to remain congruent with the proposed approach. Where possible, this has been supported by triangulation with participants, such as three interview participants providing their views on the survey data. Interview participants also reviewed chapter four's rich descriptions of their interviews and some minor amendments were made, where my representation of their views did not accord with their intended message. I comment further on matters of triangulation in chapter 3.5.3 below.

A further consideration for bias can be the avoidance of null findings, especially if the researcher seeks publication and believes that negative findings may reduce opportunities for publication. Opportunities to publish in my case have come about where there has been an interest in the full range of findings and conclusions that may be drawn from my research; I have not been expected to support any existing viewpoints on the efficacy or otherwise of knowledge of the brain and educational neuroscience for teachers. Neither have I been expected to promote any products and have no conflicts of interest arising from any potential funding body.

3.5.3 Triangulation

Within quantitative research, triangulation is often described as a means of supporting and testing validity. Validity is an increasingly less favoured term in qualitative research, since qualitative findings do not often fit into the positivist implications of the quantitative definition of validity. Reissmann (1993) instead uses the words persuasiveness, authenticity and plausibility, to which Butler-Kisber (2010) adds credibility and trustworthiness.

A number of types of triangulation exist. Evans (2009) draws attention to the triangulation of sources, methods and investigators as appropriate approaches to research in schools. The first of these is a part of the design of my research. This is evident in two ways. Firstly, there are two main sources of data (interviews and the survey), each approaching the field of investigation in different ways and therefore uncovering both common and less common responses from participants, that can then be compared and contrasted. Although I have regularly pointed out that the interview participants' different experiences and contexts does not mean their responses can be interpreted as representative of each context, the variety does naturally support triangulation. Secondly, three interviewees took part in the process of interpreting the survey data, during their second interview. It is apparent in chapter four that this has been a valuable process, as there is evidence of different interpretations of the survey findings between each of the three teachers who undertook a second interview. These differing interpretations have enlightened my own analysis, or as McNiff et al. advise:

> aim to triangulate the data; that is, obtain data from more than one source to use as evidence to support a particular explanation, and show how the data from these sources all go towards supporting the explanations you give of your situation (2003, p.69).

Triangulation does have its critics within the field of qualitative methods. Silverman (2001) takes the view that the expectation of triangulation undermines the intrinsic value of the inherent worth or advantages of individual researchers' sources and methods.

3.6 Chapter Summary

Chapter three has sought to trace the development of the methods adopted for and the philosophical underpinnings of my research. It accounts for modifications to the research design and recognises the process of ensuring that the methods are used in a manner appropriate to the research. To this end, the guidance and views of a number of leading authors on qualitative research, on Cultural Historical Activity Theory and on Interpretative Phenomenological Analysis have been assimilated.

Assumptions of qualitative research and of my own position have been examined and the final sections of chapter three are designed to reflect that limitations, ethical matters, triangulation and questions of bias have been given due consideration, during the various phases of planning, data gathering, analysis and writing.

Chapter 4: Data

4.1 Introduction

This chapter introduces data gathered from the two sources described in chapters 3.2.3 and 3.2.4. These are the online survey and the eight semi-structured interviews undertaken with five interviewees. Chapter 4.2 is a summary of the survey data. Percentages are used in the summaries of survey questions that were answered by all participants and raw figures are used for questions that were not answered by all participants. This is to avoid unnecessary confusion, for example between percentages of the total participants and percentages of a smaller number of participants. In either case, as the total number of participants is so close to 100 (n=102), it is a simple calculation to convert responses to percentages.

Chapters 4.3.1 to 4.3.5 contain rich description accounts of the first interview with each of the interview participants, for which the initial questions can be seen in appendix one. Chapters 4.4.1 to 4.4.3 are rich description accounts of interviews six, seven and eight, in which three participants each discussed the survey data. The format of the chapter is summarised in table 4.1. The data is approached analytically and discursively in chapter five.

Chapter	**4.2**	**4.3.1 – 4.3.5**	**4.4.1 – 4.4.3**
Contents	Survey data	Semi- structured interviews 1 - 5	Response to survey data interviews 6 – 8

Table 4.1 Chapter 4 format

4.2 Online Survey Summary

4.2.1 Demographic Information (Survey Questions 1 – 6)

The survey was undertaken by 102 teachers, 36 of whom describe themselves as primary school teachers and 66 secondary school teachers. The secondary school teacher specialisms cover the whole of the secondary curriculum, though there is a predominance of teachers of English (10/9.8%) and teachers of arts subjects (20/19.6%). The teachers are based in a mix of schools in urban, suburban, semi-rural and rural locations, largely in England with a small number in Wales. 30 (29.4%) teachers are male and 72 (70.6%) are female, which over-represents the greater number of women teachers in England. There is a spread of age ranges, with the largest number of teachers being between the ages of 36 and 50 (39/38.2%). Viewed as a whole, the survey participants represent a reasonable cross-section of the teaching workforce in England, though this is not meant to imply that their views and responses are a precise representation of those of the whole of the teaching workforce in England.

Survey question 6 asked the teachers to comment on the extent to which the neuroscience of education or information about the brain had featured in their own and their school's professional development work during the preceding five years. Nearly half the teachers, (43/44.9%) responded that this had never been a feature of their professional development work either personally or within school.

4.2.2 Responses to Survey Question 7

Question 7 contains 25 statements, to which the participants were asked to give a Lickert scale response, across the five options of strongly agree, agree, neither agree nor disagree, disagree, strongly disagree. Below, in table 4.2, the responses are considered in terms of how accurately they match current neuroscientific understanding, alongside the data for participants neither agreeing or disagreeing. The middle column of table 4.2, under the heading 'Accurate Responses' presents the total number percentage of responses that are in accord with the correct current interpretation of the statements, which is to say whether current neuroscience agrees or disagrees with each separate statement. In some cases, this means the participant is correct to agree with the statement and in other cases correct to disagree. For example, the first statement (7.1) is now known to be accurate and the survey data shows that 87.3% of participants know that this is accurate since they agreed with the statement, whereas for statement 7.2 only 28.4% disagreed with a statement that we know to be inaccurate. To avoid any suggestion of a pattern to which participants might attune, the response currently believed to be the correct response to each statement varies randomly between agree and disagree responses.

Statement	Accurate Responses	Neither Agree nor Disagree Responses
7.1 The brain can produce new connections right into old age	87.3% agree	7.8%
7.2 In general, we only use 10% of our brain	28.4% disagree	27.5%

7.3 Information is processed in the same way by everyone's brain	91.2% disagree	4.9%
7.4 Physical exercise can support the efficiency of the brain	94.1% agree	4.9%
7.5 Emotional experiences affect the chemicals in the brain	95.1% agree	2.9%
7.6 The brain 'prunes' or deletes neural connections that are not regularly used	58.1% agree	37.3%
7.7 Sleep affects the learning potential of the brain	93.1% agree	4.9%
7.8 Mentally rehearsing a physical act can activate the same brain areas as the act itself	75.5% agree	22.5%
7.9 Each side of the brain is exclusively responsible for different types of mental activity	35.3% disagree	23.5%
7.10 Scientific evidence shows that listening to Mozart can improve long term brain function	11.8% disagree	52.9%
7.11 The brain is not active during sleep	95.1% disagree	1%
7.12 Learning is longer lasting when created in multi-sensory ways	88.2% agree	7.8%
7.13 Remembering a phone number to use once and a past experience use the same type of memory	58.8% disagree	37.3%
7.14 The physical actions of music making link with the brain's pleasure centres	73.5% agree	24.5%
7.15 Emotions can affect learning	99% agree	0%
7.16 Concentrating on one difficult task is more effective than	38.2% agree	46.1%

multi-tasking		
7.17 Mental ability is inherited	46% disagree	31.4%
7.18 Specialist training can cause identifiable differences in areas of the brain	73.5% agree	26.5%
7.19 There are structural and biochemical differences between male and female brains	61.8%	26.5%
7.20 General intelligence is fixed and cannot be increased	82.3% disagree	8.8%
7.21 At birth we have the capacity to learn e.g. music/language of any type, from any culture	97.1% agree	2.9%
7.22 Our brains have a natural tendency for exploration	95.1% agree	2.9%
7.23 Imitation is an important part of learning	93.1% agree	5.9%
7.24 Everyone has one dominant preferred learning style	44.2% disagree	22.5%
7.25 The 'fight or flight' response affects learning	82.3% agree	22.5%

Table 4.2: Accuracy of Responses to Survey Question Seven

4.2.3 Responses to Survey Question 8

Survey Question Eight asked participants, if they could, to 'describe a learning and teaching episode that you have led, where you can identify the impact of your conscious knowledge relating to the brain'. This question was answered by 38 of the 102 participants (37.3%). The responses are categorised in table 4.3.

Categories of Responses	**Number of Responses (from total of 38)**
Using multiple modes of sensory input (described as 'VAK')	11
Supporting SEND, behavioural and emotional needs	8
Whole school approaches (Social and Emotional Aspects of Learning (SEAL), Mindset, Building Learning Power, Big Brain Day)	5
Developing practical skills through imitation and repetition	3
Using lesson knowledge in different ways	2
Knowledge of brain used to assist in the devising of interventions	1
Mindfulness activities	1
Teaching about metacognition	1
Use of the outdoors	1
Teaching revision techniques	1
Presenting information to a faculty meeting	1
Teaching Modern Foreign Languages	1
Concerned about not knowing anything about the brain	1
Incomplete response	1
Total	38

Table 4.3 Responses to Survey Question Eight

4.2.4 Responses to Survey Question 9

45 of the 102 participants responded to Survey Question Nine. This question asked participants to 'describe any aspects of your teaching that you think might benefit from greater knowledge of neuroscientific processes that could be activated with your students'. Table 4.4 summarises the responses. Some participants noted more than one aspect, resulting in 49 separate responses, identifying 30 aspects across the 45 participants who chose to answer the question. Three participants made additional qualifications to their comments. These are noted at the foot of table 4.4

'Aspects of your teaching that you think might benefit from greater knowledge of neuroscientific processes'	**Number of Responses (from 45 participants making 49 responses)**
All aspects	8
Memory and retrieval	7
Developing pupil confidence/overcoming fears	2
Balance of rote learning and application of skills	2
Scientific clarification of learning styles	2
Pupil independence	2
Revision	2
Neuroscience knowledge as a confidence booster for teachers	2
Understanding SEND	2
Retraining of the brain/neuroplasticity	2
Using lesson knowledge in different ways	2
Mental processes in learning new skills	1
Practical ideas for learning styles	1

Mismatch of pupil verbal and written skills	1
Teacher empathy with contemporary children	1
Personal, social, health education (PSHE)	1
Planning	1
Consequence	1
Empathy	1
Learning through mistakes	1
Implicit versus explicit learning	1
Social and emotional difficulties	1
Brain development in younger children	1
Deeper learning	1
Developing positive beliefs about learning	1
Responding to individual difference	1
Understanding communication difficulties	1
Behavioural issues	1
Persistence	1
Metacognition	1
Problem solving	1
Total suggested aspects	30
Qualifying comments, made by 3 participants: • This whole area is fascinating • Should know more about this • Need time to explore this properly • I feel very ashamed I don't have more knowledge but time is a constant battle against us and it makes such reading very difficult	

Table 4.4 Responses to Survey Question Nine

4.2.5 Responses to Survey Question 10

Survey Question Ten explores the experience of the survey participants of five approaches to learning that have recently been popular in schools in the UK. These are learning styles, BrainGym®, brain training, VAK (visual, auditory and kinaesthetic) and Multiple Intelligence Theory (MI). Participants were asked if each of these plays any part in their teaching or had done so in their teacher training. As with Survey Question Nine, some responses contain qualifying comments and views. As the online programme took participants to each section one at a time, meaning that they were unaware of what was asked on the next page, some participants discussed VAK under learning styles. Each of the five approaches to learning drew a different number of participant responses. Some of the responses indicated acceptance or approval, some disapproval, whilst others made more neutral comments. With the exception of learning styles, the approaches were unfamiliar to some participants, at least under these titles. Table 4.5 summarises the responses.

Approach to learning	**Number of participant responses**	**Support or approval**	**Neutral**	**Disapproval**	**Not encountered**
Learning styles	62	21	37	4	0
VAK	51	12	33	2	4
Brain-Gym®	47	6	32	8	1
Multiple Intelligence Theory (MI)	38	6	23	3	6
Brain Training	28	1	10	2	15

Qualifying Comments	
Learning styles	• Have worth only if used together and not exclusive of one another • Discredited now • Each individual student has a preferred learning style • Don't believe there is such a thing anymore
VAK	• Combine all three in each lesson • Knowing that some children prefer images to just being told is useful • Requirement to use • Nearly made me quit • Multi-sensory expectations …. have broadened experiences for pupils • We are still encouraged to use this • Has fell (sic) out of favour recently • Encourages students to use a non-preferred learning style • Simplistic
Brain-Gym®	• Only experienced in INSET and would be very interested to know more • A myth • Annoying • Load of rubbish • Has evolved into my own exercises • Use occasionally when the students look bored • Warms up children ready to learn and focuses them for the day ahead • At least once a day • Encouraged to use by my school • Have adapted exercises • Really helped children to wake up and concentrate • Simplistic • Cross body work a daily feature • Brain Gym (sic) techniques everyday
Multiple Intelligence Theory	• Should remember more than I do • Spearman 7 intelligences • Requirement to use • More of the same • Not sure I agree with the separate nature of intelligence as proposed by Gardner • Seemed to give teachers more

	acceptance of pupils' differing approaches to learning • Nice theory • Focused whole school work on MI. Mixed age group teaching in 'intelligence' groups • Recognition that everyone is good at something • Received training and use daily
Brain Training	• Tried a little Mindfulness last year • Discredited now • Use in the classroom, can effectively see progress • Use 'games' to engage the interest of some children • Personal brain training programme tried • Use of DS (e.g. mental arithmetic)

Table 4.5 Responses to Survey Question Ten

4.2.6 Responses to Survey Question Eleven

Survey Question Eleven asked participants to assign percentages to represent the relative influence on educational potential and achievement of genes, school experiences and environment beyond school. There was also an option to add any other factor that participants considered relevant. Once again, there was a small number of qualifying comments added to responses. Tables 4.6.1.to 4.6.5 summarise the responses.

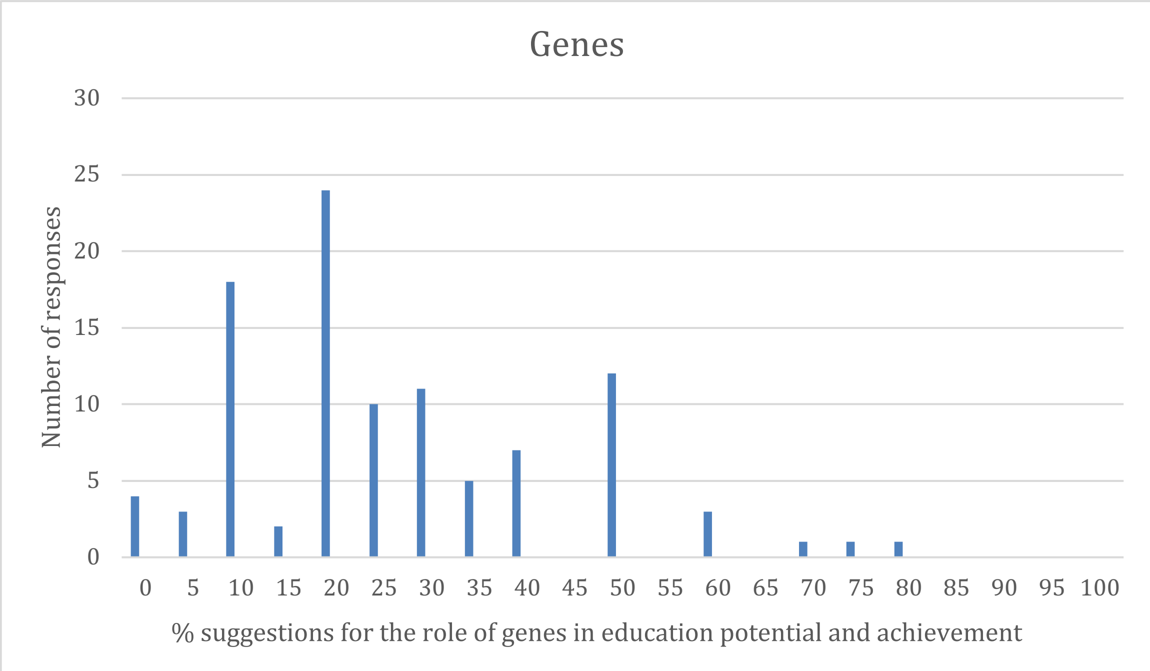

Table 4.6.1 Participant suggested percentages for the role of genes in education potential and achievement

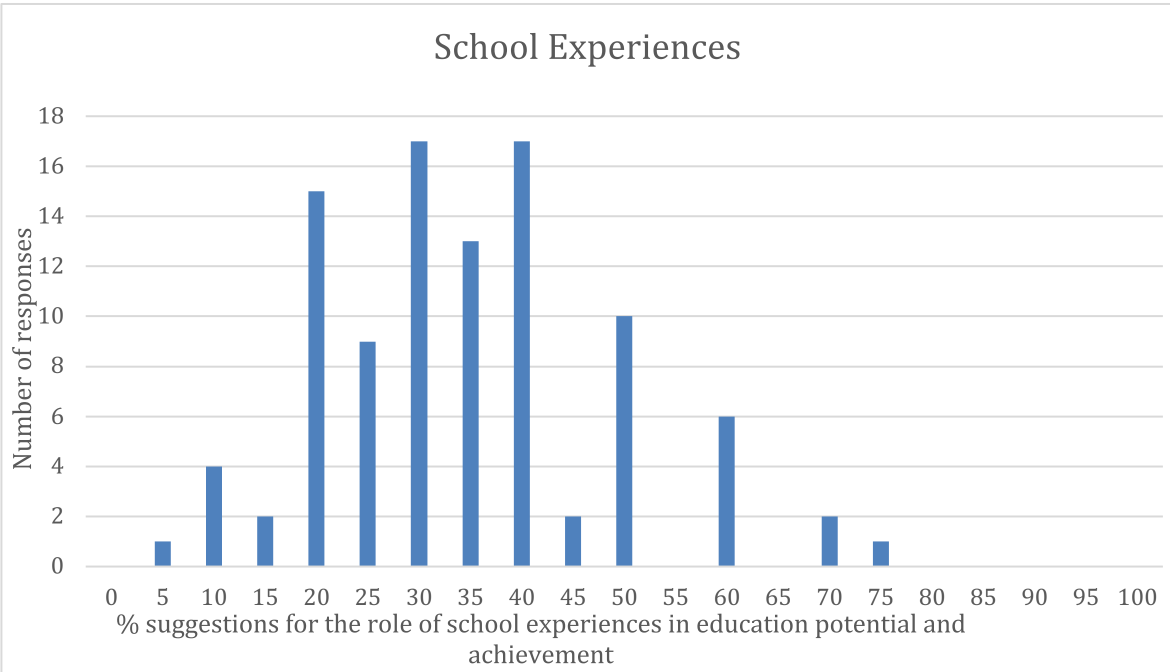

Table 4.6.2 Participant suggested percentages for the role of school experiences in education potential and achievement

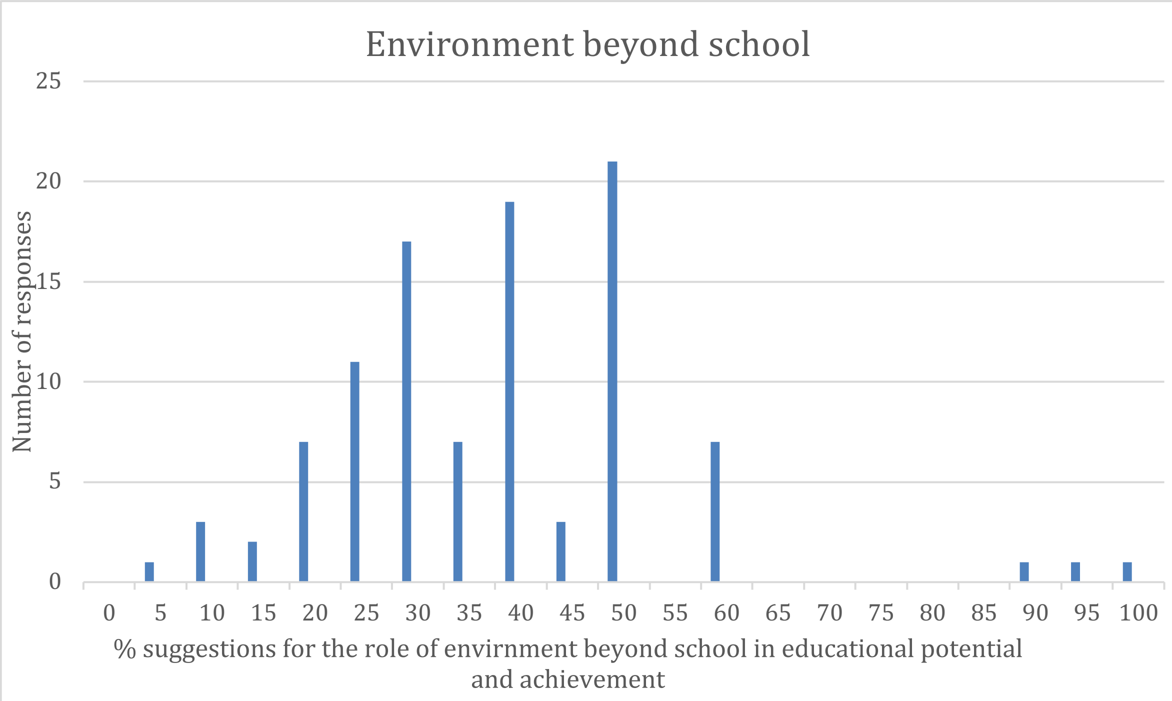

Table 4.6.3 Participant suggested percentages for the role of environment beyond school in education potential and achievement

For each of the three areas above, a small number of participants added the qualifying comments listed in table 4.6.4.

Genes	School Experiences	Environment Beyond School
Depends on age including adolescence	Depends on the quality of the provision	Depends on access to wider environment
Depends on individual genetic profile		

Table 4.6.4 Participant qualifying comments added to responses to Survey Question 11.

11 participants responded to the option to add any other factor that they believed to be a significant influence on educational potential and achievement. These responses are gathered in table 4.6.5.

Additional Influencing Factors
Child's own interest in a particular subject/area that is down to their own mind not to do with genes
10% Friendship groups
Early years attachment
Combination of factors above (i.e. genes, school experience, wider environment) different for each person
15% Peer and social 'status'
30% Physical and emotional wellbeing
15% Peer groups and social pressure
40% Mindset of hard work and I can give it a go! Growth mindset!
Assessment of individual need
Emotional and other experiences
Self-belief and attitude to learning 60%

Table 4.6.5 Additional influencing factors on educational potential and achievement added by participants in response to Survey Question 11, (including percentage potential influence suggested by participants)

4.3 Interview Data

4.3.1 Introduction

Each of the eight key interviews is written up below, in the manner described by Creswell and Miller (2009) as 'rich' or 'thick' description (p.124). This approach draws out context and additional details alongside the words used by interviewee and interviewer, in keeping with rich description as proposed in the qualitative paradigm captured in table 3.1. Paraphrasing Denzin (1989), Creswell and Miller emphasise that rich description is helpful in ‘bringing a relationship or interaction alive’ and in ‘providing a detailed rendering of how people feel’ (2009, p. 129).

At this stage, each interview is treated as an individual data source, so description and commentary relates only to the interview in question, with no attempts to link the interviews together. That task is instead undertaken in chapter five, wherein both the collective themes gathered through the interview data and themes that are deemed important even though they may have emerged from just one interview, are considered further.

The core questions for the first five of these semi-structured interviews can be seen in appendix one. As the interviews are semi-structured, the questions sometimes naturally weave into the conversation. Variations in how the questions are presented are reflected in the interview descriptions. The descriptions of interviews one to five are each preceded by a brief professional biography of the participant, along with brief details of their school. Each participant is given a pseudonym.

Interviews six, seven and eight were undertaken in a different format. The two most experienced teachers and the most recently trained teacher amongst the participants were asked to consider the survey data that I had gathered. This is the data that is summarised in chapter 4.2. The participants each discussed the complete survey data set. The three participants were free to consider the data and comment on what they found of interest and discussion then developed around their observations. This makes for an informative triangulation of the survey data, since each participant reflects differently on some of the survey data and chooses to focus on different things to each other and also on different things to me.

The points that struck me as most significant whilst writing up each interview description are summarised at the end of each interview. This is in preparation for their further analysis in chapter five. Through this collation of the key points, one can see connections between them, which in turn contributes to the development of the seven over-arching themes through which all the data is analysed in chapter five.

4.3.2 Rich Description: Interview 1

Interview participant 1 (‘Kath’) is an experienced teacher who currently works in a secondary school, having initially taught in further education. Her school has faced many challenges for some time, serving a disadvantaged area and receiving many pupils from homes struggling with substance abuse and unemployment. In its most recent Ofsted inspection, for which the report was published in January 2017, the school was given an overall judgment of ‘inadequate’. Kath teaches a number of subjects. She makes reference to this during the interview and also explains why she teaches a considerable number of classes that the school considers to be particularly difficult. Her interest in the brain has contributed to her thinking and practice in tackling the challenges her work presents.

In describing the sources of her knowledge of the brain for question one, Kath presented a notable academic foundation. She referred to her initial degree being in psychology and her master's degree in education, in each of which 'there was quite a bit about brain development' (line 8). She regarded 'psychology, neuroscience, education, how they interact' (line, 9-10) as a personal interest and it appeared that her psychology background gave her some confidence with which to pursue this interest.

When asked what she would suggest stood out as influential on her classroom practice (question 2) amongst the sources Kath had listed and the many books that she had purchased, Kath was not specific in her response. Names eluded her, though she did refer to 'chapters from medical textbooks, on-on (.) er teenage, adolescent brain development' (lines 21-22). Interestingly, she further described how she has been able to access the literature. Having found an article abstract of interest, Kath has been able to utilise the fact that she has 'always known enough people who work at universities' (line 25) to be able to get copies of complete articles, an option not available to all teachers.

Having herself raised the issue of access, Kath suggested that 'access is the – the biggest difficulty towards getting up-to-date information' (lines 29-30), but not just because of the question of journal articles. She added that the journey from academic article, to academic book to 'popular, consumable book' (line 32) is a time consuming process that often leads to information being out of date by the time it is more readily available.

At this point Kath did make a more specific reference, to “Hattie’s book on evidence-based research’ (line 41). Although Hattie’s work makes very little reference to neuroscience, the comment that this reference brought about again reflects Kath’s confidence in exploring this field:

> I like to try different things and I like to try and apply knowledge from one area to another. So I like to apply what I’ve learned about the development of the brain to how children learn. (Lines 41-44).

This also hints at a certain freedom to experiment that Kath feels she enjoys in the context of her teaching post and she explains this later in the interview.

Kath’s response to question three, which asks about the impact of knowledge of the brain and the sources discussed in response to questions one and two, displayed an interesting position that again hinted at her confidence in exploring the field for herself. She stated that she was less interested in ‘the how-to books’ (line 52) (though she acknowledged that those can be useful) and more interested in ‘understanding the concept’ (line 54). She illustrated this by giving an example of ‘a fourteen year old (who) is physically incapable of seeing the shades of grey the way an adult can’ because ‘their intellectual and moral development and emotional development is at a certain point’ (lines 55-57). She further stated that ‘my personal knowledge of how the brain develops has fundamentally changed the way that – that I work with young people, rather than any one particular book’ (lines 59-61). In describing this as ‘personal knowledge’ Kath appears to refer back to this knowledge having been gained through her own willingness to pursue it rather than through any standard training or professional development activity. In concluding her response to question three Kath again affirms her viewpoint, returning to the significance she places on ‘conceptual understanding’ (line 62) rather than pre-digested classroom strategies.

After discussing how knowledge of the brain may have influenced classroom practice, question four asks participants to reflect on what they regard as the evidence that any such changes in practice make a difference. In response, Kath chose to focus on behaviour problems and the fact that she teaches a considerable number of classes where challenging behaviour can be an issue. She felt that her understanding of the adolescent brain ‘enables me to have a positive relationship with them’ (line 72-73). Kath also hypothesised that she has some freedom to experiment in her methods, whether with ideas from neuroscience or elsewhere, because she accepts a timetable dominated by classes regarded as difficult. In her view, the success of her strategies with these classes results in her continuing to be timetabled to teach a high proportion of such classes.

When asked about if and how the neuroscience of learning fits into the culture of her school or department (question five), Kath discussed external pressures that she felt mitigate against the exploration of neuroscience or other areas of potential professional interest. The use of words such as ‘directives’ and ‘dictated’ is revealing:

> the directives as to how we teach are dictated much more by other requirements. They’re dictated much more by the requirement to demonstrate progress in learning (Lines 91-93)

Kath mourned the cessation of the school's *Learning to Learn* programme, pointing out that some of her year 11 students still talk about their understanding of learning and revision methods that they gained from the programme when they were in year 7, which again reveals Kath's interest in the efficacy of understanding the underlying processes of learning and development. She went on to describe a whole school professional development programme based on Carol Dweck's work on *Mindset*. The programme made brief mention of the plasticity of the brain. Kath suggested that external pressures continued to affect the roll out and impact of this initiative. Though trialled across the school, 'concepts around growth mindsets' (line 101-102) became optional:

> Those teachers who have taken that on board have done their best to integrate that into their schemes of learning. But that's more, more if the person is personally interested, rather than that's a school-led directive. I'm sure there are individuals at the top within the school who would like us to be doing those sorts of things, but the harsh reality is, can you prove progress to Ofsted when they come in? (Lines 102-107).

It is significant that Kath's school has for some years operated in very challenging local circumstances and has continuously struggled to climb out of the lower categories of Ofsted grading. Kath appears to feel that the focus on this important, immediate concern has the ironic impact of squeezing out areas of professional interest that could in fact significantly support progress in the longer term.

Kath offers one of her key beliefs about her role in response to question five, which asks whether it is useful for children to have some understanding of the brain. She again draws attention to the now defunct *Learning to Learn* programme:

> I have always believed that if a child leaves school believing they don't need teachers, I've done my job. And the only way they're going to leave school not needing teachers is if we have taught them enough about how they learn that they are able to learn for themselves. And part of that, a-a huge part of that, is actually understanding how their own brains work, how their own brains develop and how they can learn. (Lines 115-120).

She goes on to say that the *Learning to Learn* programme did this, as it was not focused on individual subjects. Kath also re-iterates the significance to her of being able 'to understand how things work in order to be able to use them' (line 126-127) and adds 'I think that's true for most people' (line 128).

Apart from an earlier mention of plasticity when talking about Mindset, the only point at which Kath used any neuroscientific language was her use of 'neuroplasticity' in her response to the final question, which enquires about what participants feel neuroscience might help teachers with in the future. The challenging local context is a central component of Kath's interest in neuroplasticity. She describes the damage she believes to be done by the distressing circumstances in which many of her pupils live, including substance and alcohol abuse alongside other dimensions of social deprivation such as long-term unemployment. Kath explained that many of her pupils have endured 'developmental trauma' (line 136) which she believes has affected the capacities of the brain due to 'physical, structural alterations' (line 149). She proposed that neuroplasticity suggests that whilst these changes are real and measurable, neuroplasticity implies that they are also changeable. Kath is concerned that some of her colleagues do not see this kind of damage as potentially reversible, at least to some extent and that they believe that 'these experiences will have shaped the child's abilities and the child's brain' (line 144-145) and act as a negative 'future prediction' (line 146). These concerns have prompted Kath to explore neuroplasticity further. Her response also points to questions of the interaction of genetics, environment and experience.

Interview One Key Points Summary

- significance of background in psychology
- enthusiasm for devising own teaching and learning strategies based on neuroscience information
- effects of school and local context
- importance placed on pupils' understanding of learning
- value given to neuroplasticity

4.3.3 Rich Description: Interview 2

Participant 2 ("Grace') began her teaching career as a secondary school drama specialist. Via a variety of posts in different schools and contexts she is now the headteacher of a special school for pupils aged 2-11 who present with profound and multiple learning difficulties and physical disabilities. In 2012 the school received an Ofsted 'good' judgement overall.

Grace began with a response to question one (sources of knowledge of the brain) that is notable in a number of respects. Advanced level biology was her first reference point, but having cited this she then said, ‘so I must have touched on it’ (line 6-7). There is some apparent uncertainty here as to whether the brain did actually feature in the A-level course and certainly no attempt to clarify any further details. Grace quickly moved on to her teacher training, noting that how the brain works and how individuals learn in different ways was covered. Some scepticism was evident, since Grace declared that some of this was ‘a load of nonsense’ (line 8-9). It is also possible that the ‘nonsense’ in question might refer to anatomical information that she found of no practical value or relevance as a beginner teacher. She returned to the individuality of learning, stating that ‘I kind of think that perhaps most people learn in the same way’ (line 11) and that making learning accessible was more significant. It is notable that this suggestion is tempered by the words ‘perhaps’ and ‘most’. It is also seemingly contradictory with what she then goes on to say, that in her school it is necessary to work in different ways with individual children. However, as Grace explains, this is because her students’ learning is adversely affected by brain injuries. Guidance from educational psychologists and the NHS is of huge importance in the context of Grace’s school, which one might suggest then in fact supports a merging of each facet of Grace’s standpoint: knowledge of her students’ brains informs the creation of access to learning on an individual basis. In concluding her response to question one, Grace remarked that ‘so that’s how I know of the very scant knowledge that I know of the brain’ (lines 19-20), choosing a word such as ‘scant’ to play down any implication that she is in possession of any degree of expertise in this field. It is evident at this point and further on in both this interview and the second interview in which Grace participated that she has considerably more dealings with brain-related matters than a majority of teachers in the UK.

In discussing question two (the influence of the knowledge and sources described in response to question one), Grace introduced a further source, referring to her use of Special Educational Needs journals. She suggested that this was partly due to wanting to know more when the educational psychologists ‘say that this – if you use this, if you do that, then it will enhance learning for that child’ (lines 31-32). While clearly appreciative of the educational psychologists’ advice, it seems that the context of Grace’s work prompts her to explore the advice further, in a manner perhaps less likely amongst teachers in mainstream schools. She declares ‘I read a lot more journals now. Not because I’ve got more time, but I feel as though I need to know’ (lines 34-35). Sometimes Grace’s further research has led to two-way dialogue, when she has noted aspects of a brain imbalance or injury and then returned to the NHS and the educational psychologists for further guidance. It would seem essential that however modest Grace may be about it, some quite advanced level of understanding of the brain is vital to her work, in order to engage in such dialogue. The dialogue has led to further practical advice and relevant technology being made available, each of which might not have been accessed but for Grace’s further queries emanating from her further research. Grace also felt her own research was significant in releasing additional resources, as without it the school was ‘very much dependent on whether or not the ed psych knew about stuff’ (lines 46-47). Grace advanced this notion that she has a responsibility to be an advocate for the needs of individual students rather than simply a receiver of the declared guidance and that to do so required an understanding of the relevant brain injuries and conditions: ‘but so long as you know what - you know what it is you are dealing with, it’s perhaps up to you to go and find out’ (lines 49-50). The question of sources arose again as Grace’s response to this question drew to a close and a need for caution was evident: ‘so the Internet is a very useful thing. Not everything on the Internet is gospel’ (lines 50-51).

In the light of her answers to the first two questions, as might be expected in Grace’s case, talking about examples of how knowledge of the brain has impacted on day to day practice (question three) was undertaken in terms of specific conditions and individual children. In particular, she focused on Attention Deficit Hyperactivity Disorder (ADHD), something she pointed out is often compounded with other difficulties that her pupils experience. Grace is concerned with some of the side-effects of the ADHD medication *Concerta*, a methylphenidate that acts upon the brain’s and the nervous system’s biochemistry to alleviate impulsive actions.

Grace described how the school has learned to make provision for the medication wearing off. She explained how difficult behaviours often emerge at this point. She and her colleagues have realised that *Concerta* suppresses appetite and as a consequence as the dosage wears off considerable hunger can occur. As a result ‘some children get grumpy or restless or very tired or they will actually actively seek food half way through a lesson and it is not their fault’ (lines 70-71).

Grace felt that this was important, practical understanding of the brain-related effects of some medications. She drew from this a principle guiding the knowledge upon which she and her colleagues focus:

> And it’s got to have some practical use; it can’t be airy-fairy, almost. It’s got to have – you know, the information that we seek about how the children are actually processing the drugs that they have, and what the effects of those drugs are, almost, we have to – we have to understand what the practical issues are. So it’s not, kind of, up there. It’s more grassroots, really (lines 74-79)

Grace described the further difficulty of having to judge which problem behaviours are medication-related and which ones are not and that this is dependent on knowing the children very well.

Capitalising on the semi-structured nature of this interview, it was logical to suggest to Grace that she continued to discuss examples in this manner, since this was already exploring the territory of question four (evidence that the brain knowledge-influenced aspects of practice could be shown to make a positive difference). The ways in which she and her colleagues make such assessments related strongly to the school’s context and ‘dips’ in and out of their understanding of the brain-related effects of some of the children’s conditions. Some criteria were predictable, such as the quality of children’s work or their capacity to sit still, either at all or for certain periods of time. They encourage verbal children to talk a lot, which they look on as ‘thinking out loud’ (line 104). This helps to assess the ‘pathway’ (line 105) of a child’s thinking, a choice of word that possibly owes something to the role of networks within the brain in cognition, or at least the current common practice of describing such networks in computer-like terminology. Grace uses this term in a slightly different way at a later stage. Creating the best mental state for learning was evident in other criteria, as evidenced in behaviours that reduce anxiety. Some behaviours, such as ‘hand flapping’ (line 111), can be interpreted in different ways, as a reduction of hand flapping could reflect increased attentiveness for a child with ADHD, yet for a child with Autistic Spectrum Disorder (now often referred to as Autistic Spectrum *Condition* or *ASC*), the hand flapping might indicate an effort to concentrate harder, as the hand flapping can be an attempt to block out other stimuli.

Grace continued on this theme, explaining further that evidence could also be seen in improvements in playground behaviour, the reduction of accidents around the school, the removal of the need for a ‘positive handling plan’ (line 137), or a child’s improved capacity to respond to a number of adults rather than only to one key individual. Though Grace flows naturally into discussion of all these parameters, their relationship to information about the brain in general or the brains of individual children is difficult to specify. What is of interest is Grace’s choice of these examples.

The question of where, if at all, neuroscience fits into the culture of Grace's school drew out further examples that Grace considered to be relevant. She describes the faith she and her colleagues place in sensory drama, which she also referred to as multi-sensory experiences, within the same sentence (line 182). She cites a range of experiences: visual, tactile, lots of smells, lots of sensations, vibration, heat and light (all mentioned in lines 188 to 192). What is implied is that multi-sensory learning is a part of the school's pedagogical culture.

Grace found her way from this point into a rather different example, in which she described a child who does everything with his or her left side limbs and looks around on the left hand side. She explains how they would offer stimuli from the right and while doing so would keep a log of how often this resulted in the child turning to the right rather than full circle from the left. The log would reveal the day-to-day impact of the strategy and also reflect any increase (or decrease) in the child's movements to the right. The influence of lateralisation of the brain is evident in Grace's clarification of the strategy: 'what you're doing is you're making sure that you're, - you're trying to kind of get the synapses working in this side of the brain, really, isn't it?' (lines 220-222). There is evident trepidation as Grace's sentence leads her to offer a neuroscientific explanation. Again any suggestion of expertise is played down ('really, isn't it?) and we have in this sentence one of very few direct references to brain specifics (synapses).

Grace identified the commercial product Brain-Gym® in her response to the question of whether it is helpful for students to have some understanding of learning and the brain (question six). Grace described the Brain-Gym® activity 'Lazy Eights', explaining that it assists her students with balance and with understanding 'where their bodies finish and the world starts" (line 239). She did not discuss how the efficacy of this exercise is assessed though did comment on the fact that her students' difficulties with balance and clumsiness are often the result of brain injuries sustained at birth.

Brain-Gym® was also credited by Grace for activities that prepare students to learn: 'we tell them that it wakes their brains up and it gets their minds working' (lines 243-244). She doubted that her students have any understanding of the mind, other than knowing 'it's a powerful thing' (line 241). There is no apparent reason for the shift from referring to the brain to instead referring to the mind. One aspect of mind or brain function, imagination, is singled out for further comment. Grace relates how the students enjoy using their imagination, except for ASC students who do not understand activities based on imagination. She identifies this as an area for further research and understanding that would reduce frustration for this group of students and comments that 'I don't think they understand about the brain, they just can't understand why we don't understand what their brain wants' (lines 258-259). There is a curious shift in language here, where the brain becomes a separate entity to its owner. Grace then returned to the non-ASC students, echoing her previous observation that some of them do understand something about the brain: 'some of the children, um, appreciate that the brain can – that – that they have this powerful thing inside their head and they can use it' (lines 262-264).

Grace's response to the final question was both passionate and instantaneous. The question seeks to explore what each interview participant would like to be able to ask neuroscientists to investigate. Grace's response is worthy of quotation in its entirety:

> I think if you could categorically say what a child can smell and hear and touch when they're non-verbal. I think if they could possibly have a test so that you know how much a child sees or how they're processing the things they're feeling – the touch – or how they're processing the pain. If there was – if – if you could under – if you could get inside them and find that out, that would be wonderful because we've got some children who clearly are in pain but we don't know which part of them is in pain, and that's awful because it's a bit of a stab in the dark and you do it by trial and error. We've got some children, we're not quite sure how they perceive the world, how they're seeing it, how they smell it, or what it is that's causing them a lot of anxiety. I think, and we kind of know how to reduce anxiety in ASD children, simply because there were some higher – you know, you've got someone on the very, very edge of the spectrum who's really, really horribly intelligent who can tell you what it is. But we've got nobody in a wheelchair who has been born with a brain injury to tell us what it feels like and how the world is for them and what we could do to make it more interesting or them more comfortable or for them to communicate. And I

> think if you could possibly help with the communication of-of an understanding of those kind of people, that would be absolutely amazing, wouldn't it? (lines 271-290)

This impassioned plea raises a persistent question; how do teachers and neuroscientists communicate, through what channel might Grace's concerns be raised with neuroscientists who share her concerns? The immediacy of Grace's words might suggest a willingness to participate in dialogue with neuroscientists and perhaps even a frustration that such an opportunity, as far as she is aware, does not appear to exist.

Grace is one of three participants who took part in a second interview, which explores her responses to the survey data.

Interview Two Key Points Summary

- playing down of personal knowledge of the brain
- working with other specialists (e.g. NHS, educational psychologist)
- SEND and multi-sensory experiences
- finding trustworthy information sources for neuroscience
- medication and the brain
- impassioned closing plea regarding communication with brain-injured young people

4.3.4 Rich Description: Interview 3

Interview participant 3 (‘Chris’) is an experienced primary teacher. She has served as a primary headteacher, before opting to return full time to the classroom in recent years. A considerable amount of her experience has been gained in schools in challenging circumstances, though she now works in a rural primary school, where she is enjoying developing some additional provision based on the principles of the forest school model. The school is deemed to be a smaller than average primary school and was rated as ‘outstanding’ in 2013.

Question 1 (sources of knowledge about the brain) led Chris to answer from the twin standpoints of sources and her own recall of information about the brain. She twice stated that she had no idea from where she had learned what she knows about the brain (line11, line 18). She also presented examples of her knowledge with undisguised uncertainty:

> you sort of learn basic anatomy. About, you know, things like the reptilian brain and frontal lobes and the (.) fight-flight (.) whatever it’s known as, freeze, responses. Is that the hypothalamus? So I know about – is that somewhere different? I don’t know! (lines 6-11)

Chris quickly moved onto how this had influenced her in the classroom without me presenting question three, and talked about fight, flight and freeze, describing how she realised a need to ‘apply that in your professional life because you know it’s about not putting children in those situations’ (lines 14-15).

Chris continued to talk about her own understanding of the brain, moving on to the concepts of the dichotomous brain and lateralisation. Her remarks about lateralisation are a straightforward recognition of the relationship between each side of the body and the opposite side of the brain, but her thoughts about the idea that a brain and therefore its owner can be dominated by 'a more emotionally creative side and a more practical and logical side' (lines 28-29) ushers in a range of observations that reveal how strongly Chris's thoughts about the brain are influenced by her personal values. She believes that the dichotomous brain idea has been used in the promotion of views that she sees as 'gender-stereotypical' (line 29). Questions of personal values in general and gender in particular emerged several times during the interview. Chris is concerned that 'we shouldn't allow boys and girls to be limited by those kind of constructs' (lines 40-41) and that reports of research that describes differences in the anatomy of male and female brains should not be used to support stereotypical ideas about what activities and dispositions are 'appropriate' for boys or girls in school. At this point we talked briefly about research that has concluded that any one brain is actually a mix of female and male brain anatomy traits and no single brain is entirely anatomically male or female.

The challenging of gender stereotypes dominated the conversation for a period and although no direct reference was made to the brain Chris's strategies for combating stereotypes appear to have a significant impact on the environment in which her pupils learn and develop. Examples abound –

choosing a girl to handle the 'minibeasts' in a science project examining insects, putting a boy in the top group for literacy even though his scores do not initially equate with the group, doing the same with a girl in the top mathematics group and seeing them both match their peers, or quietly acknowledging a boy's efforts to comfort a distressed friend. Chris is conscious of the issue that the environment she seeks to create may well not be replicated in her pupils' home environment. This seems to make her even more determined that 'people's potential…isn't going to be defined by their gender' (line 59) and she notes that to achieve this in the face of other environmental factors that are less supportive of her position means that she has 'to fight twice as hard' (lines 60-61).

Question 6 (the value of children having some understanding of learning and the brain) led the discussion away from gender. Chris takes the view that this is not only of interest to children, but to most people: 'I think children are fascinated by it, aren't they? Well, we all are, aren't we?' (line 168). Chris felt that an idea heavily promoted in UK schools and elsewhere in this century, that of visual, auditory and kinaesthetic learning (VAK), was potentially helpful. Whereas VAK products and training tended to recommend that teachers found out which of these three modes best suited the learning preferences of each of their pupils, Chris instead saw VAK as a way of impressing upon children that they need to learn in all of these ways. She wished her pupils to 'become aware of the fact they need to (.) they need to learn things in lots of different ways (lines 185-187) and 'in order for your brain to assimilate skills and knowledge you need to give it the best possible chance you can' (lines 196-197).

At this point Chris referred to 'things like neurons and connections and things' (line 200-201), again in a manner that downplayed any suggestion of any level of specialist knowledge of the brain. What Chris was leading to at this point was the effects on learning of practice and how understanding the process of practicing from a brain perspective would be helpful for children, especially when they find themselves grappling with something they find difficult, when they 'really, really struggle' (line 206). Chris is describing myelination and the building of networks within the brain, but doing so in her own terms.

The final interview question (what might neuroscience help teachers with in the future) prompted Chris to talk about children who are difficult to help, not just academically,

> because there are some children who you know (.) you know that they are making sense of the world in their own way but it's so completely at odds with the way most of the rest of us do, that it's really, really hard to work out how you reach them and how you unlock their potential (lines 252-257).

Chris made another, more brief reference to gender in relation to this question, before moving on to comment on recent training at her school on Howard Gardner's *Theory of Multiple Intelligences* and Daniel Goleman's work on *Emotional Intelligence*. This was the only point during the interview that individual researchers, theorists or authors were mentioned by name. Chris also commented that our previous conversations, including a pilot interview almost a year prior to this interview, had caused her to look more critically at theories such as those of Gardner and Goleman. Once again, whilst seeking a convincing evidence base for these theories, Chris had her own ideas about how they could be useful in the classroom. Understanding a child from the point of view of different intelligences, she suggested, could be ‘the way in’ (line 282) when a particular topic or subject did not appear to capture a child’s interest. She also made the point that some children’s self-esteem might be improved by discovering that they displayed intelligence in certain fields and the increased self-esteem might provide the confidence to rise to challenges in other areas of learning – ‘self-confidence grows and actually then other things become possible, don’t they?’ (lines 290-291).

We discussed research that has pointed out that no neuroanatomical evidence can be cited to support Gardner’s claims for the existence of difference intelligences. Chris’s reply to this was pragmatic and supportive of the usefulness of the theory: ‘I don’t think that matters, does it?’ (line 295). This raises valid questions about what we tell our pupils and resulted in further discussion of the fact that there are other skills and traits that as yet cannot be identified via brain imaging. We also discussed how Howard Gardner has declared that whatever ‘other’ intelligences there may be, it is undeniable that literary and mathematical intelligence are the most important. ‘Only because of our education system’ (line 274) was Chris’s challenge to this.

To support her point, Chris talked about her recent experiences of Forest School training and how her own academic abilities were immaterial when faced with some of the tasks that her and her fellow trainee forest school teachers were set. With some amusement she told how she considered deploying tactics her pupils might adopt when faced with academic challenges that they felt unable to meet: ‘I’m like, “oh God, no! I don’t know what to do. I’m just gonna copy someone”’ (lines 283-284). This then brought about a brief discussion of Carol Dweck’s work on Mindset and the need for acceptance that getting things wrong plays a crucial part in learning, yet here were adult, professional educators not wanting to look like they could not do something in front of their peers. This brought us back to the brain, since Carol Dweck has frequently referred to the plasticity of the brain as important evidence that learners have the capacity to improve at any task.

The interview formally closed at this point, since all the questions had been explored and discussion had now moved on to other aspects of working with young children, in particular Chris’s experiences of developing the forest school approach in her mainstream primary school. There was one final outcome from the interview, however, as Chris contacted me later that day to draw my attention to some research literature she had found, exploring the forest school concept from a neuroscience perspective.

Chris is one of three participants who took part in a second interview, which explores her responses to my survey data.

Interview Three Key Points Summary

- brain regarded as a source of fascination, yet no sources of knowledge identified
- viewpoints regularly expressed through deeply-held personal values
- 'brain'based' teaching products 'subverted' for own teaching purposes
- hope that neuroscience might offer a deeper understanding of how some children make sense of their world
- interview leads to personal further investigation of neuroscience

4.3.5 Rich Description: Interview 4

Interview participant 4 ('Amy') is a mature entrant to the teaching profession and is a modern foreign languages (MFL) specialist. Having commenced a Postgraduate Certificate in Education (PgCE) teacher training programme five years ago, Amy is the most recently trained participant. After training Amy taught in a state secondary school for three years and then moved to an independent school that hosts both residential and day pupils. Amy is the only interview participant who does not live and work in England and is based in Wales. The Welsh Inspection of Education and Training Office, Estyn, rated her school as 'excellent' in its 2012 inspection.

In response to question one (identifying sources of knowledge of the brain), Amy replied quickly, referring to her PgCE programme, which she completed four years prior to the date of this interview. There had been an opportunity during the programme to explore different fields of educational research and Amy had opted for a group that examined the existing science on 'getting our subject into people's heads' (line 12). As a consequence of this investigation, Amy continues to receive updates about research in the field of the science of language learning, from various international sources. The brevity of these updates appears to appeal to Amy, as she described them as 'titbits' (line 16) and 'little bits and bobs' (line 17). There also seems to be an avoidance of the language and complexity of the original research in these updates, which adds to their appeal.

Amy made an interesting observation that points to the heart of my question, the question of teachers' mediation of information about the brain. She stated that in addition to the sources she had discussed, 'then there's just the stuff you make up as you go along through experience of life, I suppose' (lines 18-19). Perhaps what is implied here is the personal creation of pedagogical beliefs, rather than some form of fiction.

Amy also raised the issue of the lack of time to explore original sources, but felt that the update sources amply covered this for her:

> I haven't got time to look through at what might be relevant. But because I've signed up to all these language-specific sites, they just happen to come to me. So I find this extremely useful. I don't have to look, I just decide which ones I want to look at when they've arrived (lines 24-27)

Practicality and convenience is wrapped up in the choice of words such as 'relevant' and 'subject-specific'. Given the limitations of time, Amy does not wish to have to 'dig' for insights that may be of use to her. We might have discussed at this point how Amy feels able to have trust and confidence in these sources, since to an extent the sources are deciding for her what might be relevant. Instead we moved on to identifying the sources.

It transpired that Amy lets her iPad log the sources, so none came to mind. We agreed that we could explore this in another conversation. We moved on to question two's exploration of how the sources discussed have influenced classroom practice. Amy referred back to her PgCE programme's examination of the acquisition of a second language. This had led Amy to an app called Memrise. Amy's description of the evolution of the app and her use of it is revealing in several ways:

> The neuroscientists had decided that the analogy of planting a seed of knowledge, watering it – i.e. practising it regularly – um and seeing it come to fruition, which is when they believe it's moved from your short term memory at the front to the long term memory at the back where it's gonna stay. That whole process, they've developed an app which is playful but extremely effective. I tested it and I - because I know French, Spanish, English, Latin – all sorts of Roman languages – I picked Chinese, Mandarin Chinese and I tried to learn some using their method alone. Then I left it a year before I went back to see if I had any recall, and it was massively, massively effective. Having not looked at these seventy five characters in a year, I was over 80% recall. Which kind of proved to me, through my own little piece of research, that, that technique that they employ does work (lines 39 – 51).

Referring to 'the neuroscientists' suggests unfamiliarity with the fact that there is disagreement amongst neuroscientists and also assumes that the Memrise app is designed and/or approved by neuroscientists. A similar faith is evident in the phrase 'that technique that they employ works', where there is no further clarification of what this technique is believed to be, although I did not specifically ask for this clarification. We did discuss how extensive research on memory formation and recall is and that this is a likely rich source for educators. Given the commonly described difficulty that Mandarin Chinese presents to learners with western first languages and in its written form even to young Chinese learners, Amy's 'own little piece of research' is of interest. So is her decision to test this out for herself in the first place, rather than just accept the evidence she subsequently describes. This suggests a desire to further understand the 'technique' to which Amy refers.

There is some dated thinking about memory formation evident in the reference to front and back (of the brain), although Amy displays awareness of the concepts of short-term and long-term memory. The significance of the former is receiving considerable attention in educational contexts at present. We did engage in some further conversation about the suggestion that memory formation is an area of particular interest to teachers and that there is growing neuroscientific knowledge and investigation of memory.

The issue of the efficacy or otherwise of the use of analogy when talking about the brain is evident in Amy's description of 'planting a seed'. This is an interesting consideration in the case of teachers talking about the brain, since the use of analogy is an explanatory technique that many teachers use regularly. In addition some teachers will be aware of research that draws a correlation between the capacity to think in fluid analogy and levels of intelligence. Given the variety of analogies that are often used to describe processes of the brain, there is potential for considerable confusion.

In discussion, I commented to Amy that I am frequently hearing teachers talk about the brain through analogy, rather than neuroanatomy or neuroscience. Her response plays down any suggestion, and perhaps any expectation, of knowledge or expertise about the brain: 'well I'm not an expert so I'm not qualified to talk about the brain in those terms' (line 64).

Since Amy had raised the Memrise app, described her own trial of it and had declared that she does use it with her pupils, we considered it further, to explore evidence of its effectiveness (as in question three's examination of evidence of positive impact). Amy chose to explain how the app has had an impact on the progress of one particular pupil. The pupil is an interesting case. Amy teaches him Spanish and he is on the special educational needs and disabilities (SEND) register at the school due to some difficulties with English. The nature of these difficulties, to do with 'processing words' (line 80) suggests to Amy that the pupil would be likely to find this even more problematic in a second language. This is where the app appears to have made considerable difference. The pupil enjoys using the app, especially its point scoring system that allows him to see his progress and also to see that he is ahead of others in the class. The app is not used in class, but Amy can see who is using it and how much they are using it. So she knows that this pupil has used it frequently and she can see that

> he's studied these words and they've stayed because in class, six or seven – eight - weeks down the line he knows words that he should not really know. I know that he knows those words because Memrise planted them in his brain a month or two ago and they stayed (lines 87-90)

The seed analogy finds its way into Amy's description here, but also an almost personification of the app, to which she credits the action of the planting.

In considering question five (how, if at all, neuroscience fits within the culture and practice of the department and/or school), Amy felt that there was no wider view on this at her school (although she updates this in interview eight). She made the point that she felt free to explore this if she chose to and suggested that areas of investigation for professional development were more open-ended at her current school than at her previous school. She went on to suggest that this is to some extent due to there being less prescription about teaching methods at her current school. In turn she ascribes this apparent freedom to an approach to accountability that is concerned with ends (i.e. results) more so than means (i.e. teaching and learning strategies): 'I've got the wider constraints of a curriculum to get through by the end of the year, but as long as I've covered all that I can do whatever I want' (lines 136-138).

When asked about the value of children having some knowledge of the brain (question six), Amy was primarily concerned about her older pupils (UK key stage five, so generally aged between 16 and 18). She was concerned that ‘they don’t understand how their learning works at all’ (lines 164-165). This conclusion was partly based on Amy’s own investigations of her pupils’ learning styles, a concept of which they appeared unaware. Of course, the existence or value of individual learning styles is much contested, but what is of interest here is the association made by Amy between learning styles and knowledge of the brain. She proposed that improved understanding of learning would have a positive impact on her pupils’ approaches to note taking and revision, for example. Whilst the learning styles issue might be a slightly different debate, Amy’s response further demonstrates that she is receptive to neuroscience-informed information about learning, drawn from reliable sources.

In relation to the question of what Amy would most like neuroscience to assist with (question seven), she again chose to consider one specific pupil. In the case of this pupil, she had in fact recently been thinking about whether any neuroscience research might shed light on the issue in question. The pupil has an Italian mother and an English father ‘and is dyslexic in Italian but not in English’ (line 186). Amy had encountered this with other pupils and other languages.

Amy’s final comment on this demonstrated an appetite not just for raising issues for investigation from a neuroscientific perspective, but also for taking an active role in such research: ‘it doesn’t make any sense to me at all and I’d love to figure it out – I’d love to do some research myself on dyslexia in bilingual children’ (lines 186-188).

Amy is one of three participants who took part in a second interview, which explores her responses to my survey data.

Interview Four Key Points Summary

- subject-based dimension – the science of language learning
- interest in apps and technology to support learning and the neuroscientific validity of these
- use of analogy
- personal mini case studies
- suggestion that school status affords more opportunity to explore neuroscience (and other areas of professional interest)
- pupil knowledge of the brain as a support for understanding learning
- neuroscience and specific needs (some subject-related)

4.3.6 Rich Description: Interview 5

Interview participant 5 ('Sam') is a secondary school art specialist, though she has taught other art and design subjects and food technology. At the time of the interview she was about to take up a new post as deputy headteacher in a privately operated school for children with behavioural, emotional and social difficulties.

From the outset, Sam was eager to dispel any suggestion that her agreement to take part in the interview implied any expertise about the brain itself. In response to question one, (sources of knowledge of the brain, whatever the extent of this knowledge may be), her initial reaction was ‘oh my word. Alright, yeah, not complicated questions’ (line 6). Yet in a mere fourteen lines she then made reference to a wide range of sources of information relating to the brain and to several of the issues that knowledge of the brain creates for teachers. Sources included Advanced Level biology and ambulance training from her youth, each of which she regarded as ‘nothing to do with teaching’ (line 10). The commercial product Brain-Gym® was the first education-related source that was referenced and its influence was evident in other comments, such as the reference to ‘wake up and how you get the brain to work’ (lines 14/15), the focus on using each side of the body to stimulate the opposing side of the brain and the use of crawling. Sam recalled that this was related to Special Educational Needs and in particular dyslexia. She did not voice any awareness of the extent to which the theories of Brain-Gym® have been both decried and debunked, though it does emerge later in the interview that she has her own uses for some of the Brain-Gym® activities, having adapted them to serve quite different objectives to those of their original creators.

Although teachers frequently make use of analogy, the confusion it can create was evident, as Sam mis-quoted the commonly heard phrase that the brain is *like* a muscle, instead reporting on a training session in school that featured ‘learning about the brain *being a muscle* and having to exercise it’ (lines 13/14, my italics). In her work on *Mindset*, which has struck a chord with many schools in recent years in the UK and elsewhere, Carol Dweck has used the ‘like a muscle’ analogy frequently in both her writing and in presentations (for example at the Osiris Mindset Conferences in London and Manchester in

2014, in her books such as Mindset (2012) and in her 2014 TEDx presentation ‘The Power of “Yet”’). Sam makes a specific reference to Growth Mindset, describing this as ‘the emotional side’ (of the brain, line 20). It appears that information that speaks of the left and right sided brain has spilled over into Sam’s own constructs, resulting in this term. Sam returns to this idea in her response to question two.

Question two invites participants to consider which of the sources they describe in response to question one have been an influence on their classroom practice. Sam responded from two standpoints – subject teacher (art and design) and from a pastoral role. She described a drawing in the air activity, which she appears to have developed from a Brain-Gym® activity, but to serve a completely different purpose to that proposed by Brain-Gym®. Sam uses this activity to help overcome some pupils’ lack of confidence with drawing and to challenge the belief that ‘you can draw or you can’t draw, it’s from the hand’ (line 31). She then describes how she uses the idea that the brain is always developing, in her tutor and pastoral role, to encourage students ‘to not put a cap on what their abilities are’ (line 40).

Sam continued to describe the impact of her knowledge of the brain on her classroom practice and emphasises Special Educational Needs again as well as disadvantage, particularly in the context of one of the schools in which she has worked. She referred to activities that she assumes to have some sort of basis in how the brain learns, although she questioned the genuine purpose of some of these, suggesting that some of them were imposed on the teaching staff in order to satisfy external pressures, specifically Ofsted (line 131). She commented again to this idea of activities undertaken for compliance, questioning its value to children, stating ‘it wasn’t for the benefit of the child, it was for the benefit of everything happening’ (lines132/133). Given the nature of the discussion, it might be taken from this that Sam sees teaching and learning ideas reportedly rooted in neuroscience as potentially another fad that school leaders might feel compelled to appear to promote. In contrast, however, in talking about school culture and continuing professional development, she describes a school that had explored Mindset and how children learn, drawing on some aspects of neuroscience in the process. Rather than staff being required to take specific actions as a result, she points out that ‘they were stepping a foot into it. They were opening the doors to the whole idea’ (lines 152/153). Sam appeared much happier to have the opportunity to consider and explore possibilities presented to her and her colleagues rather than be instructed to deploy strategies about which she is unconvinced. She seemed to value being offered the ‘stepping their foot into it’ opportunity. She reinforced this in mentioning that in one of her schools ‘there was nothing’ (line136) in terms of the brain or other aspects of developing practice collaboratively. Notably, no specific brain-related references are made even though they appear to have been used in the training sessions. Within this part of the discussion, Sam tackled question five, the matter of neuroscience within the school or department’s culture, without the prompt of the actual question.

When discussion moved on to whether children should know some things about the brain (question 6), Sam stated that 'it's really important for them' (line 184). She is concerned that children should understand that each of their brains is different and develops in different ways at different paces. She raised concern that this conflicts with the expectations of the curriculum, for example 'because by year 2 you should be doing certain things' (line 187). She again uses the 'muscle' analogy, though uses the phrase 'the brain's a muscle' (line 192) as well as 'and I think that if children understand that er and knew the brain (is) like a muscle' (line 196/197), further demonstrating the potential confusion that analogies about the brain can create. Sam's rationale for children to have this understanding is certainly valid: '(the brain) has to be exercised and practicing things, they'll understand how they learn and not give up' (lines 197-199).

Sam returned to the issue of curriculum expectations at set points, suggesting that this can be emotionally difficult 'with teenagers and hormones' (line 207/208). Through the work of Sarah-Jayne Blakemore and others we now know that developments in the brain are also an aspect of the challenges of adolescence, yet Sam continues to frame this as a hormonal issue, as do many teachers and parents.

In the future, in relation to question seven, Sam hoped that neuroscience can contribute to further understanding of communication with children. More specifically, she referred to 'mental block' (line 252) and 'barriers' (line 253). She expanded on this issue by describing a local running project in which she participated and which has been supported and written about by a local GP. Sam describes how overcoming the physical challenge of training to run five kilometres was as much a mental act as physical: ‘it’s not all about the physical act. An awful lot of it is about the brain act’. It is noticeable that she chooses the word ‘brain’ rather than the perhaps more predictable ‘mental’. She appears to imply that some understanding of the brain can support our psychological understanding of ourselves and our individual struggles. There is some conflation, when she states that ‘the brain is what – what causes a barrier, an awful lot, it’s how you *feel’* (lines 286/287, my italics). This relates to the brain/mind problem, which occurs when the two words are seen as interchangeable.

Interview Five Key Points Summary

- insists no expertise or special knowledge
- ‘brain-based’ products adapted for own teaching and learning purposes
- use of analogy
- SEND
- the use of brain-related and/or other new strategies for unsuitable reasons, such as fads, appearances
- children’s understanding that all brains differ
- understanding of the brain contributing to our understanding of ourselves

4.3.7 Rich Description: Interview Participant 2 (‘Grace’), Second Interview (interview 6).

For clarity, the brief details of Grace’s background offered at the start of interview 2 are repeated below:

Participant 2 (“Grace’) began her teaching career as a secondary school drama specialist. Via a variety of posts in different schools and contexts she is now the headteacher of a special school for pupils aged 2-11 who present with profound and multiple learning difficulties and physical disabilities. In 2012 the school received an Ofsted ‘good’ judgement overall.

I also repeat the introductory details about the second round of interviews, undertaken by Grace (participant 2), Chris (participant 3) and Amy (participant 4):

Interviews six, seven and eight were undertaken in a different format. The two most experienced teachers and the most recently trained teacher amongst the participants were asked to consider the survey data that I had gathered, which is described chapter 4.2. The three participants were free to consider the data and comment on what they found of interest and discussion then developed around their observations. This makes for an informative triangulation of the survey data, since each participant reflects differently on some of the survey data, chooses to focus on different things to each other and brings a different perception to my own initial conclusions about the survey data.

Without any prompting, Grace began to scan the survey data and in less than a minute started to comment on what she saw. She was surprised to see that

53 of the 102 survey respondents stated that the brain had never featured in their professional development. She found this surprising for two reasons, firstly, in light of the attention given to children's mental health at present and secondly because it is something that has become quite routine at her own school:

> we find out about the plasticity of the brain, we find out when we can affect the brain positively and when the brain has been affected negatively and, what we can do to ameliorate those affects and the kind of time limit we have (lines 9-12).

Grace moved on through the data at her own pace. She struggled to change her own position about the creation of new connections in the brain. She commented not on the survey responses but the statement itself, explaining that the idea of new connections at all stages of life did not fit with her understanding that connections are made up to the age of 25 and then 'the ones that you don't use kind of wither and die' (line 16).

Grace curtailed discussion of this by moving on to the 10% of the brain question and again did not comment on the survey responses and made her own comments about the statement. She took the view that how much of the brain we use varies dependent on what we are doing and that stress and anxiety can cause a general increase in the amount of brain activity taking place. Grace reiterated her point:

> I think there are certain activities where you can see that the brain is really, really active and certain activities where it's far less active. There

> are certain things you can do to make it far more active. So, for instance, when children do Brain-Gym® and they're doing 'Lazy Eights' and loads of circles, all of those are to activate your brain so your brain, in effect, wakes up and is receptive to the next (um) set of activities (lines 32-35)

Despite her regular exposure to information about the brain and the specific brain related difficulties of her pupils, rather than offer her own thoughts about the significance of activities intended to create initial engagement, Grace chooses to justify her comment in terms of Brain-Gym®. It appears that much of the heavy criticism of Brain-Gym® and the debunking of it claims to a scientific basis have not crossed Grace's path. Or if they have, the persuasiveness of the product's marketing and training has left a strong impression.

In responding to the next statement on the survey, that suggests that 'information is processed in the same way by everyone's brain' (survey question 7.3) Grace spoke from her working context, pointing out that a damaged brain has to find different ways to do things and that individuals who can, for example, sense colour or smell colour must process information in different ways. She does at this point engage with the survey data, expressing surprise that there was any agreement with the statement (a total of four, plus five who neither agreed nor disagreed, of the 102 respondents). Grace expected that 'we all know children who've got sensory impairments who rely on different parts of their brain to kind of compensate' (lines 47-49).

Again Grace moved on to the next statement of her own volition and again was eager to state her own view rather than review the spread of respondent views (survey question 7.4 ‘physical exercise can support the efficiency of the brain’). She spoke of the positive effect of exercise and specified activities such as ‘crossing the midline’, balancing and yoga. She suggested the latter could be calming and therefore encourage concentration whereas lots of dance might ‘get all your, you know, good stuff popping off in your head and lighten your mood’ (lines 58-59). Grace moved directly on to the next statement (survey question 7.5 ‘emotional experiences affect the chemicals in the brain’) though this time was quick to point out that respondent agreement with this was very strong (95.1%). She suggested that this is because people understand this through personal experience rather than through training or information and that ‘you don’t need to be a teacher’ (lines 65-66) to grasp this point.

Grace then returned to the matter of the pruning and deletion of neural connections, discussing a lecture she had recently attended, presented by Professor Barry Carpenter, CBE. She drew a connection between emotional experiences and trauma, specifically in the early years of a child’s life, as having a seriously damaging effect on the rapid synaptic growth that occurs at this stage and explained in Professor Carpenter’s lecture. Initially, she stated that this was a ‘disabling’ experience (line 78), though quickly began to search for a different word. Together we agreed on ‘disadvantaging’ (line 81). The lecture itself had caused Grace to begin to question the often raised point that in Finland, regarded as one of the world’s most successful education systems, children start school at a later age than in the UK. In Grace's school, there are children as young as two. Rather than suggest these children should not yet attend, she described how the school has sought to increase the richness of the school experience and introduces some concepts of phonics and mathematical thinking between ages four and five. Her reasoning was based on her learning about early synaptic proliferation, that had led her and her colleagues to believe they should be 'really fastidious about making sure that everything is put in there' (lines 89-90) and that 'if you create that environment then perhaps those brains will – the bits won't wither and die because you're feeding them' (lines 95-97).

The validity of statement 7.7 ('sleep affects the learning potential of the brain') was again confirmed through Grace's own experiences as much as through the data, which had 95.2% agreement). Rather than her pupils, Grace referred to some of her colleagues who are young parents and whose performance at school can be affected by broken sleep brought about by the needs of their very young children.

Grace began to talk in analogy when considering statement 7.8 ('mentally rehearsing a physical act can activate the same brain areas as the act itself'). She described the formation of neural pathways in terms of the creation of a path or shortcut in a park that is more convenient than the 'official' route, whereby the path becomes clearly delineated because of frequent use. She then explained how she had used mental rehearsal herself, with varying degrees of success. She cited stress as a major factor in the rehearsing coming undone in the ‘real’ situation.

‘Each side of the brain is exclusively responsible for different types of mental activity’ (statement 7.9) brought out a contextualised response. She was surprised that 41% of respondents agreed and she pointed out that in cases of brain damage, such as that experienced by many of her pupils, different areas of the brain take over functions not previously associated with that area. She theorised that support for the dichotomous brain idea continues to be promoted by quizzes in social media, which claim to ‘test out if you are a right-side thinker or a left-side thinker’ (line 140). Grace described these quizzes as media items ‘dressed up as science’ (line 142).

Grace moved on again of her own accord, eager to express an opinion about statement 7.10 (‘scientific evidence shows that listening to Mozart can improve long term brain function’), again based on her own experiences. She used the term ‘the Mozart Effect’ and stated that she had found using music an effective way of preparing children for an activity or a change of activity and we agreed that in a general sense this is something that music has always done, since it influences the pervading atmosphere in any situation. Grace was more sceptical about the suggestion that the music of Mozart of anybody else can influence long-term brain function.

I moved discussion onto statement 7.11 (‘the brain is not active during sleep’) and initially Grace was alarmed that anybody would agree with that, since at the very least the brain continues its monitoring role during sleep. Four respondents had agreed, with another neither agreeing nor disagreeing. Using analogy again, she also observed that during sleep as well as dreaming her brain would be 'sorting out what's happened during the day and kind of putting it in various cupboards' (lines 178-179).

Grace agreed that the 88.2% agreement with statement 7.12 ('learning is longer lasting when it is created in multi-sensory ways') was a clear indication of the faith placed in this concept by teachers and moved on to statement 7.13 ('remembering a phone number to use once and a past experience use the same type of memory'). She was keen to theorise about this for herself. She suggested that in the case of the phone number, like things learned for an examination and not expected to be needed again, one would 'put it somewhere and to recall it for that moment, and as soon as you put the pen down, almost, you've deleted it' lines 197-198). Grace then suggested that other memory items are retained because 'you attach importance to it' (line 200). Whilst we agreed that some understanding of how memory works would be useful knowledge for teachers, Grace commented that the 37.3% who neither agreed nor disagreed had perhaps not really ever thought about this and nor had it come to their attention since it has never been promoted through school priorities or in-service training.

In the interests of time and with a concern that we would be able to discuss the responses to different types of questions that occur later in the survey, we did not discuss statement 7.14 and moved on to 7.15 ('emotions can affect learning'). Again Grace's response was seated in her own experiences in the classroom – occasions when an angry or aggravated child has clearly needed time to calm down before engaging in any form of dialogue or learning activity - and the fact that 'everybody is a human' (line 223). She commented that for two teachers to disagree was 'a curious response from a teacher' and was also surprised that 30% opted for the response 'agree' rather than 'strongly agree'.

Grace suggested some caveats in her reaction to statement 7.16 ('concentrating on one difficult task is more effective than multi-tasking'). She felt that this can be dependent on the tasks, or how well one knows the tasks and that some tasks require the use of brainpower and skills. We agreed that the question could have clarified that it was referring to, for example, concentrating on something that makes new cognitive demands. Grace's thoughts shed light on the large 'neither agree nor disagree' response (46.1%).

We moved on to the question of whether 'mental ability is inherited' (statement 7.17). Grace stated that she sees a 'direct correlation between the ability of parents and the ability of children' (line 270) though she balanced this against two significant further comments. Firstly, she demonstrated awareness of how her working context influenced her response and secondly that mental ability 'can be enhanced by parenting, environment, education (lines 274-275), to which she then added the significance of motivation.

Next we considered statement 7.21 (‘at birth we have the capacity to learn e.g. music/language of any type, from any culture’). Grace expected that teachers would display an intrinsic recognition of this, going as far as to say, ‘you don’t even need research to tell you that’ (line 298). Grace’s expectation was borne out by the 97.1% agreement to the statement.

Items that attracted Grace’s attention guided our path through the remaining statements and responses. The high level of agreement with statement 7.22 (‘our brains have a natural tendency for exploration’) chimed particularly with Grace’s experience of working with children with autism. She described how many of these children, at the more extreme end of the autistic spectrum, could not access information and explanations and instead needed to explore, bit by bit, to make sense of the world in their own terms. Grace then commented on statement 7.24 (‘everyone has one dominant preferred learning style’), which had drawn responses spread across the Lickert scale options. She proposed that we learn through a mix of modalities. Her final comment on this section of the survey was to conjecture that the 17% who neither agreed nor disagreed with statement 7.25 (‘the fight or flight response affects learning’) must surely have encountered ‘a child who is in crisis, they’re either going to bite you, kick you or cry. And if you advance towards them with a maths paper, you know, at what point are they gonna go “oh, I’m gonna stop that and start doing that maths’’ ‘(lines 332-333).

The latter sections of the survey differ to the preceding section, in that they afford the opportunity for participants to respond in prose. I asked Grace to ‘dip in and out’ (line 345) and share her thoughts on anything that attracted her attention. The first comment that did so, in response to question 8 (‘if you can, please describe a learning episode that you have led, where you can identify the impact of your conscious knowledge relating to the brain’) once again brought Brain-Gym® into our discussion. A teacher hinted that there are issues surrounding Brain-Gym® and we discussed some of these, such as the lack of peer review for the journal set up by the creators of Brain-Gym® and the reported lack of evidence for the scientific claims made for Brain- Gym®. Grace’s response reflects some scepticism mixed with a persistent Brain-Gym® idea (‘crossing the midline’): ‘I think any exercise has the same effect as Brain-Gym®. As long as you cross the midline. As long as you are doing that kind of activity. Yoga does the same thing. Intensive interaction is the same thing’ (lines 405-407). In a similar way, Grace then commented on a teacher’s reference to brain training. She suggested that this was not a new idea: ‘it’s not training, it’s practice. It’s what we used to call practice’ (lines 416-417).

Grace then considered question 10.5, which asks if Multiple Intelligence Theory has played any part in respondents’ teaching or training. Grace again commented from the viewpoint of her working context and drew together Multiple Intelligence and the previous discussion of brain training. She noted that many of her pupils have a ’spiky profile (line 426), ‘particularly good at one thing and then quite often poor at other things compared to mainstream children’. Grace explained further that the ‘one thing’ was often something based in ICT, which she suggested was due to practice: ‘their pathways are like “oh, I do that, that happens. I press this, this happens”, and we’re kind of marvelling at their IT ability but really it’s just something they’ve practiced a lot’ (lines 438-440).

We then examined responses to question 11, which asked respondents to consider the influence of genes, school experience, environment beyond school and other factors on educational potential and achievement and to try to suggest an approximate percentage weighting for the impact of each of these. Grace was alarmed at the variance in the responses to genes. These ranged from 0% to 80%. Interestingly, Grace then expressed her own position that supported a more balance view. She declared that ‘I think your genetics do have a massive impact. And then I think that the environmental factors can either massively enhance that or detract from that’ (lines 458-460). She explained her view further, referring back to her earlier comments about the need for the early proliferation of brain connections to be met with a rich environment. She warned against genetic information being treated as proxy: ‘I wouldn’t throw the baby out with the bathwater and say, “oh well, genetically they’ve got this material and therefore they’re never gonna make much of themselves”’ (lines 468-470).

Interview Six Key Point Summary

- challenge of changing long-held belief or practice
- responses to survey data rooted in own school context
- use of analogy
- use of Brain-Gym®

- engaging in the genes-environment debate

4.3.8 Rich Description: Interview Participant 3 ('Chris'), second Interview (interview seven).

For clarity, the brief details of Chris's background offered at the start of interview 3 are repeated below:

Interview participant 3 ('Chris') is an experienced primary teacher. She has served as a primary headteacher, before opting to return full time to the classroom in recent years. A considerable amount of her experience has been gained in schools in challenging circumstances, though she now works in a rural primary school, where she is enjoying developing some additional provision based on the principles of the forest school model. The school is deemed to be a smaller than average primary school and was rated as 'outstanding' in 2013.

I also repeat here the introductory details about the second round of interviews, undertaken by Grace (participant 2), Chris (participant 3) and Amy (participant 4):

Interviews six, seven and eight were undertaken in a different format. The two most experienced teachers and the most recently trained teacher amongst the participants were asked to consider the survey data that I had gathered, which is described in chapter 4.2. The three participants were free to consider the data and comment on what they found of interest and discussion then developed around their observations. This makes for an informative triangulation of the survey data, since each participant reflects differently on some of the survey data, chooses to focus on different things to each other and brings a different perception to my own initial conclusions about the survey data.

This transpired to be the longest of all the interviews, since we discussed the survey responses for 67 minutes, running to some 28 pages of transcript. In part, this is due to the fact that Chris was interested to explore some of the contextual information that the respondents had been asked to supply. In particular, her attention was drawn to survey question six, which asks if the neuroscience of education has featured in personal or school-based professional development. Chris felt that amongst the 32% who said that neuroscience had featured in personal or school-based development respectively would be primary teachers who took the question to refer to learning styles (in the form of visual, auditory and kinaesthetic) and Brain-Gym®. She felt that for most people it is not ‘a day-to-day concern. You’re too busy to work out where (laughs) things come from’ (lines 10-11). Chris then raised issues of language and terminology, suggesting that some teachers may not recognise any of their development work as neuroscience, even though some training might fit with the word. She went as far as to say ‘if you want to further the use of neuroscience then you need to find other ways of describing it, maybe. ‘Cause it’s a very scary word, isn’t it?’ (lines 32-33).

Chris expanded this point further, commenting that many primary teachers feel they have limited backgrounds in science and therefore find teaching it a challenge. She hypothesised that for teachers who are a little anxious about the word ‘science’ then putting ‘neuro’ in front of it makes it sound like something outside of their field and beyond their potential scientific comprehension.

Chris was then invited to explore the statements about the brain that received Lickert scale responses (section 7 of the survey), deciding for herself upon which of these to choose to comment. She anticipated that statement 7.2 (‘generally we only use 10%of our brain) would result in a high proportion of ‘neither agree nor disagree’ responses and was therefore surprised to find 44% agreement with this statement, with a further 27.5% neither agreeing nor disagreeing. She described this as ‘one of those assumed bits of knowledge’ (line 69) for which individuals were never really aware of the origin.

Chris moved on to statement 7.3 (‘information is processed in the same way by everyone’s brain’). Her comments focused on the statement itself and she conjectured that ‘probably most of us have no idea how information’s actually processed’ (lines 87-88). She then made the observation that ten people sat listening to the same lecture would be taking different information and understanding from it.

Chris was not surprised to see extensive agreement with statement 7.4 (‘physical exercise can support the efficiency of the brain’). She was keen to add to this that ‘it’s good for your mental health, not just efficiency’ (lines 106-107) and she also stated that the ‘feel good factor’ (line 108) resulting from exercise can make us more likely to be wanting to learn. Chris felt that the associated growing interest in and concern about mental health amongst school pupils was a needed development.

Chris anticipated that there would be strong agreement with statement 7.6 (‘the brain deletes or “prunes” neural connections (synapses) that are not used regularly’), so was surprised that agreement was around 50%. She had expected that media reports about the need to keep the brain active into old age and the accompanying promotion of ‘brain training’ games and activities like Sudoko – ‘things that were supposed to stop you getting Alzheimer’s’ (line 132) would have played a stronger influence on the responses. She was aware, however, that evidence about the wider efficacy of brain training is not well evidenced; the training games, Chris suggested, were ‘just like the eleven plus’ (line 143) in that they might make you better at that activity but with no guarantee of an effect beyond that. She noted a similar experience with the intense preparation for standard assessment tests (SATs) undertaken by her pupils, the impact of which she felt did not transfer to other learning.

Chris then made an interesting observation about statement 7.7 (‘sleep affects the learning potential of the brain’). As she anticipated, this brought about one of the strongest levels of agreement from respondents. Chris felt that this was a result not of teachers’ specific knowledge of matters of sleep and the brain, but ‘because so many teachers deal with children who come in and are exhausted and tired out and not ready for anything, really, apart from go back to sleep again’ (lines 153-155). Chris’s choice to emphasise this point (‘exhausted *and* tired out’ – my italics) perhaps indicates the extent to which she has encountered this difficulty. Chris was curious that any teachers had disagreed with the statement (one disagree and one strongly disagree) and conjectured that this might reflect a negative state of mind at the time of undertaking the survey. We briefly discussed the fact that we can have no real idea of the circumstances under which any individual completed the survey and the potential influence of that upon their responses.

Chris was now adopting a pattern of making her own predictions about the levels of agreement with each statement and then comparing her prediction with the findings. She expected statement 7.8 (‘mentally rehearsing a physical act can activate the same brain areas as the act itself’) would attract a lot of agreement, which it had and she then moved on with some excitement to statement 7.9 (‘each side of the brain is exclusively responsible for different types of mental activity’) with the comment ‘oh right, sides of the brain, this’ll be interesting (laughs). Oh, isn’t that interesting!’ (lines 171-172). What Chris found interesting was the spread of responses, displaying 41.2% agreement, 35.3% disagreement and 23.5% uncertainty. She cited online quizzes about left and right-brained characteristics as a likely source of teachers’ vague knowledge of this issue. Chris expressed scepticism about online quizzes: ‘they just make them up, don’t they? (laughs)’ (line 198), but she also raised a concern about the use of the idea of the dichotomous brain as a problematic factor in gender issues.

Although Chris discussed the effects of music in the classroom during her first interview, in considering statement 7.10 (‘scientific evidence shows that listening to Mozart can improve long term brain function') she cited a source that she had not previously mentioned. This was a BBC Radio Four programme, during which, as she recalled it, the key message had been 'if you played Mozart before SAT tests, the kids were more likely to get good results' (lines 206-207). Her follow up to her comment revealed her scepticism: 'seriously? There you go. Yeah' (line 207). Chris imagined that there would be uncertainty in the participant response to this statement and 52.9% did opt for 'neither agree nor disagree', yet only just under 12% actually disagreed. Chris mused further on the scientific basis of statement 7.10, believing it to be 'something to do with its (i.e. the music of Mozart) uniformity and mathematical, I don't know, symmetry' (lines 209-210). Chris recalled from conversation during our first interview that there had been considerable difference between the researchers' tentative theories and how journalists chose to report them. She then suggested that retractions of misleading reports would be obscure and too late after the initial publication, implying that the public, including teachers, would be unlikely to see them. Chris's concluding thoughts about the use of music linked back to her first interview, as she re-iterated her thoughts about using different music to create different moods and atmospheres, something she had clearly had success with through trial and error, rather than through any neuroscientific evidence of its efficacy.

The small number of agreements (4%) with statement 7.11 ('the brain is not active during sleep') puzzled Chris as she anticipated 100% disagreement. She wondered why anyone would think this. She then mentioned dreams and what she described as ‘the filing system’ (line 254), a point she emphasised further: ‘your brain when it’s asleep is filing. It’s just getting everything sorted out’ (lines 254-255). It is noticeable that Chris refers to the brain being asleep, rather than the individual.

Chris raised several points in her response to statement 7.12 (‘learning is longer lasting when created in multi-sensory ways’). She expected the high (88.2%) level of agreement with the statement. She hypothesised that personal experience would be a factor in these responses, in that teachers might recognise that they remember some things more strongly than others. Saying this then made her seek clarification – did the statement say ‘memory, or ‘learning’? She added her own clarifications that this could mean ‘learning bits of information, or is it learning how to do something, or is it understanding a concept’ (lines 267-268), thus raising the question of shared understanding that is necessary when educators and neuroscientists talk about learning. Chris was curious about some respondents disagreeing with the statement and suggested that this might be a result of emphasis on preferred learning styles and the difficulty of then letting go of this theory. She described her own preference for learning through analogy, illustrating this with a story without which she cannot do a particular knot used in some of her forest school activities.

The learning styles question persisted. Chris continued, stating that she felt that ‘most people definitely need to see things. Is that a learning style or is that just a tool in your learning kit?’ (lines 301-302). We discussed neurobiologist

John Medina's suggestion that typically at least 70% of information we gather is received visually and also discussed our shared belief that weaker modes of sensory input should be improved rather than rejected for learning purposes; poor listeners need to become better listeners, rather than expect to rely on their supposedly stronger visual learning ability. Chris introduced a poster shared on Facebook by a maths teacher colleague, which claimed 'if children don't learn the way we teach them…..we have to teach them the way they learn' (lines 320-324). She suggested that even if a teacher felt that a class needed to learn to listen more effectively, curriculum pressures allow little opportunity to address this, 'because you have to jump through those hoops and get those levels passed' (line 329).

Chris's first reaction to statement 7.13 ('remembering a phone number to use once and a past experience use the same type of memory'), was to suggest that responses to this would be influenced by participants' understanding of types of memory, going as far as to say, 'we don't know what they are, do we?' (line 322). She then qualified this, suggesting that most teachers were probably aware of the concepts of short-term and long-term memory, because 'that relates to everyone's experience' (lines 327-328). It seems an issue was emerging here, about the significance of memory in learning and that this might be something that teachers need to know more about.

The next statement to attract Chris's attention was 7.16 ('concentrating on one difficult task is more effective than multi-tasking'). She was interested to know whether the responses could be considered by gender, alluding to the popular notion that multi-tasking is something that women can do and men cannot. Chris also raised the question of what might be meant by ‘difficult’. If we were talking about a mathematical concept, she suggested, then ‘difficult’ ‘for some people might be seven nines and someone else it might be calculus, mightn’t it?’ (lines 390-391). Chris noted that the responses implied uncertainty. She also pondered on her own example of chess masters, capable of seemingly playing six games of chess simultaneously. She concluded that the multiple games for these individuals in fact constitutes one difficult task and that they would find it very difficult to ‘do something (else) completely un-chess-like’ (line 396).

Chris felt that the responses to statement 7.17 (‘mental ability is inherited) reflected the likelihood that teachers would weigh up the relative balance of ‘nature/nurture’ (line 406) and that the general public’s response to this statement would show a higher level of agreement. She also talked of what she referred to as ‘chance’ (line 416), by which she meant instances of ‘Mr and Mrs, you know, very intelligent, have a child with special needs’ (lines 416-417). Chris suggested that this might explain why no teachers had strongly agreed with the statement. We return to this issue in discussion of section 11 of the survey.

Statement 7.19 (‘there are structural and biomechanical differences between male and female brains’) set off a wide-ranging discussion of issues of gender. The statement resulted in 61.8% agreement, with 26.5% neither agreeing nor disagreeing and 11.7% disagreeing. Chris was curious about how this might then map onto teachers' expectations in the classroom and children's subsequent interpretations of what is expected of them in terms of their gender, as well as raising a concern that this is a binary view of gender. Chris also described some of her own deliberately gender-neutral practices. Chris concluded that the high level of agreement 'saddens me, 'cause it can be used as an excuse, instead of – (.) and it limits, you know, artificially puts a ceiling on girls and boys" (lines 489-491).

Using the words 'ok, moving on' (line 501) Chris acknowledged that our discussion of gender had been lengthy and she then read out statement 7.20 ('general intelligence is fixed and cannot be increased'). Conversation around this centred on the statement itself as much as the responses to it. Chris pointed out that there may be confusion amongst respondents about how 'intelligence' is defined and also that some may equate it to potential. We also conjectured that even though some teachers agreed with the statement, that in itself does not indicate that each of these teachers necessarily believe that they somehow know the finite limits of any one child's intelligence or potential.

Chris's attention was then drawn, with some evident excited anticipation, to statement 7.24 ('everyone has one dominant preferred learning style'): 'everyone has one dominant –ooh! – preferred learning style. Go on, what did we get? What did we get?' (lines 529-530). Chris predicted an even split, which is not what she found and her surprise is evident in her reaction: 'oh gosh, they're all over the place, aren't they, these answers?' (line 533). Chris offered her own explanation, stating that 'there's been so much (.) bollocks that you just don’t know what to believe’ (line 540). The pause before finding a noun to capture the assorted information received about the question of learning styles suggests some frustration with the conflicting guidance that Chris and by implication her colleagues have received. Chris then made an interesting point that for teachers who have been required to plan and prepare their teaching with learning styles given priority, which is a laborious and time-consuming process, it is then difficult to reject the concept, since that would represent a rejection of one’s own work: ‘what you might have spent hours of your life preparing and teaching, it is fairly hard to then say “oh, it was rubbish after all’. That’s quite a bitter pill to swallow, isn’t it?’ (lines 545-547). There is a suggestion of how personally significant teacher beliefs about how they work can be, in Chris’s use of the word ‘life’ where she might have chosen other words, such as ‘time’, evenings’ or weekends’. Her point here is a powerful one that is relevant to other beliefs or debunked teaching approaches that have maintained a place in the professional thinking of individual teachers and is relevant to teacher beliefs about the brain and their own capacity for working with information about the brain.

At this point we began to consider section eight of the survey, which allows for more prosaic responses. Respondents were asked to ‘describe a learning and teaching episode that you have led, where you can identify the impact of your conscious knowledge of the brain’. Chris first commented on several things that she thought need not be considered specifically to do with the brain or neuroscience, for example mindfulness, mindset and building learning power. Chris was supportive of each of these approaches and although she was not surprised to see them mentioned she did state that ‘I don’t know whether I would’ve necessarily have fastened it to the tag of neuroscience” (lines 609-610). Chris made the same point just a few lines later, this time with reference to outdoor learning, phonics and respondent comments on different aspects of special educational needs. Chris’s observations point to some confusion about the contributory disciplines of educational thinking. Interestingly, Chris is very interested in outdoor learning and the forest school model and following this interview she found some research supporting the forest school model from a neuroscientific perspective.

Section nine of the survey invites respondents to describe aspects of their teaching that they think might benefit from greater knowledge of neuroscientific processes. Whilst scanning through the responses, Chris noted that many teachers had simply commented ‘everything’ or ‘all aspects’. She offered her own interpretation of this. She felt that it represented two things, firstly that these respondents believe that there may well be beneficial insights to be gained from neuroscience and secondly that the respondents feel that they should know more about neuroscience. We briefly considered to what extent the act of undertaking the survey might bring about the latter feeling.

Chris made some further broad observations about the theories and methods asked about in section 10 of the survey (learning styles, Brain-Gym®, brain training, visual, auditory and kinaesthetic (VAK) and Multiple Intelligence Theory). Chris’s key concern was that when schools use these approaches they are unable to accurately gauge their impact, ‘because it’s one of very many things that a teacher will be doing with those children that day' (lines 773-774). She also pointed out that it would be unlikely for a class teacher to arrange a class into a trial group and a control group: 'she's not gonna do it with just half the class' (line 776).

From her view as a primary teacher, some of the practices mentioned in the responses of secondary teachers alarmed her, such as the testing for learning styles and VAK and the noting of the outcomes of such tests against pupil names in class registers. Slightly startled, she asked 'does that actually happen in high school?' (lines 806-807). Chris began to explain that the process of labelling pupils with supposed learning characteristics and then attempting to teach them accordingly got things the wrong way round:

> when you have to start pigeonholing these things into a particular intelligence, as opposed to just saying "there are lots of different ways of teaching. We might all need, you know, different ones at different times and different situations"' (lines 824-827).

Chris was also surprised by some of the responses to section 11 ('please indicate, with percentages adding up to 100, how much you consider each area contributes to educational potential and achievement: genes, school experiences, environment beyond school, other [optional]). Besides the wide variance in participants' suggested figures, Chris was also surprised by the extremes, pointing out responses to 'genes' ranging from zero to 80%. We noted that two responses were prepared to challenge the question, each of which commented that the percentages would depend on a range of factors.

Suggested percentages of the influence of school experiences and environment beyond school also showed a wide variance. Chris pondered on what might make a teacher respond that school had little influence and in one case that environment beyond school counted for 100% of potential and achievement. Chris proposed that such responses might well reflect the circumstances of the teacher, who might be grappling with daily difficulties in the classroom. Again we noted teachers qualifying their percentage suggestions, commenting that the quality of school provision and access to a wider environment would influence the relative percentages for any one child.

At the end of what had become a lengthy interview, Chris's attention was drawn to some of the 'other' factors that teachers suggested. She remarked that some of these were 'fascinating' (line 950), in particular references to peer pressure, early years attachment and self-belief. As she considered the 'other' category further, she proposed that some of the suggestions were simply examples of the wider environment – physical and emotional wellbeing, friendship groups. With some amusement, Chris's final observation was that the task of getting all the responses into 'some coherent form' (line 952) was not one of which she was in any way envious.

Interview Seven Key Points Summary

- issues of neuroscience language and terminology and teachers' anxieties with science
- references to mental health
- concern at lack of transfer of 'brain training'

- references to gender (in relation to the dichotomous brain)
- issues of social media and media reporting about the brain
- use of analogy
- letting go of previous practice

4.3.9 Rich Description: Interview Participant 4 (‘Amy’), Second Interview (interview 8).

For clarity, the brief details of Amy’s background offered at the start of interview 4 are repeated below:

Interview participant 4 (‘Amy’) is a mature entrant to the teaching profession and is a modern foreign languages (MFL) specialist. Having commenced a Postgraduate Certificate in Education (PgCE) teacher training programme in 2011, Amy is the most recently trained participant. After training Amy taught in a state secondary school for three years and then moved to an independent school that hosts both residential and day pupils. Amy is the only interview participant who does not live and work in England and is based in Wales. The Welsh Inspection of Education and Training Office, Estyn, rated the school as ‘excellent’ in its 2012 inspection.

I briefly explained the content of the survey to Amy and that I would like her to comment on the responses. Following a brief consideration of the summary of the demographic information given by participants, I brought Amy’s attention to question six, which asks about previous experience of educational neuroscience within a professional development context. Amy responded immediately with reference to her own school, in particular the significance of the appointment of a new Additional Learning Needs Co-ordinator (ALNCo), the equivalent in Welsh schools to the role of Special Educational Needs and Disabilities Co-Ordinator (SENDCo) in English schools. The connection to the question of educational neuroscience is that this appointment has resulted in a much greater focus on the developmental needs of individual students. Amy explained how the new ALNCo is ‘trying to show that not everybody is the same and there are some that have got completely different needs to the rest’ (lines 7-8). Amy expressed concern about the workload that is resulting for both the ALNCo and the rest of the staff as a result of this interest in difference. This workload, she suggests, is in part due to the fact that there had not previously been enough interest in individual differences and the ALNCo has ‘opened a can of worms’ (lines 15-16).

Amy saw this, alongside the appointment of a new headteacher, as a major culture change, from one that she described as ‘old school’. (line 30). She clearly feels very strongly about the need for these changes, citing sixth form students for whom these changes have come too late and who ‘should have had help seven years ago’ (line 34). She went on to say that although information about cognitive and general development had previously been shared regularly in school, it was not considered in terms of implications for individual students.

Amy is the most recently trained interview participant and commented on educational neuroscience from the perspective of her own training, which we also discussed in interview four. She expressed frustration that at the time of her training there had been emphasis on identifying and working with three types of learning or learners (visual, auditory and kinaesthetic) yet this was now being regarded as ‘bunkum’ (line 56) and ‘hogwash’ (line 57). To boot, Amy claimed that she often actually considers herself to be a visual learner. This is quite a curious comment from a modern foreign languages teacher and we returned to this point later in the interview.

As we moved on to statement 7.1 (‘the brain can produce new connections right into old age’) Amy again spoke from her own experiences before considering the survey responses. She stated that she believed the brain can do this, ‘to an extent’ (line 65) but that it ‘feels more difficult to do’ (line 66) as one gets older. Amy’s personal evidence for this view is the fact that learning foreign words, something that she has done with relative ease since the age of 11, now takes more effort to ensure that words are retained. She then declared that she agreed with the 57 participants (55.6%) who had agreed with the statement and she clarified that she would not go as far as to ‘strongly agree’, which 32 participants (31.4%) actually had stated.

When we began to consider statement 7.2 (‘generally we only use 10% of our brain) Amy commented that she had read something about this recently and that this could not possibly be true. She expressed surprise on looking at the responses: ‘oh my gosh, 40% agree that we only use 10% of our brain’ (line

84-85). She then hypothesised about this: ‘because they read it somewhere, because they heard that statement and it’s familiar to them, maybe. I strongly disagree’ (lines 85-86). As her reaction would suggest, Amy was equally surprised that only 11 participants (10.8%) strongly disagreed.

Agreement was more readily found for statement 7.3 (‘information is processed the same way by everyone’s brain’). Amy quickly disagreed with this, as did a majority (91.2%) and she then read out the next statement, ‘physical exercise can support the efficiency of the brain’ (statement 7.4). Amy then commented that lots of things affect the brain but made no further comment about exercise. She did mention that ‘they say if you sip water whilst you’re sitting in an exam, that improves your performance’ (lines 102-103). Despite my efforts to generate discussion around physical activity, Amy pressed on to statement 7.5 (‘emotional experiences affect the chemicals in the brain’).

Amy personally agreed strongly with this statement. She expanded on her understanding, describing how depression can be triggered by events but in many cases ‘it isn’t because something has happened, it’s the chemicals in the brain’. I commented that a chemical imbalance may be a factor but not the only factor in such cases and that the idea of a chemical imbalance had developed familiarity. Amy again chose to move on to the next statement rather than enter into discussion.

Amy read out statement 7.6 (‘the brain “prunes” or deletes neural connections (synapses) that are not used regularly’). She had questions of her own about this. She stated that she had read of this idea of ‘use it or lose it’ (line 125), but felt that this conflicts with her experiences as a linguist of remembering words that she may have learned many years ago and has rarely used since. She suggested that ‘if you know your way round your own brain, you can dredge it up’ (lines 127-128) and like many survey participants she was ‘conflicted’ about this statement. I made a lengthy response to Amy’s thoughts, referring to significant periods of synaptic pruning and the behaviour of the longer term memory in cases of Alzheimer’s. Amy was attentive to these comments and I then raised the question of the effects of sleep, leading us to statement 7.7 (‘sleep affects the learning potential of the brain’).

Amy quickly agreed with this statement, as did 92.3% of participants. She took the opportunity to raise concern about students being ‘up all night on their tech’ (line 144). We moved straight on to statement 7.8 (‘mentally rehearsing an act can activate the same brain areas as the act itself’). 77 participants (75.5%) had agreed with this and Amy stated that she strongly agreed, once more opting not to comment on the responses, though we did conjecture as to how many of the 23 participants (22.5%) who neither agreed nor disagreed might be teachers of areas of the curriculum that have a physical dimension, such as physical education or music and might therefore be in a position to make active use of this idea.

Without prompting Amy scanned the next statement and uttered the reaction ‘oh my word’ (line 153). Statement 7.9 proposes that ‘each side of the brain is exclusively responsible for different types of mental activity. Amy offered some extensive theorising based on perceptions of her own brain:

> ‘(laughs) and it’s funny because sometimes when I think, I feel like I can feel it in a particular place, but I feel like most of what happens in my head happens over here. I don’t even know what is over there but it feels like there. But when I went back to uni and started using my brain again I swear I could feel the front working. I swear it felt like I could physically – it’s like there were cogs turning. But I don’t know about sides. I think, possibly areas of the brain are responsible for different types of activity but I don’t know about sides of the brain. Or being exclusively responsible’ (lines 157-164).

Amy read out the number of agreeing participants, which amounts to 41.2%. We discussed the possible manifestations of such a belief in the classroom and how it might support stereotypes. Amy commented that she thought this to be ‘dangerous, but people do love a convenient category, don’t they?’ (lines 179-180). She then read out statement 7.10 (‘scientific evidence shows that listening to Mozart can improve long term brain function’). Amy asked if Mozart was significant in this statement, which led us to discuss the research that had led to the idea of ‘the Mozart Effect’ (not a term coined by the researchers) and how the researchers had not succeeded in replicating their initial findings, but had found that the short term effect on spatial reasoning that they had initially seen as a result of listening to the music of Mozart was in some cases evident after listening to entirely different music or no music at all. Amy began to make connections: 'well yes, there's people playing music to their unborn babies' (line 207) in the belief that "it's going to make my child intelligent'" (line 210). We discussed ways in which teachers have used music, for example as a method for creating different atmospheres.

Increasingly conscious of her next commitment, Amy moved on to statement 7.11 ('the brain is not active during sleep'). She swiftly aligned herself with the 'strongly disagree' responses, pointing to the data and stating that "I'm with this set of people here' (lines 212-213). We considered that teachers should have an understanding of the role of sleep in development and memory and learning. This prompted Amy to share another personal experience, quoting her nine year-old daughter, 'who says, "when I go to sleep, I'm growing. My body is making me better if I am feeling unwell and I'm downloading information I have learned during the day into the hard drive". That's how she thinks of it' (lines 220-223). Amy laughed when I pointed out the use of the computer analogy and once again pressed on to the next statement.

Statement 7.12 ('learning is longer lasting when created in multi-sensory ways') drew the response 'I think that depends' (lines 227-228). When challenged as to upon what this may depend, Amy replied 'who it is' (line 230), perhaps reflecting the agenda of increased attention to individual needs that she had described being prevalent at her own school in recent months. On the basis that no two brains are the same, Amy felt that how learning occurs would be 'completely individual' (line 232), therefore multi-sensory learning might work well for some and less well for others. She again weighed this up from a personal perspective, stating that ‘it probably is true for me, I think’ (line 233). She then offered a further observation, narrowing in on the statement’s reference to ‘longer lasting’. In Amy’s experience, she has encountered students who could be given a word on a piece of paper and subsequently would remember it ‘forever’ (line 845) whilst others would forget it almost instantly. In addition, Amy hypothesised that motivation and purpose would have an influence on memory. She took little notice of the survey response figures for this statement, yet had many points that she wished to raise.

The next statement also explores memory (7.13 - ‘remembering a phone number to use once and a past experience use the same type of memory’). Intuitively, Amy disagreed: ‘it doesn’t feel like it, to me’ (line 255). In this case she specified that she was ‘going on personal experience’ (lines 255-256). She observed that for her a past experience memory would be ‘somewhere else’ (line 260) in comparison to the phone number. After indicating that she would align herself with the 44 participants (43.1%) who had disagreed with the statement, she continued to describe how the question of poor working memory has been brought into focus in her own school. Whilst her colleagues seemed to recognise the issue of students for whom working memory impedes progress, they also felt overwhelmed at the prospect of attempting to cater for yet another type of individual need. The new additional learning needs co-ordinator has led them in the direction that individual students should understand these needs and learn to manage them for themselves rather than expecting teachers to modify everything for them, in individualised ways. Amy saw this as ‘a completely different thing. That empowers them throughout the entire school and beyond’ (lines 295-296).

The next two statements brought swift, strong personal agreement (7.14 – the physical actions of music making link to the brain’s pleasure centres and 7.15 – emotions can affect learning). It is worth noting that Amy is a singer, though at this point she did not make reference to her own experiences of the powerful effects of music. The issue of multitasking was the next statement to draw a longer response (7.16 – concentrating on one difficult task is more effective than multi-tasking).

Amy once again referred to personal experiences, noting that she needs silence to undertake demanding translation work, in French for example, yet some of her students ask if they can listen to music whilst doing such a task. The gender-based folklore that women can multi-task but men cannot appears to be a source of irritation for Amy, as she described situations where men have expected her to undertake simultaneous, complex tasks, quoting the ‘women can multitask’ myth whilst doing so. Again using personal examples, she related how she can cook and talk about the weather, but not about anything requiring greater thought.

Looking at statement 7.17 (mental ability is inherited) Amy sought clarification, as she had for several statements previously: ‘do they mean intelligence?’ (line 304). She declared that she did not know what was meant by ‘mental ability’, but that if it meant intelligence then she would strongly disagree. 47

survey participants (46%) also disagreed or strongly disagreed. Amy continued to explain that she saw ability or intelligence as the product of a number of factors, yet again illuminating her thoughts with a personal example. She rates herself as poor at maths, yet her daughters are very good at maths. So is their father, but Amy points out that she has always been encouraging about maths and about how ‘maths is fun. Maths is great. Maths is marvellous’ (lines 320-321), which she knows is not necessarily the approach taken by many parents who personally find maths difficult. She referred to this aspect of parenting as being ‘like a marketing job’ (line 300) and also pointed out that in addition to the potential hereditary and environmental influences they may have created as parents, her daughters may well also have had great maths teachers and other experiences that combine to positive effect.

I also discussed my own daughter’s experiences of maths, relating more to anxiety than to lack of mathematical aptitude, after which we moved on to statement 7.18 (specialist training causes identifiable differences in areas of the brain). This brought reference to an example from Amy’s subject area (modern languages), as she pointed out that ‘there’s a physiological difference in bilingual (people) from birth’ (lines 388-389). Amy made no comment on the participant response figures and followed the pattern that had now developed, whereby she decided when to move on to the next statement or set of responses. She declared that she had little prior information from which to evaluate statement 7.19 (there are structural and biochemical differences between male and female brains), after initially responding with the comment ‘ooh, sharp intake of breath’ (line 396). She further commented that she would have opted for the ‘neither agree nor disagree’ response, as did just over a quarter of participants (27/26.5%). I talked for a moment about findings from research on the implications of this statement. Amy chose not to engage with this any further.

Instead, as before she introduced the next statement (7.20 - general intelligence is fixed and cannot be increased). She strongly disagreed with this and questioned why any teacher would support such a view (10, or 9.8% did so, with a further 9 or 8.8% neither agreeing nor disagreeing).

Conscious of the now limited time, Amy pressed ahead. She was pleased to see that all but three participants agreed or strongly agreed with the statement ‘at birth we have the capacity to learn e.g. music/language of any type from any culture’ (7.21) though she did not expand on why this pleased her. She then strongly agreed with statement 7.22 (our brains have a strong tendency for exploration), which had also met with agreement from all but five participants.

She had more to say about 7.24 (everyone has one dominant learning style). It was not the responses, but Amy’s experiences of the labouring of the concept of preferred learning styles during her teacher training that drew comment. She then described a personal process, having ‘self-identified’ (line 509) herself as a ‘visual learner’. I pointed out the significant auditory dimension to being a modern foreign languages specialist. Amy then explained that upon hearing a word she then needed to visualise it in order to remember it. I suggested that this was simply a cognitive process and one that would work in an opposite manner for words she saw before hearing them, i.e. her memory would be reinforced by sounding them in her head or out loud. This led to protracted discussion about the apparent attention given to the question of learning styles in the planning of teaching, in preference to working with the well-established classic theories of learning.

The last of the statements, 7.25 – the fight or flight response affects learning, once again drew a response based in Amy's personal experiences. She recalled that 'fear' was the 'main tool' (line 567) in two schools attended by her and her brother. Again she took little note of the participant responses, instead declaring that 'being afraid is not a good place to be for anything positive to happen' (lines 569-570).

Amy began to scan through the responses to section eight of the survey, in which participants are asked to describe, if they can, a teaching and learning episode in which conscious knowledge of the brain has had an identifiable impact. Amy commented that she had previously mentioned (in our first interview) her interest in different ways of learning language vocabulary and in the role of technology in supporting this. Though she still uses paper and ink methods, from her own observations she believes that computer-assisted methods bring better results. She pointed out one particular aspect of this approach to which she ascribes its effectiveness, which is the competitive nature of computer learning applications such as the app Quizlet. She did, however, suggest that her observations were influenced by her own positive view of computer-assisted vocabulary learning (CAVL), effectively confessing to some confirmation bias in her monitoring of the outcomes from each method of vocabulary learning. Quizlet, she explained further, allowed for peer competition, whereas Memrise, which she discussed in our first interview, works better as a personal learning application. Quizlet features random elements and assigns participants to teams. As a result, Amy stated, 'I've never seen year 9 boys as engaged as when they are trying to beat someone else at guessing this word first. It's insane' (lines 630-631). We then discussed the work of Paul Howard-Jones, who has investigated the efficacy of computer-based learning games, in particular focusing on the role of the neurotransmitter dopamine. Amy hypothesised that this changing learning environment has been beneficial for students who have previously retained little of their modern language learning. Their previous poor memorisation has hindered progress and the computer-assisted approach has helped move this forward.

When we moved on to the question of with what might teachers wish neuroscience to assist, Amy declared that this seemed 'wide open – I don't know where to start' (lines 698-699). She focused on some participant responses and was surprised by one that hoped for more information about the brains of individual students, which took us back to the issue of manageability that we had discussed earlier. Amy then began to drift away from participants' suggestions to her own questions: 'I suppose for practical purposes I'd want to know what's the best catch-all method that could appeal most universally, what's the best thing to do? How do they learn best? What time of day is it when they learn best?' (lines 711-714).

This latter question prompted a description of a class that Amy finds highly variable in its capacities, dependent on the day and time. We considered the research around adolescent changes in circadian rhythm and the practicalities of schools responding to this. Amy suggested that although a later start time for the adolescent year groups may not be practical, more notice could be taken of the times of day at which the greatest intellectual demands are placed on this age range. She expressed interest in the idea of this being researched further: 'that would be interesting. I would love to know that' (lines 725-726).

Amy then theorised about various approaches to learning listed for question 10 (learning styles, brain training, Brain-Gym®, multiple intelligences) and suggested that they all might have simply a general effect in preparation for learning. She used words and terms such as 'warming up', 'stimulating' and 'kickstarting' (lines 746-748). This seemed to imply that she was less convinced about the more precise effects that the methods have sometimes claimed to have, but could see wider uses for the methods.

Moving on to the survey's final section, which asks participants to indicate approximate levels of influence of genes, school experiences, environment beyond school and 'other' factors upon educational attainment, Amy pointed out that she had already been asked a similar question earlier in the day. She quoted the precise question as ‘to what extent do you think that genes determine intelligence’ (lines 763-764) and recalled that this was for some sort of social science research. In the case of this question, Amy was more interested than previously in looking at participants’ responses. She noted the wide variability in participants’ viewpoints and then conjectured that the profile of influences would be different for different individuals. Amy took this a step further and stated that it also ‘depends on individual genetic profile’ (line 773). We then considered some of the ‘other’ factors that participants had identified and Amy was quickly drawn to the issue of motivation. She had recently read of GCSE students being offered large sums of money, in some cases as much as ‘£5000 per A star’ (line 797). She joked that such an enticement might have resulted in her gaining better grades herself, but more seriously she was alarmed at such extreme cases of ‘dangling a carrot, wow’ (line 801) and concerned about the impact of this on intrinsic motivation. This discussion took up the remainder of the time available for the interview.

Interview Eight Key Points Summary

- CPD flexibility, with some freedom from agenda driven by national and inspection expectations
- interest in pupil ‘difference’
- curiosity about memory and possible influences on its efficiency, such as motivation
- personal theories about own brain, such as locations of certain types of cognitive activity
- interest in the effects on the brain of bi-lingualism

- technology supporting learning
- interest in collaborating on future research, including research suggestions

4.4 Chapter Summary

Chapter 4 has presented a detailed compilation of the online survey data, followed by rich descriptions of the eight interviews, drawing on the interview recordings and transcripts. These two data sources have been presented separately for purposes of clarity, affording the reader opportunity to examine each dataset prior to them being analysed and discussed concurrently in chapter 5. However, an array of key points from both the survey data and the interviews, many of them connected, some of them duplicated and yet other that stand alone but are worthy of further investigation, have been identified. These lay groundwork for the themes, discussion and analysis presented in chapter five.

Chapter 5: Analysis and Discussion

5.1 Introduction

This chapter presents analysis and discussion of the data that is set out in chapter 4. As it represents an early phase of analysis, the process of coding the data is first considered, followed by exploration of the grouping of the codes into sub-themes which are then gathered into seven, over-arching main themes. These themes are then traced back to the initial codes, drawing each stage of the process together and ensuring that the coding remains integral to the discussion of the themes that concludes this chapter. Chapter 5.2 expounds each stage of this procedure, which is summarised in chart 5.1.

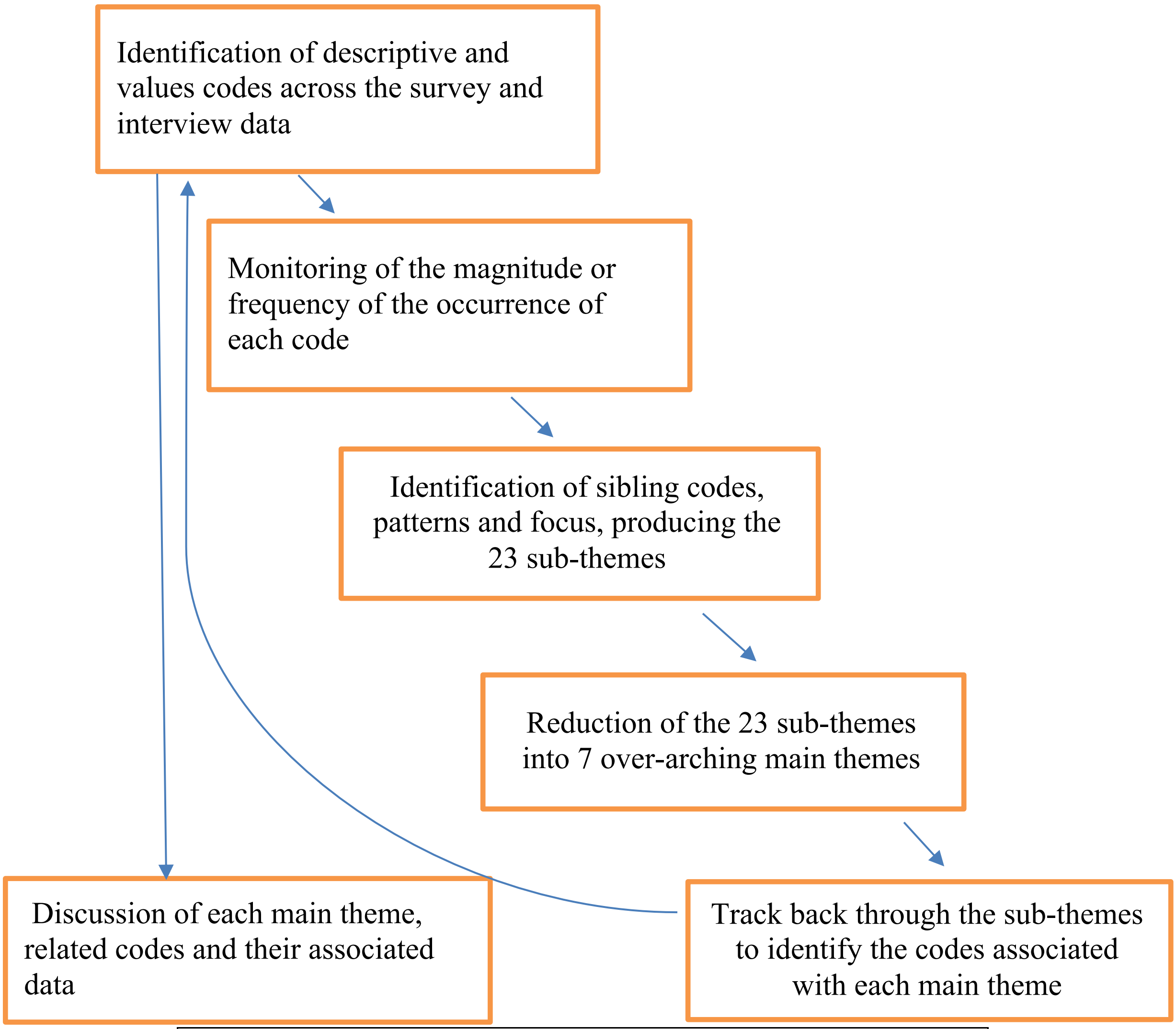

Chart 5.1 Flowchart depicting stages of coding and analysis

5.2 Data Coding and Initial Themes

Data coding was undertaken with both survey and interview data, following the principles and procedures discussed in chapter 3.2.5. and using the coding terminology proposed by Saldaña (2009). For clarification, Saldaña's terms are italicised when first used in this chapter.

A first cycle of *descriptive* and *values* coding was undertaken, for which single words were chosen to describe content and to identify issues of value or concern to participants. The *magnitude* or frequency of the occurrence of each code was also recorded. Magnitude has been viewed with caution; where something has been mentioned by a number of participants then this is clearly of interest, but this does not imply that something mentioned by only one participant is potentially less important or less worthy of further investigation; in some instances, it is the lack of reference that warrants further consideration.

A second cycle of coding scrutinised for *patterns* or *focus*, as well as *sibling* codes. This process identified connections between codes and also constitutes a first stage in analysis of the outcomes of the coding process itself. Decisions concerning the choice of code words were made either on an *in vivo* basis, which is to say that the code is a word used by one or more participants, or were chosen by me as suitably representative words. As discussed in chapter 3.4.3, here there is potential for researcher bias, both in the choice of words and in the choice of which aspects of participant responses to code. I am conscious of the potential tension between what participants consider of importance and what the researcher considers of importance.

It should also be noted that the coding of the survey responses takes care to code participant comments but attempts to avoid giving artificial weight to language that appears frequently in these responses as a result of being a component of a survey question. Alongside the codes drawn from participant comments within the survey, the thematic analysis and discussion presented in chapter 5.3. to 5.10.3 also draws on interpretation of the survey data. For example, where a Lickert-type survey question has resulted in a very mixed response, this might correlate with the codes *confusion* and *uncertainty*.

Table 5.1 summarises the two coding cycles. Firstly, it displays all code words. Secondly, it reflects how codes were deemed to be connected or to be potential *pattern*, *focus* or *sibling* codes, resulting in the initial thematic suggestions displayed in the second column. It can be seen in table 5.1 that many of the codes relate to more than one potential sub-theme.

	Code	**Possible sub-theme**
1	Access	Information, sources
2	Analogy	Meaning-making
3	Anxiety	Student traits
4	Assessment	External pressures, child development
5	Attainment	External pressures, child development
6	Autism	SEN(D)
7	Behaviour	Child development
8	Brain differences	Specifics
9	Brain-Gym®	Products
10	Child self-perception	Child development
11	Children Learning (about the brain)	Information (about brain)
12	Clarifying	Information
13	Colleagues	Training
14	Communication	Information, training
15	Concentration	Skills
16	Concepts	Information
17	Confidence	Child development
18	Confusion	Information
19	Context	Context
20	CPD	Training

21	Culture	Context
22	Current practice	Context
23	Declarative, semantic	Strategies
24	Deficit	Language
25	Dichotomous brain	Myths, information
26	Diktats	External pressures, context
27	Disagreement	Information, time constraints
28	Dyslexia	SEN(D)
29	Early years	Child development
30	Ed psych	Training, support
31	Emotional	Child development
32	Emotional Intelligence	Traits, theories
33	Environment	Environment
34	Exercise	Life style
35	Focus	Skills
36	Forest schools	Environment
37	Gender	Values
38	Genes	Information, training
39	Ideals	Values
40	Imaging limits	Technology
41	Impact	External pressures
42	Indicators	Information
43	Journals	Information, sources
44	Language	Language
45	Lateralisation	Myths, information
46	Learning styles	Products
47	Learning to learn	Strategies
48	Medical	Medical, SEN(D)
49	Memrise	Products
50	Mental health	Child development
51	Metacognition	Strategies
52	Mindfulness	Strategies, products
53	Mindset	Strategies
54	Motivation	Child development
55	Multi-sensory	Information, strategies, SEN(D)
56	Neuromyths	Information, sources, myths
57	Neuroplasticity	Specifics
58	Neuroscreening	Technology

59	Ofsted	External pressures
60	Outdoor learning	Environment
61	Parents	Context, environment
62	PGCE	Training
63	Progress	Context, external pressures
64	Pruning	Specifics,
65	Psychology	Training
66	Reaction	Values
67	Recall	Information, training
68	Rehearsal	Strategies
69	Repetition	Strategies
70	Reptilian	Specifics
71	Research	Sources
72	Rewards	Child development
73	Risk taking	Child development
74	Scepticism	Information, sources
75	SEN(D)	SEN(D)
76	Sensory	Specifics
77	Sleep	Life style, environment
78	Social Brain	Child development
79	Social cognition	Adolescence
80	Social media	Environment, technology, adolescence
81	Sources	Information, sources
82	Stereotypes	Child development
83	Struggling learners	SEN(D)
84	Study	Skills
85	Surprise	Information
86	Synaesthesia	Medical, information,
87	Synapses	
88	Teachers	Context
89	Technology	Strategies
90	Timing	Strategies
91	Uncertainty	Sources, information, training
92	VAK	Strategies, myths, products
93	Visualisation	Strategies

Table 5.1: Codes and possible themes

Table 5.2 lists the sub-themes alphabetically and indicates the number of occurrences for each sub-theme. As with the codes, frequency or magnitude has been treated cautiously, though as the table indicates the regularity with which some sub-themes arose demands further consideration, whilst not implying that lower frequency means less worthy of further exploration. The reverse is conceivably true; something mentioned less frequently may be of importance but not familiar to many participants.

Sub-theme	**Number of occurrences**
Adolescence	2
Child Development	13
Context	6
Environment	5
External pressures	5
Information	21
Language	2
Life Style	2
Meaning-making	1
Medical	2
Myths	5
Products	5
SEN(D)	6
Skills	3
Sources	6
Specifics (about the brain)	5
Strategies	11

Technology	3
Theories	1
Time Constraints	1
Training	7
Traits (in students)	2
Values	2

Table 5.2 Alphabetical list of sub-themes and their rate of occurrence

5.2.1 Final Themes

As table 5.1 shows, the 93 codes initially suggested 23 sub-themes. These were then further considered in order to reduce them to a manageable set of themes. Table 5.3 shows how the 23 sub-themes were gathered into seven over-arching themes.

Theme	**Sub-themes**
1: Information sources and knowledge	Information, sources, training, time constraints, myths, specifics (about the brain)
2: Meaning and values	Values, meaning making, language, theories
3: Contexts and external pressures	Context, external pressures
4: Environment and lifestyle	Environment, lifestyle
5: Medical and SEN(D)	SEN(D), medical
6: Products and Strategies	Products, strategies, technology
7: Children's development	Child development, traits, skills, adolescence

Table 5.3 The seven over-arching themes and their related sub-themes

A final stage of the coding analysis, which connects up the initial codes and the final themes has been to present these alongside each other. This can be seen in table 5.4. This process draws the coding and thematic analysis together and assists in the discussion of each main theme in sections 5.3 to 5.9.

Themes	**Codes**
1: Information sources and knowledge	Access, brain differences, children learning (about the brain), clarifying, communication, colleagues, CPD, concepts, confusion, dichotomous brain, disagreement, ed. psych., indicators, journals, lateralisation, neuromyths, neuroplasticity, P.G.C.E, pruning, psychology, recall, reptilian, research, scepticism, sensory, sources, surprise, synapses, time constraints, uncertainty, VAK.
2: Meaning and values	Analogy, deficit, gender, ideals, language, reaction, theories
3: Contexts and external pressures	Context, culture, current practice, diktats, impact, Ofsted, parents, progress, teachers
4: Environment and lifestyle	Environment, exercise, forest

	schools, outdoor learning, parents, sleep, social media,
5: Medical and SEN(D)	Autism, dyslexia, medical, multi-sensory, SEN(D), struggling learners, Synaesthesia
6: Products and Strategies	Brain-Gym®, Declarative/semantic, learning styles, learning to learn, Memrise, metacognition, mindfulness, mindset, multi-sensory, neuroscreening, rehearsal, repetition, technology, timing, VAK, visualisation
7: Children's development	Anxiety, assessment, attainment, behaviour, child self-perception, concentration, confidence, early years, emotional, emotional intelligence, focus, social cognition, social media, rewards, risk taking, social brain, stereotypes, study

Table 5.4 Main themes related back to initial codes

5.3 Discussion

In chapter 5.4 to 5.10, the seven themes are discussed through an interpretative phenomenological analysis (IPA) perspective. Ways in which the themes interlink are considered. As previously described in chapter 3.3.9, IPA seeks to understand phenomena through the participants lived experience of them, in this case to further understand the question of how teachers mediate information about the brain and educational neuroscience. The role of cultural historical activity theory (CHAT) within my analysis has also been discussed in chapter 3.3. CHAT is particularly relevant in the analysis of particular themes, such as theme three (contexts and external pressures).

The discussion does not assume that my findings can be generalised over the whole teaching population. The discussion does, however, provide a potential basis for further investigation across this population and the themes suggest key areas through which teachers' engagement with and understanding of the brain and educational neuroscience could be purposefully enhanced. Where possible, the discussion situates my findings and interpretation amidst other research in the field. Chapter six then offers conclusions and recommendations as well as suggestions for further research that emanate from the discussion.

5.4 Discussion of Theme One, Information Sources and Knowledge

5.4.1 Sources of Existing Knowledge

Though teachers can often cite examples of sources that have been influential on aspects of their professional learning and in the development of their professional practice, the participating teachers were much less clear about where their existing knowledge of the brain comes from and did not draw on any consistent sources. Frequently, they described previous educational experiences, not directly related to their training or development as a teacher. Sam stated that her knowledge of the brain had come from experiences that were ‘nothing to do with teaching’ (interview 5, line 10) and went on to describe first aid training. Chris stated that she had ‘no idea’ where her knowledge had come from (interview 3, lines 11 and 15). Although Kath professed interest in the field and felt her psychology background supported this interest, she did not recall any specific sources whilst Grace, whose work involves regular exploration of brain issues, chose to state that her ‘A level biology course must have touched on it’ (interview 2, lines 6-7). The absence of noted, consistent professional sources and the references to experiences elsewhere and from many years ago highlight the continuing disconnection between the extensive, ongoing research and the teachers’ daily activities. It also appears that the participants looked back into their past training, as if they had a sense that there ought to be something at the start of their development as teachers that examines issues of the learning and the brain.

A considerable volume of the knowledge of the brain that the teachers discussed had been constructed through personal experience, again in the absence of any specific professional guidance. Examples include Amy’s thinking about memory, based on her personal interpretations of where in her brain she perceived activity to occur, Chris’s reference to ‘assumed knowledge’ (interview 7, line 69) and Grace’s comment that there are things we intrinsically know about the brain for which ‘you don’t need to be a teacher’ (interview 2, lines 65-66). It may be tempting to be dismissive of such knowledge and as we saw in chapter 2.5 Anderson and Della Sala (2011) believe that neuroscientists frequently are, but such dismissal fails to recognise the importance of this knowledge on two counts. Firstly, it is essential to neuroscience's understanding of its educational audience and secondly, however faulty or out of date the teachers' working knowledge may be, it has still frequently served them as one aspect of the creation of successful routes to learning for their pupils.

This personalised divergence of thinking about the brain needs to be recognised, without judgement, as a factor in improving communication between the fields of neuroscience and education. I suggest that this is a dimension of what Palghat et al. (2017) see as the preliminary sharing of assumptions; 'differing worldviews give interdisciplinary work value. However, these same differences are the primary hurdle to productive communication between disciplines' (p. 204). Whilst teachers and educational neuroscientists may well not be afforded time to consider many philosophical aspects of 'worldview', there are important key discussions to be had and understandings to be reached. Palghat et al. refer to this assimilation of views and assumptions as a 'hard problem' (p. 204) and offer two frameworks that may support the process. The first is Eigenbrode et al.'s (2007) framework for philosophical dialogue for collaborative science and the second is Donoghue's and Horvath's (2016) abstracted conceptual framework, which can help collaborators identify key areas for shared understanding.

The most commonly cited knowledge of the brain to influence practice, as evidenced in survey question eight, was the use of visual, auditory and kinaesthetic approaches to teaching and learning, commonly referred to as

VAK. Though some teachers commented that this approach is now viewed less favourably, there was no evidence of its supposed scientific basis being questioned. The VAK approach has received promotion through commercial products, such as online tests to ascertain pupils' VAK strengths and weaknesses and has also been promoted in many schools' own professional development provision. Though teachers may lack the knowledge to challenge the unfounded claims of VAK's scientific basis, it has had some positive effects in that it has prompted some teachers to think in different ways about how their pupils engage with learning. More recently many UK schools have realised that rather than concentrate on a supposedly preferred mode of visual, auditory or kinaesthetic learning, pupils need capacity in each of these, that in any case the three often interlink and that they are not a complete list of ways to learn. Chris captures this in interview seven, where she questions whether the scientific foundation of VAK, learning styles and Multiple Intelligences Theory matters, if they have prompted developments in teaching. This is an interesting observation to come from an interview participant who expressed much scepticism. Rather than be alarmed by the teaching profession's apparent willingness to work with dubious theories and products, it is perhaps more important that we recognise how the profession tests such theories. I return to this in discussion of theme six (products and strategies).

Some references were made to other colleagues as sources of information about educational neuroscience. Something the data cannot do directly is indicate how reliable or up to date this source might be. Only one reference was made to other professionals, when Grace spoke of discussions with the educational psychologist linked with her school (interview two). This has been useful for Grace, though is only possible because of the nature of her school, something that I return to under theme three (contexts and external pressures).

5.4.2 Access to Sources

The teachers spoke of difficulties in accessing research papers, due to this requiring log in capability via a higher education institution. No teachers mentioned open access or sources such as the Chartered College of Teaching's (CCT) research depository, which is available to teachers who have registered with the college, though nor did I ask about these options during the interviews.

Access is also affected by time constraints. In the course of their busy working lives, most of the teachers felt unable to devote time to learning about educational neuroscience, though if it was relatively easy to consider, related to the teachers' main duties and largely free of technical terminology, it was viewed more positively, such as the online modern foreign languages information and the brain updates that Amy described. In general, however, educational neuroscience is some way down the perceived priorities of the teachers. I return to this issue under theme three (contexts and external pressures).

Access must also be affected by limited existing knowledge, as teachers may not consider that contributions to professional thinking about aspects of their work exists in the educational neuroscience field and cannot search if they do not know what they are looking for.

5.4.3 Teacher Expression of Knowledge of the Brain

The teachers' expression of their knowledge of the brain and educational neuroscience within the data is almost entirely free of neuroscience terminology, for either components of the brain, brain development or brain activity. Reviewed strictly, such references numbered only four throughout the data (neuroplasticity, pruning, reptilian, synapses) though use was made of more general words such as recall and sensory. Words drawn from psychological theories of memory, such as declarative and semantic, were also used. Teachers appeared to view these latter two as brain functions rather than theories of memory. As one might expect from teachers, references were made to brain-related conditions such as autism and dyslexia.

The data therefore suggests that teachers tend to possess little in the way of a lexicon of educational neuroscience. This can only make dialogue, access and engagement difficult. It is compounded with Chris's view that many of her primary school colleagues, who are required to teach the whole primary school curriculum, do not feel confident about teaching science and it may well follow that they would feel equally under-equipped to engage with the literature of educational neuroscience. Chris went as far as to suggest that 'if you want to further the use of neuroscience, find other ways of describing it, maybe' (interview 8, lines 32-33). In the interviews particularly, there are many examples of teachers doing precisely that, particularly through the use of analogy. This is considered further in theme two (meaning making).

Amy offered a slightly different explanation of her preference for analogy and non-neuroscientific language. She described herself as 'not qualified' (interview 4, line 64) to use such terminology. Amy and Chris appear to express a sense of inferiority in working with neuroscientific information, yet it will ultimately be their actions and those of other teachers that explore the potential of educational neuroscience in classrooms. Despite their uneasiness with or lack of knowledge of the terminology, they both expressed enthusiasm about the idea of being involved in educational neuroscience research, notably in aspects of their work where they do feel a sense of expertise (learning of second languages and forest schooling respectively). In their own ways, they are already doing such research, a point explored under themes two and six (meaning making, products and strategies).

5.4.4 Continuing Problems with Teachers' Knowledge of the Brain

Participant responses to question seven suggest some improvements in teachers' awareness of some the common neuromyths, when compared to previous investigations of this issue (such as Howard-Jones et al., 2005, Dekker et al. 2012, Lee, 2012). At the same time, many of the participating teachers appear to still subscribe to some neuromyths and are unsure about some now strongly debunked myths.

For example, a majority of teachers agreed that the brain can produce new connections into old age (statement 7.1). It would be useful to now explore whether this piece of knowledge is used, in support of the messages about lifelong learning that schools seek to promote. Yet nearly half of the survey participants agreed with the statement ‘generally we only use 10% of our brains’ (statement 7.2) and over a quarter felt unable to agree or disagree. In interview six (see sub-chapter 4.3.2) Grace commented that she thought that the brain is more and less active at different times, under different demands and stresses and that some teachers might take the view that disengaged, bored students would be using much less of their brains’ capacity. This may have influenced some responses, Grace suggested. Belief in this myth most likely does not have any significant bearing on classroom practice, at present, but such fundamental misunderstandings may become problematic if educational neuroscience becomes an established dimension of teachers’ understanding of learning.

Other responses display continued confusion, particularly about three prevalent neuromyths. The idea of the dichotomous brain, wherein one side of the brain is responsible for scientific, mathematical and analytical activity whilst the other is responsible for artistic, creative activity was refuted by just over a third of participants. This raises a question, of whether teachers who subscribe to the notion of the dichotomous brain may then, perhaps subconsciously, characterise some of their students on this basis and as a result, alter their expectations of some students.

Survey participants were also divided about the notion of multi-tasking. In response to statement 7.16 (concentrating on one difficult task is more effective than-multi-tasking), the statement was refuted by just over a third of participants. This response is curious in that it does not appear to correlate well with the fact that the participating teachers are likely to extoll the benefits of maintaining focus on the task in hand and avoiding the distraction of other tasks. Bradbury (2014) points out that multi-tasking is in fact rapid but not especially efficient *switching* between tasks and can be detrimental to brain health. Loh and Kanai's investigation (2014) pointed out correlation (but not necessarily causation) between decreased grey matter in the anterior cingulate cortex, a brain area involved in cognitive and emotional control, amongst 75 people who multi-task with several media devices. A Stanford University study raised concerns as far back as 2009 (Ophir et al., 2009). This study found that the regular multi-taskers were actually worse at switching from one task to another, a problem that the researchers suggested was due to their inability to block out irrelevant information. These studies support the case for the single focus and avoidance of distractions that teachers generally require of their pupils, yet few teachers appear to come into contact with such research.

A third myth, that 'scientific evidence shows that listening to Mozart can improve long term brain function' (statement 7.10) also divided the survey participants. Only 12 participants disagreed with the statement, uncertainty was evident in 54 participants opting to neither agree nor disagree and the remaining 36 agreed with the statement. Grace commented on this in interview six, which is described in sub-chapter 4.3.2. She noted that music is a useful means of altering or enhancing a particular classroom atmosphere, but she was less sure about long term effects on brain function. Chris also commented on the Mozart Effect in her second interview (interview seven, 4.3.8). She noted that a BBC Radio 4 programme that she had heard a few days before the interview had claimed that playing Mozart to children about to undertake the English Standardised Assessment Tasks (SATs) would make the children 'more likely to get good test results' (interview seven, line 207). The research that led to the invention of the term 'Mozart Effect', a term that the researchers did not coin and made no such claim, initially appeared to show an increase in a very specific ability: spatial reasoning (Rauscher, Shaw and Ky,1993). What was rather less reported was that the effect was very short-lived, in some cases merely a matter of seconds. The participants were all college students in America, so there was no evidence here of effects on the brains of babies or the school-aged population. Furthermore, subsequent research by Rauscher and Shaw (1998) pointed out that the 'effect' was not evident with all participants, others appeared to be affected by different music such as J. S. Bach or pop music and in yet other cases the music made no difference. Having encountered and absorbed misleading information, there is then a potential problem in countering it. Chris commented in interview seven that any retractions in the media of the excessive claims made by journalists would not necessarily reach many people who had taken in the initial claim.

Papadatou-Pastou et al. (2017) propose that the most effective way to reduce the acceptance of neuromyths amongst teachers is for teachers to have greater general knowledge of the brain. This improved knowledge would then assist teachers in recognising myths. Papadatou et al. describe the acceptance of neuromyths amongst teachers as ‘worrisome, as the adoption of such myths wastes money, time, and energy resources that could be rather spent on evidence-based practices’ (p.2). They suggest that knowledge of the brain and educational neuroscience should form a part of teacher training programmes. Horvath et al. (2018) however, claim to have demonstrated that there is no correlation between teachers’ awareness of neuromyths and the outcomes of their teaching and dismiss this as an irrelevance. If it is irrelevant then that may be taken as another demonstration of the gap between educational neuroscience and teachers’ day to day activity.

Currently, this is not a requirement of teacher training programmes in the UK, though there are some instances of this occurring, at the discretion of programme staff. Amy, the most recently trained of the interview participants, commented that learning about the brain did feature in her training, but looking back felt that this was undertaken from the viewpoint of the emerging VAK and learning styles trend. The question of educational neuroscience and initial teacher training is considered further in chapter six.

Confusion and uncertainty are apparent in the data in one further area, the question of the role of genetics in learning and development. In the second round of interviews, during which Chris, Grace and Amy each reviewed the survey data, each of them pointed out the wide variance in the percentages allocated to the influence of genes and environmental factors in educational development. This is relevant, as not only are behavioural geneticists already advocating the use of genetic information in educational planning (Ashbury and Plomin, 2014), but also the outcomes of teachers' work, in the form of attainment data, are already being evaluated through reference to genetic data (Morris et al., 2018). Despite the uncertainty, the survey data demonstrates that teachers have interesting contributions to make to the debate about the various influences on educational development (which interact with genes), as we saw in the additional suggestions presented in table 4.6.5. In addition, there is an ethical dimension to the use of genetic information in educational contexts, a debate in which teachers should be participants. I return to this question in chapter six.

5.4.5 Future Knowledge

As table 4.4 summarises, teachers offered 30 aspects of their work to which they believed educational neuroscience might contribute. Some of these one would anticipate, such as behaviour issues, since problems of behaviour are an ever-present aspect of life in schools and work with young people. Several others, however, relate strongly to research in the field.

The strongest example of this is memory and retrieval, to which there were seven references in the survey and discussions of in several interviews. It is easy to explain teachers' interest in memory and retrieval and there is extensive potential opportunity for collaboration with educational neuroscientists, given the extensive work on this aspect of brain function and the immediacy it has for teachers. As pointed out in chapter 5.4.3, some of the teachers participating in my research use language drawn from psychology, making reference to declarative, procedural and semantic memory but at no point do they mention neuroscience findings about areas of the brain involved in different types of memory, the networks of the brain that are increasingly being found that serve memory or the role of our ability to combine unrelated memories in creative activity, for example. One might argue, as we have seen Horvath et al (2018) do so in the case of neuromyths, that knowing about these things would not make any difference to teacher effectiveness. I argue that there are examples in my data of teachers' willingness and interest in taking information like this and using it to support their own experiments with pedagogy. I consider this further under theme six (products and strategies). Paul Howard-Jones (2008b) has suggested that by the middle of the next decade there could be National Curriculum targets in England for working memory. Teachers' interest in this could lead such an introduction, rather than it come about simply through mandatory requirements. In interview eight, Amy hinted at wider questions about memory, in querying what the significance of purpose and motivation might be for memory, so thinking beyond the mechanisms of memory formation.

Other areas of neuroscientific interest raised by the participating teachers are also receiving attention from neuroscience research. For example, one teacher specified 'responding to individual difference' and many of the other areas suggested relate to individual difference. Now that there is extensive generalised information about the adolescent brain, Foulkes and Blakemore (2018) are calling for more research that explores difference rather than similarity. This would appear to be another clear point of access for teachers and is considered further under theme seven.

I suggest that there is neuroscientific significance in all of the suggestions presented in table 4.4. This raises the question of how the interest of teachers and the investigations of neuroscientists can be synergised and this question is considered further in chapter 6.

A final consideration from table 4.4 is the suggestion of two teachers that neuroscientific knowledge could improve their professional confidence. This is interesting in that it is not about direct strategies but about self-perception. Taken alongside the various comments, such as those at the foot of table 4.4 ('this whole area is fascinating', 'should know more about this', 'need time to explore this properly') that reflect a level of interest, time constraints notwithstanding, it is reasonable to suggest that there is willingness amongst teachers to become more informed and even a degree of anxiety about and recognition of a general lack of current knowledge. I acknowledge that the survey itself may have generated such a concern for some participants.

5.5 Discussion of Theme Two, Meaning Making

5.5.1 Values and Beliefs

It was noted in chapter 5.4.1 and discussed by Palghat et al. (2017) that underlying assumptions, values and beliefs ideally need to be explored for differing disciplines to collaborate on research. In each of her interviews, Chris illustrates how her personal values influence how she deduces meaning from neuroscience information.

None of the questions for the first round of interviews made any reference to gender, but Chris made it clear that her views on gender play a highly influential role on how she responds to some types of neuroscientific information. She stated clearly that she would ignore anything cited within neuroscience that challenged her views on gender and expressed a concern that research can be distorted to support beliefs about gender that strongly conflict with her own. She made it clear that she would resist any attempt to use neuroscience to make a case for gender stereotypical activities or methods of learning for girls or boys.

In her second interview (interview seven), when considering the survey responses to statement 7.19 (‘there are structural and biochemical differences between male and female brains’), Chris reiterated her comments from interview three and again we discussed issues of gender at some length. The question then arises, what fundamental personal and professional values or beliefs might influence teacher responses to educational neuroscience?

In her second interview (interview six) Grace demonstrated how difficult it can be to change longstanding beliefs, in this case about prior knowledge of the brain. Grace felt unable to agree with statement 7.1 (the brain can produce new connections right into old age) as she had learned some time ago that the brain was unable to make new connections beyond the age of 25. As has been pointed out previously and is explored further in theme three (contexts and external pressures), Grace has the more regular dealings with matters of the brain than the other interview participants, so the continuing influence of her prior knowledge here is surprising.

Chris pointed to a further difficulty in how and when teachers change their views or re-evaluate their professional knowledge. Chris commented on how difficult it can be for teachers to change their knowledge, understanding and working practices '… what you have spent hours of your life preparing and teaching. It's fairly hard to say, "oh, it was rubbish after all". That's quite a bitter pill to swallow, isn't it?' (interview seven, lines 545-547). There is a question here then, about whether teachers in training are introduced to the idea of the temporary and provisional nature of knowledge and the implications of this for changes in knowledge and practice that will occur during their teaching careers. This is significant for all aspects of knowledge and practice, not just for educational neuroscience.

5.5.2 Language and Analogy

As we saw in chapter 5.4.3, the participating teachers rarely expressed their knowledge of the brain or educational neuroscience through neuroscientific terminology. A key means by which the teachers make such knowledge meaningful for themselves is through analogy. In chapter four several analogies for brain processes were noted. It might be expected that teachers adopt such a strategy, as analogy and metaphor are common features of teaching. This may seem like a simple matter of finding language to convey meaning, by describing the brain through its apparent similarity to other things. Comparison theory would say that this is indeed a matter of language. In their classic work on metaphor, Lakoff and Johnsen (1980) take a very different view of metaphor. They suggest that rather than simply being a matter of convenient language, metaphors create frameworks for thoughts and actions. What this may mean for the development of teachers understanding of neuroscience is an area for further investigation. We saw in chapter four that analogies can deteriorate to a point where they are inaccurate - ‘the brain is a muscle’, rather than ‘the brain is like a muscle’ in that it needs regular use to be healthy and strong. Epstein (2017) insists that the computer analogy (which was used by participants and as Amy described is used by her ten-year-old daughter) and the use of words like ‘storage’ and ‘processing’ is problematic. He goes as far as to suggest that such language is a barrier to further understanding and that it simply reflects the highest levels of technological development of our time, just as our predecessors in the industrial age sometimes discussed the brain as if it were a machine.

5.5.3 Creating Pedagogical Meaning

There appears to be an appetite amongst the interview participants for exploring for themselves just what neuroscientific findings might mean in pedagogical terms, rather than this be decided by others and translated into pedagogical strategy on their behalf. Kath referred to ‘how to’ guidance (interview 1, line 54), stating that she disliked this and preferred to apply her reading about the brain to her own experiments with how children learn. Sam described strategies that she felt she had developed from information about the brain, that she utilises in both her subject and pastoral roles. Amy talked of her own experiments with approaches to memorisation. After her first interview, Chris opted to examine educational neuroscience that explores the value of the forest school model, not looking for strategies or activities per se but for further thinking about and justification for using the forest school approach. Grace explained a number of strategies that she and her colleagues had developed in response to congenital brain injuries endured by their pupils. These and other strategies are considered further in theme six (products and strategies) and the potential significance of this apparent interest in developing the pedagogical dimension of educational neuroscience is further discussed in chapter six.

5.6 Discussion of Theme Three: Contexts and External Pressures

The extent of and the nature of the participating teachers' engagement with information about the brain and educational neuroscience is influenced by their working contexts and the external pressures that they perceive their individual schools to be under. This contributes to considerable variation of exposure to educational neuroscience across the different working contexts.

5.6.1 Context

In Grace's school, there is a sense that engagement with brain-related information is a day to day matter, since many of their pupils have suffered brain injuries from birth. Grace is able to explore brain-related issues with an education psychologist on a comparatively regular basis.

Amy suggested that the independent status of her second school allows her and her colleagues freedom to explore educational neuroscience or anything else that could have a positive impact on practice. Whether there is in fact more extensive engagement with educational neuroscience in independent schools and if so, what is gained from this, each warrant further research. Research conducted through a collaboration of the independent Queen Anne's School, Caversham, England and Reading University is evident in chapter 2.5 and is also discussed in chapter 5.10.1. Like Amy's school, Queen Anne's feels able to set its own research agenda and is fortunate to have partners at its local university who have appropriate research interests to enhance the partnership.

Sam and Kath described different contextual features, whereby engagement with educational neuroscience was influenced by external factors. These are considered below.

5.6.2 External Pressures

Although Kath felt some freedom to explore educational neuroscience, as part of her efforts to work with difficult classes with which she has gained a reputation for positive outcomes, she felt that as a contributory field educational neuroscience was not considered a priority in her school. She stated that she believed that there was interest amongst her colleagues, including her senior colleagues, but in Kath's opinion educational neuroscience was simply not a priority. She explained that this was because it could not be demonstrated to bring about rapid, short term improvements and that such improvements dominate the school's agenda. She continued that this is due to the category of the school's inspection outcomes, which repeatedly leaves the school required to demonstrate rapid improvements. Kath's concerns raise a question of equality of opportunity for teachers to engage with research of a more longitudinal nature, within the context of high accountability and particularly the higher frequency of inspection of state schools in difficulty in England.

Sam expressed a different frustration that also had its origins in the external pressure of Ofsted inspection. Sam felt that there had been pressures in one of her previous schools to adopt some supposedly neuroscience-based practices in order to impress Ofsted, or because they appeared to be fashionable and in Sam's view the school leadership wanted the school to be seen to be adopting these practices. There is wider context to this concern, in that some of these practices receive commercial promotion that is selective with research findings, as discussed in chapter 2.6. Ofsted (2018), has itself gone to some lengths to expose what it refers to as a myth that their inspectors expect to see any specified practices, but Sam's concern demonstrates how educational neuroscience can become entangled in wider issues of practice, school policy, marketing and accountability.

5.7 Discussion of Theme Four: Environment and Lifestyle

Aspects of their pupils' environments and lifestyles raise concerns for the teachers and reveal some further confusions. Interest in these factors, however, also suggests that they offer a useful context for teachers' understanding of the brain and educational neuroscience. Areas of concern are inter-connected, such as concerns about sleep and the overuse of personal, technological devices or the connection between physical activity and mental health.

5.7.1 Sleep

Sleep has received considerable attention in educational neuroscience research, such as the Teen Sleep project described in chapter 2.5. This attention is to some extent reflected in the data. All but five of the 102 survey respondents recognised that sleep is an active time for the brain. However, some views about sleep and brain health are based on teachers' personal experiences with tired pupils rather than specific knowledge of the brain, something upon which both Kath and Chris remarked.

Amy was particularly concerned about the impact of technology on brain health, specifically the often-undetected use of mobile phones and other devices late at night. This has been reported on extensively in international media and a number of organisations, such as Teen Safe, have published guidelines for parents. Amy specifically identified the role of sleep in the consolidation of memory. Extensive research exists about this, as it does for other aspects of sleep's effect on brain development and brain health and these may be particularly fertile areas through which teachers might enhance their understanding of the brain. For example, Stickgold and Walker (2007) explain that although the consolidation of memory is a long, complex process that happens over many stages, or as they describe it, 'a continuing series of biological adjustments that enhance both the efficiency and utility of stored memories over time' (p. 331), they have no doubt that the various stages of the sleep cycle each play an essential role. They argue that each of these stages is essential in the post-learning, rehearsing and initial encoding phases, i.e. after learning episodes in school. They maintain that this is true of all memory types listed in typical taxonomies of memory (types such as explicit, implicit, declarative, procedural, episodic, semantic).

5.7.2 Exercise

As can be seen in responses to survey statement 7.4, all but five of the 102 survey participants agreed that exercise plays a supportive role in the efficiency of the brain. Though this appears to be a secure piece of knowledge among the participating teachers, Chris wanted to explore this further and queried the word 'efficiency'. She wanted to make the point that exercise is a factor not just in an academic or cognitive idea of brain efficiency but also in mental health, mirroring the growing concerns about the mental health of the school-aged population. It is fair to suggest that Chris and many other teachers would like to understand more about the relationship between mental health and the effect of exercise on the brain, as well as between academic progress and the effect of exercise on the brain.

5.7.3 Environments

As discussed in chapter 5.4.5, survey question 11, which asks participants to approximate percentages for the impact on educational achievement of genes, school environment, wider environment and any other factors that participants wished to add, revealed widely varying views. Whilst there cannot be a single ‘correct’ answer to this question, confusion is evident. Chapter 5.4.5 considers this confusion in relation to genes. Here under theme four, the confusion about school experience and wider environment beyond school (so including the home environment) is considered.

It is curious that some participating teachers actually assigned a surprisingly low percentage to the impact of school experience. If this was only one or two teachers, then one might explain it as a consequence of recent frustrations with difficult students or classes, or with local and national educational developments. However, 13 teachers considered school experiences to account for 20% or less of educational achievement, some regarding it to be as low as 10%. One might then expect that these teachers would then instead ascribe greater influence to the wider environment, but such a pattern is not evident; some do, whilst others have given a greater weighting to genes as an influencing factor. Taken as a whole, the responses suggest that whilst there are strong opinions amongst teachers about how these factors influence educational achievement (and by implication the development of the brain) there is scope to understand this better and, in some cases, for example where 5% or less has been assigned, for views to be challenged.

Kath expressed a concern that some of her colleagues, in her opinion, believe that developmental damage brought about by the troubled home environments of many of her school’s pupils cannot be undone. There is evidence that examines these fears and also projects that aim to minimise such early damage. It would be valuable for Kath and her colleagues to have the opportunity to consider research and projects such as those described below, which speak directly to their concerns.

D'Angiulli et al. (2012) discuss how their study and a series of others 'reflect genuine cognitive differences' (p. 1) in the brain mechanisms of executive attention and cognitive control of adolescents from lower and higher socioeconomic status. Though D'Angiulli at al. consider their sample of 28 young people to be small, considerable efforts were made in their study to rule out factors that might confound the results, so some participants were withdrawn due to, for example, other potential influential factors such as ADHD or foetal alcohol syndrome. They found the higher socioeconomic background participants to be better at ignoring irrelevant aural stimuli, whereas the lower socioeconomic background participants gave cognitive resources to the 'distractors'. D'Angiulli at al. hypothesise that this may be a consequence of the lower socioeconomic group living in less stable and less predictable environments, in which it may be a self-preservation mechanism to pay attention to unexpected stimuli. Such a viewpoint could have a considerable impact on discussions of attention and focus in a school such as Kath's.

The term *neuroprotection*, which Bonnier (2008) explains was originally used in reference to substances that could prevent cell death, has now come to refer to interventions designed to support the brain development of at-risk groups of infants. At a national level, Bonnier discusses two projects amongst many, Sweden's New-born Individualised Developmental Care and Assessment Programme (NIDCAP) and the Infant Health and Development

Program (IHDP) in the USA. These projects focused on premature births, low birth weight and poor socioeconomic status. Both found they were at most effect when intervention involved both parent and child. Cognitive rather than motor development showed the greatest improved outcomes and even more so in cases where more than one risk factor had been identified. It would be valuable for Kath and her colleagues to be informed of such projects, that seek to mitigate the developmental damage about which they are concerned and knowledge of which would expand dialogue beyond their personal experiences.

In the UK, the charity Save the Children has drawn on evidence about the infant brain, in its 2016 publication *Lighting Up Young Brains*. This briefly explores 'how parents, carers and nurseries support brain development in the first five years' (front cover) and is particularly supportive of the *Read On Get On* campaign. The booklet draws attention to the role of early language development in the subsequent development of reading skills, pointing to the worrying percentage of children who do not become good readers in their primary school years and are then hampered by this through secondary school and beyond. Along with memory, the neural basis for language is a key cognitive beneficiary of a healthy early environment. It seems that developments in different brain areas are staggered rather than occurring simultaneously. This presents some problems, as it surely does at other ages, with age-related expectations. As John Geake wrote, 'the most important and radical change in the ways schools operate will be to de-couple age from stage' (2009, p. 184). Radical it may well be, but if Kath and her colleagues are to consider whether such a change could be a positive factor in their school then this requires them to be able to engage with research that examines the neurological foundations of such proposals.

Each of the areas raised under this theme constitute potential points of further access for teachers, given the opportunity to examine the ongoing research, that can inform their thinking and connect work in classrooms with research findings.

5.8 Discussion of Theme Five, Medical and SEND

Medical needs, special educational needs and disabilities also constitute areas though which teachers express their exposure to matters related to the brain and constitute key opportunities for developing understanding. These areas frequently overlap, though they are discussed separately below for reasons of practicality and clarity.

5.8.1 Medical Needs

Unsurprisingly, as a headteacher of a special school working with profound and multiple learning difficulties, Grace raised medical matters more than any of the other interview participants. She pointed out, for example, that it is important for her and her colleagues to have an understanding of the effects on the brain of various medications and she described how this knowledge influences the management of some of their pupils. What is interesting here is that Grace and her colleagues have the confidence to use this information and make their own plans, rather than solely basing their actions on guidance from medical sources. This planning is supported by carefully documented observations of individual pupils.

Grace expressed frustration that there is little opportunity to share this kind of knowledge and understanding with colleagues in mainstream schools. This may reflect a wider concern for Grace that her sector is treated as a separate arena of education, yet her thoughts raise pertinent questions as far as knowledge of the brain is concerned. The brain could be a significant area of shared interest between special school and mainstream teachers, but knowledge of the brain appears to reach the sectors in considerably different formats and through separate channels. In interview three (chapter 4.3.4) mainstream primary school teacher Chris expressed a heartfelt wish to better understand children who are unable to voice their differing perceptions of the world. In the context of Grace's school, this is something she and her colleague's grapple with daily and I suggest that rich and rewarding dialogue would occur if these teachers had the opportunity to discuss this across their different types of school. I propose that such dialogue would also be of great interest to educational neuroscientists.

Across the survey and the interviews, teachers expressed concerns about mental health amongst their pupils. One survey respondent wrote that children encounter 'new emotional stresses' and commented that it would be beneficial to 'understand the modern child's brain' (a response to survey question nine that is also considered under theme seven). This may imply that there is a case for teachers to be aware of insights that neuroscience might offer into mental health concerns that affect their students, notwithstanding the broader debate as to how, when and to what extent teachers should have an active role in the management of mental health concerns.

5.8.2 Specific Educational Needs and Disabilities (SEND)

A number of participants identified specific conditions and needs as areas in which they felt greater understanding of the brain would be beneficial, again suggesting that specific needs and conditions impose context through which this knowledge is easier to understand and to act upon. Autism was the most frequently cited condition. Given that more children with autism are attending mainstream schools as opposed to special provision and more children who have always been in mainstream schools are being diagnosed with differing degrees of autism, there is again a case for the dialogue between mainstream and special sectors that Grace suggested does not happen nearly enough (see chapter 5.8.1). Some commentators suggest that this increase is to a large extent explained by changing patterns of and accuracy of diagnosis, such that children who may have previously been diagnosed with a different condition are now more likely to be diagnosed with autism and that the increase has begun to level off (Taylor et al., 2013). However, this does not reduce the concern of teachers that this is an area related to the development of the brain in which their knowledge could be greater. I consider further under theme six what teachers might do with such increased knowledge.

The other most frequently cited condition was dyslexia and the participating teachers who raised this appear to feel that their knowledge of the condition could be improved. Certainly, ongoing research is extensive and challenges some of the approaches that some teachers hold to be an appropriate response to dyslexia, such as the use of coloured filters (see Ritchie et al., 2012).

The teachers' concerns about their knowledge of autism and dyslexia apply to other conditions, such as dyscalculia and attention deficit hyperactivity disorder (ADHD). These conditions are also subject to extensive research, for example the identification of areas of the brain that contribute to dyscalculia (Seron, 2012) and to ADHD (Cortese et al., 2012). This raises the questions, also encountered under theme one, of how the extensive research in all these areas is made available to teachers and, as I consider further under theme six, how teachers then develop the confidence to experiment and develop pedagogy based on this knowledge.

5.9 Discussion of Theme Six: Products and Strategies

A considerable number of the participating teachers' comments and observations about their use of knowledge of the brain made reference to a number of teaching strategies and products.

5.9.1 Learning to Learn

Kath and Amy in particular raised the 'Learning to Learn' programmes with which they had previously worked and are now reportedly crowded out of their school's curricula. They felt that this is a loss. This suggests that they believe there is a case for children not just to 'do learning' but to also understand what learning is and how it happens. Amy expressed concern that her older students, of UK sixth form age (16-18), have limited understanding of their own learning such that it negatively affects study and examination revision. That Amy and Kath should raise Learning to Learn in the context of discussions of knowledge of the brain implies that they see programmes like these as contributors to pupil knowledge of the development of their own brains. It would follow that they would then welcome improvements to their own knowledge in order to teach about the brain and learning. There are some potential problems with this, in that complex processes within the brain might be subject to reductionist explanations and could also be a breeding ground for the creation of new neuromyths; this is a dimension of the communication challenge for educational neuroscientists and an indication of the need for dialogue between teachers and educational neuroscientists.

5.9.2 Brain-Gym®

Grace, Chris and Sam raised Brain-Gym® of their own accord during their first interviews. Survey participants were directly asked to comment on it (survey question 10.2). This question raised an interesting mix of responses. A considerable number of teachers had received training of some sort to use this programme, whether from the product’s own trainers or through training provided by colleagues. A variety of opinions were also expressed and a variety of approaches to its use were described.

What is most noticeable in both the interview and survey comments about Brain-Gym® is how teachers have adapted its exercises to their own ends, frequently somewhat unrelated to the specified brain development purposes and claims made by the product. Chris and Sam voiced their own scepticism about these claims, criticisms of which are well documented elsewhere (Hyatt 2007, Spaulding et al. 2010). I consider this teacher instinct for designing or redesigning pedagogy further below, in chapter 5.9.6. It does appear that experienced teachers can often develop effective practice from faulty resources, where they feel they have agency to do so. The question of agency is furthered considered in chapters 6.2.3 and 6.4.3.

5.9.3 VAK and Learning Styles

Table 4.5 suggests that the idea of working specifically with visual, auditory or kinaesthetic modes of sensory input (VAK, mistakenly referred to as learning styles) and the idea that individuals have a preferred learning style met with less disapproval than Brain-Gym®. This may in part be explained by the view expounded by Chris, that letting go of something upon which one had spent many hours of preparation can be difficult to do. Many survey responses appeared to have a lingering element of teachers having been required to demonstrate, at some stage in the past, that their planning took due account of VAK.

Thus it appears that whilst no longer such a focus in many UK schools, the VAK concept has entered into teachers' day to day thinking.

Despite the neuroscientific inaccuracies, as survey respondents stated the VAK approach did result in teachers attempting to 'vary opportunities' and in 'broadened experiences for pupils'. Whilst some teachers were critical, describing VAK as 'simplistic', 'discredited' and 'out of favour' there were no specific criticisms of the lack of a neuroscientific or a trials evidence base for the VAK concept or for the commercially available teaching resources and pupil VAK inventories to which it led. Some teachers, perhaps, may have felt inadequately equipped to challenge the implied scientific basis of VAK, unable to be the ‘critical consumers’ advocated by Sylvan and Christodoulou (2010).

However, it can be argued that issues around VAK have played a role in encouraging school leaders and teachers to expect to see reliable evidence for developments in pedagogy and also to recognise that they can and should be participants in such research (as discussed in chapter 2.4).

5.9.4 *Memrise*

In the case of the online learning application, *Memrise*, Amy did in fact conduct her own small-scale research, both as a user herself in learning Mandarin Chinese and in her trials of its effectiveness with her students when compared to ‘pen and paper’ methods. Amy was aware that she had assumed that there was a scientific basis to how the programme supports memorisation. What is not clear in the students’ apparent preference for *Memrise* is to what extent this simply reflects a preference to use technology rather than pen and paper. Amy appears to be grasping her way towards this question, as she did raise motivation as an area that she would be interested to know more about from an educational neuroscience perspective.

Amy also described finding *Memrise* to be a ‘playful’ way to learn (interview 4, line 43). This observation is of interest, as it hints at a wider debate about learning and a belief that in some way we are more receptive in a ‘playful’ state of mind. Chris also commented on avoiding creating states of ‘fight, flight or freeze’ as she considered these to be states of mind that are obstructive to learning (interview 3, lines 13-14). Based on these comments and observations, there appears to be a good case for an educational neuroscience perspective to contribute to teachers' understanding of learning from play. As discussed in chapter 2.5, Paul Howard-Jones has led a considerable amount of investigation into the neuroscientific basis of the effectiveness of learning through online and video games, with an emphasis on what he describes as 'chance-based uncertainty' (2010, p.70). This is not without controversy, however. Concerns have been raised that adolescent gaming may prove unhealthy for young people since an unhealthy interest in the dopamine reward of gambling might be inadvertently encouraged. In reply to these concerns, as raised by Griffiths and Hunt as far back as 1998, Johansson and Gotestam (2004) and Grüsser et al. (2005), Howard-Jones has suggested that it is not clear whether the children deemed most at risk possessed other traits that would place them in the category. One significant factor that is absent from the use of gaming as a learning tool, at least within schools, is a monetary dimension. However, given recent concerns about online gaming addiction in the UK, such as those raised by the Gambling Commission's 2018 report, Amy's interest in online games raises a wider question for her school and others: should schools be monitoring the extent to which they teach through online games and other methods that employ 'chance-based uncertainty'? Is this approach used more with particular students and if so why? Amy's comments also lead to other questions, of whether educational neuroscience can help us understand the difference between learning through play and learning through gaming and whether educational neuroscience might tell us something about how potential harmful effects can be mitigated. I return to these questions in chapter six, as areas for further research.

5.9.5 Mindset

Carol Dweck's work on self-theories, commonly referred to in schools as 'mindset', is another example of how teachers have found themselves engaging with some neuroscience. Dweck's books have spawned an array of resources designed to support schools in the development of 'growth' rather than 'fixed' mindsets and a number of teacher CPD providers offer courses on this subject. One particular trait of the brain is commonly described in support of the growth mindset concept, which is the brain's neuroplasticity. Mindset and neuroplasticity were raised by both survey respondents and by Kath and Sam in their first interviews.

It is logical that something that might point to an unpredictable dimension of young people's potential should hold appeal for teachers. In the context of her school, Kath felt that the ability of the brain to rectify difficulties created by troubled early experiences to be an important message and made efforts to emphasise this: 'I think it's really, really important to get that point across, otherwise we massively lower our expectations in what those children can achieve' (interview one, lines 150-152). Kath identified neuroplasticity as the key contribution that neuroscience could make to educational thinking at present. The background of test scores being used as proxies of future attainment must surely be a factor here, that Kath and others perhaps wish to see countered by the argument that standardised tests do not necessarily predict future achievement.

Kath has a view that the brain's neuroplasticity can to some extent mitigate the damaging effects of the environments of some students. The concept has also been taken up by a host of coaches and therapists. However, Aldridge (2016) has suggested that the idea of infinite plasticity is an example of the creation of new neuromyths whilst trying to eradicate old ones and one which may gain privilege over 'other narratives (that) might have similar effects on student motivation' (quoted from conference presentation). Bates (2012) suggests that it is misleading to imply that the brain's plasticity is infinite and suggests that genetic information will ultimately give greater clarification to individual neuroplasticity. It appears there is a more nuanced and complex debate to be had amongst teachers and neuroscientists about neuroplasticity.

5.9.6 Pedagogy and Strategy Testing

As noted above (5.9.2), the data reveal that teachers often adapt or modify pedagogy and classroom strategies, sometimes in ways that differ to the intentions of the originators and/or to accommodate their own preferences and contexts. Kath's preference for working with concepts, in her own way and as she perceives to be most appropriate for her classes, rather than using prescribed strategies, is a further illustration. This suggests that a major way forward for the collaboration of educational neuroscientists and teachers would be to allow teachers to devise and experiment with the pedagogical possibilities suggested by neuroscientific findings. Such an approach would recognise the expertise of teachers and improve the effectiveness of the relationship between neuroscientists and teachers, which as noted in chapter 2.5 can suffer from an uneven notion of where the relationship's expertise lies.

A further tension that emerges from such a proposal is one of teachers' agency in devising classroom strategies, which some suggest has diminished in many countries in an era of high accountability (Buchanan, 2015) and that this diminution has contributed to attrition rates within the teaching profession (Smith and Ulvik, 2017).

5.10 Discussion of Theme Seven: Child Development

Both interview and survey data reveal aspects of child development that are concerns or interests for the participating teachers, to which they suggest neuroscientific information can contribute. As discussed in chapter 2.9.2, the Carter Review (2014), a review of initial teacher training in England, called for a re-introduction of child and adolescent development in teacher training programmes (recommendation 1e). In light of this, the participants' comments raise aspects of development that might be included in a child development programme that draws on neuroscience as well as other disciplines.

It is also evident that participants believe it is helpful for children to have some understanding of the brain, as part of understanding their own personal development and their own capacity for continued learning.

5.10.1 Pupil Traits and Characteristics

Across the data in general and specifically in responses to survey question nine (see chapter 4.2.4) where teachers described aspects of their work that they felt would benefit from greater neuroscientific understanding, a number of pupil traits and characteristics were raised. As one might expect from a sample of teachers there is curiosity about what neuroscience can tell them about the development of several important learning traits that are significant in classrooms, such as working and long term memory, deep learning, SEND, application of prior learning and learning from mistakes, but there is also curiosity about what neuroscience can reveal about other traits that affect learning and development. As can be seen in the question nine responses, these include traits such as empathy, independence, reason, consequence, intrinsic motivation, self-efficacy, fear and anxiety. These are important responses, as they point to a richness of potential dialogue between teachers and educational neuroscientists. They also reflect the recognition by participants of the impact of these traits on pupils' progress with more specific classroom learning skills. Queen Anne's School in Caversham, England, in collaboration with its research partners at Reading University has undertaken an investigation of this nature, examining emotional contagion or how traits and attitudes may be acquired between friends and peers (Burgess et al., 2017 and Burgess et al. under review). This work has helped with understanding differences between year groups within the school. As noted in theme three earlier in this chapter (chapter 5.6.1), Queen Anne's School has some contextual advantages that support its involvement in research.

A further example is individual differences, which Amy raised in interview eight. Amy described how a change of personnel has brought about a focus on individual needs and differences, which Amy has felt was overdue, even though it has initially created a plethora of information that has not been easy to manage. What Amy and her school are exploring connects with a developing aspect of neuroscience. Foulkes and Blakemore (2018) are insistent that neuroscience research, having focused on brain similarities, now needs to explore brain differences. A majority of research has concentrated on finding generalisable traits and in one sense this is quite right, since replication of research findings is of great importance. Foulkes and Blakemore suggest, however, that 'this obscures meaningful individual variation in development' (p. 315). Foulkes and Blakemore conclude that individual variance in neuroscientific studies should now be regarded as a key area of investigation, rather than be considered an anomaly amongst more consistent findings across a sample.

5.10.2 Phases of Child Development

Grace, Chris and Kath raised questions about the impact on child development of early experiences. Kath also raised questions about development in adolescence, as did Sam. One survey participant commented that

> It would be useful to understand learning process (sic) being in the exact position of a child. Often I find myself reminiscing what it was like for me at that time. But times have changed and children have new emotional

stresses and are motivated by different incentives. If we could understand the modern child's brain using current factors learning would benefit.

(0650 responding to survey question nine)

There is extensive recent research of relevance to the questions that the teachers present, though whether the teachers are aware of this is not clear and as theme one demonstrates, raises a fundamental question about access to research and time to consider it, as well as the question of how well teachers are prepared for the fact that accepted 'knowledge' will be challenged and will change during their careers, with implications for their practice. For example, the concept of *critical* periods of development, which perhaps underlines the concerns of Grace, Chris and Kath about children's early experiences, in the light of neuroscientific evidence is now described as *sensitive* periods. As Blakemore and Frith put it, as long ago as 2005:

most neuroscientists now believe that critical periods are not rigid and inflexible. Rather, most interpret them as *sensitive* periods comprising subtle changes in the brain's ability to be shaped and changed by experiences that occur over a lifetime' (p. 26).

Again neuroscience shows us something of great significance but by itself cannot tell us what we must therefore do in our classrooms (or homes and nurseries). This further emphasises the need for collaboration between neuroscientists and teachers and the development of ever deeper shared agendas and understanding.

Blakemore and her collaborators have done much to reshape understanding of adolescence, shifting discussion away from viewing adolescence as simply a period of problematic hormonal imbalance, to instead recognising it as a period of significant brain development that we should value rather than wish for it to be over as quickly as possible (Blakemore, 2018). During the interviews, only Kath made any comments that suggest awareness of this work, whilst adolescence per se was not raised by survey participants.

5.10.3 Children's Knowledge of the Brain

Both interview and survey data show support for children to have some understanding of the brain, as a factor of their understanding of their personal development and their own learning. Reference to how this might be achieved was less evident, with neuroplasticity and ideas from mindset or self-theories being the commonly cited examples.

Whilst teachers appear to be in favour of the idea of children being taught about the brain, some difficulties also emerge. Firstly, as one survey participant observes, it can be difficult to find 'ways to explain brain development to very young learners' (6210, in response to question nine). To do this with any learners, of any age, implies that the teacher possesses both the appropriate knowledge and the strategies through which to teach it. Access to reliable information, as we have seen, presents a problem and this is before teachers even begin to think about how they might teach about the brain. Secondly, particularly amongst teachers of the 11-18 age range, there is the added complication of understanding the brain alongside emerging concerns about mental health. It is relevant that a significant volume of adult mental health concerns have their origins during this period of development (Fuhrmann et al., 2015). There is a danger here that well-meaning but mis-informed approaches, unco-ordinated with other relevant support that an adolescent may be receiving, could unwittingly cause confusion or compound existing difficulties. This is a different scenario to that of teachers devising pedagogical strategy informed by educational neuroscience.

Resources to assist children's learning about the brain do exist. One excellent example is the website *Neuroscience for Kids,* developed by Eric Chudler at the University of Washington. Though there are many online sources of information about the brain for a school-aged audience, this one is remarkable amongst them. It makes no assumptions about what children may or may not be able to cope with and is a vast resource, containing detailed brain information, lesson plans, games and other activities, as well as explorations of an array of issues. For example, the rights and wrongs of the brain–computer analogy are considered, as are the questions that arise around brain-enhancing drugs – so-called 'smart drugs'. The table of contents lists 10 areas, each of which expands to display a lengthy sub-contents list. The main table of contents presents us with the following well-structured initial options:

- The World of Neuroscience
- Brain Basics

  Higher Functions

  Spinal Cord
- Peripheral Nervous System

- The Neuron
  Sensory Systems
  Methods and Techniques
- Drug Effects
- Neurological and Mental Disorders

Whilst it may take some search time, teachers interested in compiling pupil-friendly but uncompromising information to use in school should find this a very useful site and one that pupils interested to discover more might explore further.

There are other examples that offer remarkable opportunities, such as the facility to contact a neuroscientist that is offered by brainfacts.org. Scientists who have agreed to participate in this are all willing to make visits to schools. As described in chapter 2.7 and 2.8, there are other reliable examples of both online resources and books. Further questions arise, however, as to how aware teachers are of these sources, how they find time to engage with them and precisely where the seemingly desirable learning about the brain fits into their schools' curricula.

Further important brain-related developments about which young people need to be informed include Artificial Intelligence and brain-computer interfaces. Whilst applications are initially of an industrial nature, there is much speculation of how these will expand into a consumer market. If schools purport to prepare young people for a fast-changing, technology-influenced world then these matters of the brain cannot be ignored and require some preparatory basics.

5.11 Chapter Summary

Setting out from the initial descriptive codes applied to the whole data, this chapter has explored a series of themes, interpreting what these may signify in terms of the following:

- factors that influence how teachers engage with knowledge of the brain and educational neuroscience
- areas of interest that may represent the most purposeful routes through which teachers might further engage with educational neuroscience
- questions and problems of engagement with and use of educational neuroscience by teachers arising within the interpretation of the data

Table 5.5 summarises the key points of chapter five. Each of these points contributes to the conclusions drawn in chapter six. As indicated in table 5.5, some of these points are specifically identified in chapter six.

Summary of Points Raised in Chapter 5
1. Points specifically re-visited in chapter 6
Teacher's capacity for and freedom to develop pedagogy, utilising educational neuroscience
Awareness of, access to and dissemination of educational neuroscience amongst teachers
Interaction of teachers and educational neuroscientists
Neuroscientific language and terminology: its role in teachers' capacity to engage in the debate
Genetics
School contexts and research engagement
Changing and ever-evolving nature of teacher knowledge
Brain health and learning with technology
2. Additional Points Raised in Chapter 5
The continuing problem of neuromyths
Children's knowledge of learning and the brain
Individual brain difference
Knowledge of the brain and understanding specific needs and conditions
Neuroplasticity
Use of analogy

Table 5.5: Summary of points raised in Chapter Five

Chapter Six: Conclusions, Limitations, Further Research

6.1 Introduction

This chapter draws together a number of findings from chapter five into a series of conclusions and implications. The chapter then proposes several areas for further research, emanating from the findings and conclusions. Further investigations suggested by the limitations of my research are discussed in chapter 6.3.

The conclusions below should be considered in light of the aims of my research. As stated in chapter 1, my intention has been to investigate teachers' mediation of information about the brain and educational neuroscience, in an effort to understand more about how teachers experience and act upon this information, for the purpose of contributing to the development of the working relationship between teachers and educational neuroscientists. The more profound and productive this relationship can become, the greater the potential gains in terms of classroom practice. As we saw in chapter 2.5, this relationship is not well explored yet is fundamental to the progress of educational neuroscience and its contribution in the classroom.

6.2 Conclusions and Implications

6.2.1 Initial Teacher Training (ITT)

As was evident in the responses of the interview participants and discussed in theme one (Information Sources and Knowledge, chapter 5.4), knowledge of the brain amongst teachers is frequently drawn from an array of sources, many of which are not directly related to professional training. In addition, only one participant made reference to consideration of the brain during ITT. We can see from popular literature about the brain and from references made across the data that teaching methods purporting to have a basis in knowledge of the brain cross the paths of all teachers at some stage. At the same time, the data reveals limited awareness of much current educational neuroscience research. Therefore, my findings indicate that teachers in training need to be made aware of both the issues and possibilities that educational neuroscience presents and need to be equipped with a framework through which they can evaluate what they encounter. In England, there is no clearly expressed requirement for this; the current ten available routes to qualified teacher status (QTS) do not make any stipulations about educational neuroscience. This fails to ensure that trainee and newly qualified teachers are equipped to identify the kind of 'psychopedagogy' (Burton, 2007, p.5) described in chapter 2.4. or to see how they may interact positively with educational neuroscience research. I propose that educational neuroscience should be incorporated into training modules that examine theories of learning and the contexts in which they are relevant. Placing educational neuroscience alongside other theories would not only raise awareness but also clarify that it is not an educational holy grail that will replace other theories and disciplines but is another discipline that contributes to our understanding of learning and teaching. This would also present an opportunity to establish a basic lexicon of educational neuroscience terminology for teachers. As was discussed in chapter 5.4.3, teachers participating in my research used very little specific terminology and this must have a negative impact on their understanding as well as on their capacity and confidence to discuss and debate the issues that educational neuroscience raises.

Training modules that tackle theories of learning, with educational neuroscience comprising an element of this, should also consider the provisional nature of knowledge – the fact that teacher knowledge, beliefs and practices change over time. This would assist in managing the frustrations that the participating teachers expressed, when faced with changing perceptions of pedagogy in the course of their careers. That is not to say, however, that teachers should be trained to simply accept changes to practice without first subjecting them to professional critique. In the case of educational neuroscience, such critique could be promoted within ITT quite easily, through the use of Sylvan's and Christodoulou's framework (2010), which was discussed in chapter 2.6. Its five foci and related actions are clearly related to educational outcomes and are presented in a manner free of neuroscientific complexities.

It should be noted that a further implication of this addition to the curriculum of ITT is the need for those delivering ITT, whether university or school-based, to possess reliable and up to date knowledge of the issues and potential of educational neuroscience. It may well be the case that many such individuals feel as poorly equipped to provide this as some experienced teachers feel they are to receive it. The need to urgently audit what actually is currently presented about educational neuroscience in ITT is discussed in chapter 6.4.1. All of the interview participants in my research made comments that implied that part of their training involved the promotion of current ‘fads’, approaches to pedagogy that had little if any research evidence to support them, yet had quickly become both accepted and promoted. This can also be seen in the survey data, with ‘VAK’ and personalised learning the most frequently cited examples. This in turn implies that ITT providers can be as vulnerable to ‘psychopedagogy’ as the teachers they train. This issue is compounded by the fact that in several current models of ITT in England, the leaders of ITT provision are current classroom practitioners, themselves under pressure to support the practices of their school. These models of ITT in England are based on the requirement for trainee teachers to meet the Teachers’ Standards (DfE, 2012). Only one of the 43 competencies that the Standards require trainee teachers to demonstrate makes direct reference to how learning occurs (standard 2.4: ‘demonstrate knowledge and understanding of how pupils learn and how this impacts on teaching’). This can be interpreted in many ways; findings such as mine strongly suggest that the next review of the Teachers’ Standards needs to be clearer about indicative content and that this fundamental aspect of becoming a teacher is given a more prominent position within the standards, in accord with the approach to theories of learning described above.

6.2.2 Continuing Professional Development (CPD)

It is evident within my data, most notably in interviews one to five (described in chapters 4.3.2. to 4.3.6) and responses to survey question nine (described in chapter 4.2.4) that participants are curious about what educational neuroscience might contribute to their knowledge and expertise across a wide range of professional interests and concerns, including age range and subject specialisms. As with ITT, there is a case to be made for an educational neuroscience dimension in CPD, because research is so extensive and so pertinent to these areas of interest and to many emerging educational debates, such as the use of genetic information, as considered under theme four (environment and lifestyle), theme six (products and strategies) in chapters 5.4.5, 5.7.3, 5.9.5 and further considered below in chapter 6.2.5. As with ITT, the same proviso is relevant to CPD, that educational neuroscience is regarded as a contributory discipline and not an exclusive solution.

Potentially, there is powerful synergy between the interests and concerns of teachers and those of educational neuroscientists; ultimately, both parties seek to better understand and to improve the efficacy of teaching episodes and learning experiences. It is less clear how this synergy might be brought to life, especially since nearly all neuroscience research in schools tends to be led by the interests of neuroscientists, with schools providing an opportunity to gather data. Queen Anne's School in Caversham, discussed in chapter 2.5 and chapter 5.10.1, has demonstrated that this need not be the only way and that it is possible for schools to make approaches to researchers, seeking collaboration led by the school's interests and concerns.

It has been suggested that collaboration between teachers and researchers is a key factor in the future contribution of educational neuroscience to professional practice (Thomas, 2018). I agree with this viewpoint, but my analysis indicates that there are fundamental understandings often missing from such collaborations. Chapter 6.2.3 considers aspects of such collaborative relationships to which my research draws attention.

With reference to some of the seven themes, below I offer some examples of research and evidence about the brain which can enhance the work of teachers and support the development of pedagogy and are therefore a strong basis for CPD.

In chapter 2.5 we considered Tokuhama-Espinosa's proposal that teachers' enhanced knowledge of neuroscience can help them understand, for example, why children might have difficulties with tasks that appear to require similar skills, such as spelling and the use of metaphors. Recognition of the different neural pathways involved in these seemingly similar skills can give teachers not only further patience with the child in question but also insight from which to devise strategies. As Tokuhama-Espinosa also notes, this is equally true of reading, mathematics, creativity and any other area in which we have growing neuroscientific knowledge. Exploring this knowledge and its strategic, pedagogical implications falls under themes one and six.

Improving teachers' work with autistic children falls under themes one, four, five and six. Autism is an extensive example of an area of professional learning in which neuroscience can support teachers. Considering Grandin's contribution alone, there are rich opportunities for teachers to better understand the condition and how they develop their practice with autistic students. For example:

- Grandin (2014) suggests that her difficulties with skiing may be a result of her smaller than usual cerebellum. How might this affect other physical activities?
- Grandin (2006) discusses how people in many fields are recognising the potential of thinking about activities – visualisation – as an effective addition to actual practice of the activity, since there is now evidence of blood flow in the relevant brain areas brought about by visualisation. Grandin also refers to the example of her own struggles with algebra: 'there was nothing for me to picture. If I have no picture, I have no thought' (p. 29). Conversely, there is now evidence that some people cannot form any such visual imagery. This is powerful knowledge in the hands of inventive teachers and connects with Foulkes's and Blakemore's call for increased understanding of individual brains, which was pointed out in chapter 5.10.1.
- Grandin (2014) does not overlook the fact that a considerable volume of autism research is focused on genetics. She reminds us that there is not simply a single autism gene and that genes interact with the individual's environment and experiences, so genetics do not have complete control over the development of the brain. This is a complex field, however, where a considerable number of genetic factors relating to autism are under investigation. This relates to theme four.
- As well as describing autism as a continuum of sensitivity to sensory inputs, Grandin also examines how the senses can become confused for some autistic individuals, particularly when under stress or fatigued. Sounds may be perceived as colours and touch as sound, or any

number of sensory confusions. Clearly this adds considerably to difficulties in perceiving reality. Grandin warns that these problems can lead to a misdiagnosis of hallucinations or delusions. In some of the cases that she explores, individuals find it impossible to process visual and auditory input simultaneously. Brain imaging continues to isolate details of these difficulties and Grandin believes that this can help therapies to focus on the problems more effectively. Grandin refers to therapy, but this is also relevant to pedagogy and misdiagnosis might refer to misinterpretations of behaviours in school.

In interviews one and four concerns about examination stress and fight and flight were expressed. Zull (2011) describes the role played by various parts of the brain in the rapid emergence of such panic, a description that teachers might utilise in their attempts to help their students manage stressful situations, both in and out of school. Zull explains that under stress some of the information being received by the thalamus goes directly to the amygdala, without any monitoring and consideration by the cortex. Zull calls this the 'lower pathway' (p. 59), as it generates reflex responses that we might recognise in our pupils as panic, or freezing, or refusal, or even despair. This is an evolutionary response, but the lack of anything to fight or run away from leaves our pupils still consumed by the chemicals set in motion by the amygdala and unable to engage with the 'upper pathway', whereby incoming information is screened by the cortex before progressing to the amygdala and further, more constructive action.

Understanding panic and how it might affect examination performance is surely a useful first step in training pupils to cope with stressful situations such as examinations, and this includes exam-oriented, well-prepared students.

Theories of situated and embodied cognition are further examples, relating to themes one, six and seven. Given the situated nature of much school learning, the biology lab, the history room for example, for students to find themselves trying to think clearly about the respiratory system, the causes of the First World War or any other cognitive demand in an examination room where they have never before had to do such thinking previously, can be stressful. It may be worth experimenting with this in the build-up to an examination. For example, could the history class go in the room that will used for the examination and discuss the causes of the First World War or whatever the syllabus entails, perhaps associate each cause with a specific part of the room? This would give them something to think through, requiring the involvement of the cortex in advance of the amygdala and would give them the possibility of accessing memories by recalling the activities undertaken on the visit to the examination room.

Embodied cognition questions the assumption that our brains lead the way with our physical actions. Wilson and Golanka (2013) have produced extensive research on embodied cognition and point out that it quickly came to mean several things, starting with the simple idea that 'states of the body modify states of the mind' (p. 1). They explain that it is a much more complex and challenging concept:

> Embodiment is the surprisingly radical hypothesis that the brain is not the sole cognitive resource we have available to us to solve problems. Our bodies and their perceptually guided motions through the world do much of the work required to achieve our goals, replacing the need for complex internal mental representations (p. 1)

This is a demanding concept to frame in terms of educational processes. Ionescu and Vasc (2014) propose that the major implication of embodied cognition for education is a re-think of the Piagetian notion of concrete and abstract. Traditionally, we employ approaches with young children that are dominated by concrete experience and we move on to more abstract thought with older children and adults. Ionescu and Vasc suggest that embodied cognition implies that concrete experience is also needed to develop a deep grasp of abstract concepts and high-order thinking:

> It is possible that the abstract ways of teaching (i.e. knowledge not grounded in direct experience) offer fewer chances for learners at any age to thoroughly comprehend concepts, to transfer the learned content, and to maintain this content longer in their memory (p. 278)

This handful of examples offer rich possibilities for neuroscience-inspired CPD.

6.2.3 Research Collaborations between Teachers and Educational Neuroscientists

It is not enough for teachers and educational neuroscientists to simply agree to collaborate and then proceed to plan a research project; as we have seen, such an approach fails to fully understand and integrate the fundamental knowledge, beliefs and purposes of each party. My findings draw attention to two key aspects of this relationship that warrant further consideration.

Firstly, educational neuroscientists need to recognise and explore collaborating teachers' beliefs about neuroscience, in a spirit of understanding, even though there may be technical matters or inaccurate information in need of updating or clarification, as we have seen in my data, particularly within theme one (information sources and knowledge). The evidence of teachers' nuanced ways of thinking and talking about the brain and neuroscience apparent in my findings needs to be recognised both as a relevant phenomenon and as an opportunity to develop shared understanding. The themes under which my findings are structured offer a framework for both the development of this understanding and the development of teacher knowledge. It is important that educational neuroscientists have such percipience of their key audience and collaborators. Similarly, educational neuroscientists' assumptions about teachers and schools, their day to day practices and the pressures under which they operate, need to be examined and discussed with participating teachers. Several frameworks designed to support this depth of collaborative perception were noted in chapter 5.4.1 (Eigenbrode et al. 2007, Donoghue and Horvath 2016, Phalgat et al.2017).

Secondly, there is a case for teachers to expect to be see themselves as a major source of pedagogical insight within this relationship. As we saw in several instances within my findings, teachers often devise their own ways to make use of pedagogical theories and strategies, influenced by their own experience, contexts and professional preferences. This is likely to have a profound effect on research findings and can be positively factored into research design. As we saw in chapter 2.5, for example as raised by Katzir and Paré-Blagoev (2006) and Anderson and Della Sala (2011), there can be a professional imbalance in teacher-educational neuroscientist relationships that implies that the relevant expertise lies with the latter group, due to the complexities of neuroscience. This relationship imbalance risks undervaluing the pertinence of teachers' daily exposure to the challenge of generating learning, as well as further compounding a serious issue raised by Griffin (2015), who suggests that the growth of the use of external providers through the contracting of private consultants to lead CPD in schools has undermined teachers' sense of pedagogical expertise and agency. Collaborations between teachers and educational neuroscientists should be an opportunity to reverse this trend, not intensify it.

6.2.4 Sources

The issue of sources of educational neuroscience knowledge for teachers, explored in theme one (information sources and knowledge) hinges on access to sources and on the accessibility of the content of such sources. Although within my data teachers describe issues of access, particularly to journals, there is in fact a considerable amount of readily available information from reliable and up to date sources, including a growing volume of open access literature. This suggests that the issue is actually one of awareness and dissemination. A number of suitable sources have been described in chapters two and four. There are more, such as Churches, Dommett and Devonshire (2017) and Tibke (2019), who have each attempted to draw together the main educational neuroscience debates, alongside extensive review of what it can tell us about a variety of significant elements of learning, into one teacher-oriented volume. However, the question then arises of how teachers become informed of these sources and what organisation might be well placed and most suitable to undertake this task.

One possible organisation In England, the Chartered College of Teaching (CCT), with the support of the Wellcome Trust, has published an edition of its research journal, *Impact*, that examines what it describes as the 'science of learning' (2018). This is helpful, and due to the journal's delivery in hard copy to all schools in England and its availability online it will have provoked some discussion. However, this was only a single edition so does not address the issue on a longer-term basis. A standing group supported by the CCT could offer regular updates and the group itself could be drawn from a range of relevant institutions. The Wellcome Trust, in partnership with the Education Endowment Foundation, launched an education and neuroscience initiative in 2014. The projects that this initiative first funded were discussed in chapter 2.5. It has supported a number of subsequent projects to support teacher education, including the construction of 'Science of Learning' modules for primary and secondary ITT, a six month online 'Science of Learning Zone' between January and June 2018 and 'the Learning Scientists' monthly podcasts. Promising though these projects are, the limited awareness of what educational neuroscience sources are available amongst teachers in my research raises fundamental questions; are teachers generally aware of these Wellcome Trust projects and do they feel able to engage with them? A worthwhile ongoing task for the Wellcome Trust initiative would be to investigate to what extent the science of learning projects find their way to a majority of teachers, to what extent the initiative is supporting suitable CPD and in what ways teachers across the range of educational settings in the UK have acted upon this information and training.

Any such standing group, as proposed above, however it is comprised, would also need to consider the mixed economy of school governance that is now evident in England. Schools fall under the auspices of local education authorities, many with reduced roles and under the auspices of multi academy trusts of varying sizes, which have a number of freedoms that local authority schools do not. The standing group would need to liaise with the Department for Education in order to support an expectation that local authorities and academy chains would promote the group’s educational neuroscience offer. This is important if this is to be seen as significant CPD for all teachers, rather than something optional.

6.2.5 Present and Future Debates

In addition to the potential of educational neuroscience to enhance the work of teachers, there is an urgent question of how the teaching profession can become a knowledgeable and confident participant in crucial debates that educational neuroscience generates. Without this, the profession is likely to remain nervous about and even obstructive towards proposals founded in educational neuroscience. There are numerous ethical questions to be considered and it is of note that neuroethics is now identified as a discipline in itself (see for example Farah, 2010, the website of the Neuroethics Society or even the website *neuroscience for kids*, discussed in chapter 5.10.3). These debates are already moving on to questions of genetics and my research, such as the responses to survey question 11 (described in chapter 4.2.6 and discussed in chapter 5.4.4) suggests considerable confusion and uncertainty amongst teachers about the basics of genetics, let alone the question of its use in the interpretation of pupil performance data or in predicting the possible learning difficulties a child may face ('neuroprognosis'). As we saw in chapter 5.4.4, each of these approaches to the use of genetic information is already in evidence. But as Kovas et al. have demonstrated (2013), teachers can gain a working grasp of genetics 'essentials' more easily than they may imagine; Kovas et al. offer an answer to the question 'what does everyone need to know about genetics?' (p.78) in less than five pages, which includes nearly three pages of glossary. The glossary is another indication of the need for teachers to develop a level of technical vocabulary. Kovas et al. present this guide to genetic essentials within a chapter entitled 'Genetics for Education', written for a teacher audience. They point out that 'there are many persistent myths and misunderstandings' (p.82) and that 'genetic research does not undermine the importance of education, but rather it can help improve educational practice' (p.83).

6.3 Limitations

Limitations of my research each point to areas for further investigation, in addition to the further research discussed in chapter 6.4.

6.3.1 Number of Participants

Although qualitative studies generally operate with relatively small numbers of participants, one is bound to consider what variations of my findings might emerge from a greater number of interview participants and survey participants. In any case, as suggested above in chapter 6.2.4, there is a need to ensure that a larger number of teachers feel able to access educational neuroscience as users of its findings and as contributors to its future directions and debates. A further phase of research using the format of my research should move on to examine teacher engagement with more recent support from educational neuroscience, such as the Wellcome Trust learning science projects discussed above.

6.3.2 Access to Interview Participants

It was possible to conduct second interviews with three of the five interview participants. An opportunity to conduct a second interview with the other two was not available. Even in the case of the longest interviews, the participants had plenty to say and given more time for further follow up questions and discussion I suspect would have yet more to contribute. I believe this to hold true for many teachers, even though many of them, like my interview participants, would profess little knowledge of educational neuroscience; as my research has demonstrated, teachers' voices have a great deal to contribute to the development of the field, whatever their level of knowledge.

6.3.3 Further Analysis Options Offered by the Data

The following are beyond the scope and purpose of this thesis, but available within the data and worthy of further analysis:

- possible variations due to school type, age range or subject specialism
- possible variations due to length of service
- possible gender-related variations

6.4 Suggestions for Further Research

6.4.1 Educational Neuroscience in ITT

Questions have been raised through my data and its analysis in relation to participants' experiences of, or lack of experiences of, consideration of the brain and educational neuroscience during their training.

No overview or audit exists of the provision of introductions to the brain and educational neuroscience within ITT in England. It is likely that provision is inconsistent as well as variable in content and duration. It is not satisfactory to only be able to make suppositions about this; a 'state of play' audit would be revealing and could expose valuable practice worthy of further dissemination. Such an audit might also draw relevant institutions and individuals together, as well as offering an opportunity to evaluate the uptake of and impact of the 'Science of Learning' ITT modules described above, in chapter 6.2.4.

6.4.2 Educational Neuroscience and CPD

Similarly, there is no clear overview of the role played by educational neuroscience in teachers' school-based experiences of CPD, or the content of such provision. It is evident, as we saw with the use of psychological terminology about memory, that there is some confusion about what constitutes new knowledge of the brain or educational neuroscience. It would be logical to understand what already exists in terms of related CPD across a large number of schools in order to advance proposals for future, less haphazard provision, that would not be based on the promotion of questionable commercially promoted ‘brain-based’ learning packages and would also enable teachers and schools to be more discerning about such products. The seven themes that capture my research can act as a framework through which to categorise and evaluate existing provision.

6.4.3 Schools’ Participation in Educational Neuroscience Research

Within my data and analysis, several areas of further investigation relating to schools and their participation in research have arisen.

Firstly, there is tension between short term accountability and schools’ capacity to engage in research, either of limited duration or of a more longitudinal nature, or even at all. This was particularly evident in interviews one and five (chapters 4.3.2 and 4.3.6). Further research should establish whether this is a legitimate concern.

Secondly, within my small sample there are examples of views expressed about freedom to participate in research and about pedagogical agency that differ due to them emanating from teachers working in either state or independent schools. Further research should establish whether this divide is replicable across a larger sample and if so should proceed to explore how the best outcomes of research participation can be made available to a wider number of schools regardless of their status.

Finally, there is a case for investigating the balance of power and the perception of expertise within collaborations between teachers and educational neuroscientists.

6.4.4 Gaming and Learning with Technology

In chapter 5.9.4, I raised a concern about the possible dangers inherent in the use of gaming-style learning approaches and the use of learning apps. I suggest there is a case here for schools to carefully monitor the use of these approaches. In doing so, schools would be able to contribute to research that investigates wider concerns. For example, Seo (2017) has examined the effect on teenage brains of addiction to smartphone and internet use, each of which give pupils opportunities to learn through apps. Seo's team found that the balance of the neurotransmitters gamma aminobutyric acid (GABA) and glutamate-glutamine (Glx) was adversely affected amongst the addicted group, who were identified by established, standardised tests for smartphone and internet addiction. GABA has a role in slowing down brain signals, whilst Glx plays a more excitatory role. GABA has a role in a number of brain functions, including vision, motor control and the management of anxiety. Excessive GABA can contribute to depression and anxiety, as well as potentially causing drowsiness. No school would knowingly contribute to these issues, yet many schools may be unaware that their approach to the curriculum may be doing so, in the cases of some students. It is important that schools are encouraged to contribute to research that is so significant for the school population and for our future understanding of our reliance on technological devices.

6.4.5 Learning and Green Spaces

In contrast to these concerns, following our first interview one participant explored the neuroscientific evidence for the value of educational experiences in green spaces and specifically the case of the forest school model. In doing so, she has brought this to my attention and I suspect this is another dimension of growing knowledge of the brain about which many schools may be unaware. Examples include research that offers positive findings in the use of enriched environments and outdoor activity as alternatives to low doses of methylphenidate (commonly known under the trade name Ritalin) in some cases of ADHD (Panksepp et al. 2003, Kuo and Taylor, 2009). Here may lie an antidote to the concerns raised above in chapter 6.4.4., but initially it may be the correct first step to examine the extent to which schools are aware of the significance of green space learning and of trials of its use with specific learning, medical and psychological conditions.

6.5 Concluding Comments

I remain convinced that educational neuroscience can support the work of teachers and inspire pedagogical enterprise. Undertaking this research has convinced me that this should be much more of a two-way process; whatever its flaws, teachers' thinking about educational neuroscience can also support its progress. There is work yet to be done and the productiveness of this is very much dependent on the deeper development of relationships and understandings between the two professions. Without pro-active responses from teachers educational neuroscience will continue to struggle to reach beyond the laboratory. Educational neuroscientists can do more to understand and liaise with the teaching profession, its key audience and my findings and the seven main themes can provide assistance with this.

Useful resources, frameworks and projects do exist and teachers' awareness of and access to these should be supported and evaluated. Teachers' use of and discussion of these resources needs to become a welcome and respected test of their efficacy. Educational neuroscience and related fields such as behavioural genetics continue to grow and the teaching profession cannot choose to ignore this, though teachers need greater language and knowledge to become greater contributors to the emerging debates. This must come from reliable sources and be a component of training and development; national policy needs to emphasise this. The potential power of teacher and educational neuroscientist collaboration is yet to be fully realised.

6.6 Personal Critical Reflection

This final reflection explores five essential considerations that were discussed during the Viva Voce examination undertaken in defence of this thesis. The host of further debates, captured in extensive literature, can only be briefly explored here. These considerations are:

- The problematisation of oneself as the researcher and one's presence for the reader
- Changes in one's position and paradigm view
- The reconciliation of one's writing style to the demands of the PhD

- The ways in which one's chosen research lenses have been helpful and unhelpful
- Contribution to knowledge

In chapter three, I discussed issues of bias, researcher assumptions and the fact that the researcher decides what is of interest in the data. There are further dimensions to these issues. Indeed, not only did I decide what was of interest and what it might signify but also how data would be generated in the first place and what, from a vast range of literature, should be considered pertinent to my investigation. Understanding the subjective role of the researcher is something of an academic field in itself.

My earlier intention, that my data could be effectively analysed in a mixed methods approach, utilising some quantitative techniques as well as qualitative, gave way to the recognition that all my data was being viewed in an interpretative manner. Some commentators suggest that for this reason the researcher should endeavour to be visible in the writing, with the researcher's voice and assumptions regularly identified. Walshaw (2010) argues that while this may appear to bring transparency to the relationship between the researcher and research participants, in reality 'it signals a mere surface understanding about how subjectivity and intersubjective negotiations are actually produced during the research process' (p. 587). She goes on to suggest that this relationship changes throughout the research. I did not attempt to map this changing relationship, but instead attempted to minimise my 'presence' where possible, although I recognise that this cannot be achieved consistently and particularly not in chapters five and six, which are my interpretations of what is significant in my data, what it might mean and what further action it implies.

Nevertheless, mapping my subjective positioning within the research does reveal shifts in my position. Having set out as something of an enthusiast for the use of educational neuroscience in a key supportive role for pedagogy, I have moved towards a more nuanced stance that is more conscious of the complexity of the wider picture. I have also become even more sympathetic to the challenges the field presents to teachers – and in that my many years as a teacher is certainly visible. There is little shift in paradigm, however. Undertaking this research has reinforced the viewpoint that qualitative research examines phenomena as they are constructed and experienced by individuals and that this can lead us to new knowledge and new understandings. This does not mean that such findings cannot be used systematically.

My writing style generally sits well with academic tone and register. In the same period of time I was writing about neuroscience for a different audience, so the question of finding the right voice in varying circumstances has been consistently present. What has been a greater challenge as a writer has been the integral construction of such a large-scale piece of writing. To tackle this, I learned that not only would one expect to repeatedly draft and redraft individual sections and chapters, but also that each of those redrafts has implications for other areas of the thesis, at times almost representing a writer's equivalent of chaos theory. Silverman (2000) captures this, in advising that one should not expect the writing to unfold in a chronological manner. He also emphasises the significance of coherence and structure, which I recognised needed to develop across the thesis, not just within chapters. Lynch (2014) and Silverman provide a useful review of different approaches to thesis writing and how these may differ in quantitative and qualitative work. They suggest three essential styles or ‘stories’: hypothesis, analytical and mystery (Lynch 2014 p.4). On reflection I can see that I began early efforts in the first style, then moved largely to the second and in keeping my major conclusions to the end also adopted a little of the third. My various writings on my research and the field in general have led me to a number of platforms and I am conscious of the responsibilities that come with this increased exposure.

As discussed in chapter three, there are advantages and disadvantages to all theoretical lenses and I confess to being fascinated by the fact that using different ones to the ones I finally chose would yield different interpretations of my data. It is challenging to consider that even using IPA and CHAT another researcher would draw at least some different conclusions from my data. For some commentators, such as Golsworthy and Coyle (2001) this raises issues of validity. IPA and CHAT have worked effectively as a pairing in the case of this thesis and I am struck by how I might use this combination in forthcoming projects. As discussed in chapter 3.3.7, I did perceive a danger of being led in a different direction by things that CHAT drew me to but were not my primary focus. IPA counterbalanced this, while not losing sight of the significance of context, history, working practices and so forth that CHAT brought to the surface. Alternatively, I might state that CHAT offers frameworks through which to consider the contextual elements that emerge as participants explore their experiences and views, which IPA encourages them to do. I can see that IPA can easily be misused, as a means of using one's data as evidence for one's personal views, which returns us to the 'researcher in the research' problem discussed above. The 'I' appears to be the most problematic aspect of IPA, according to Brocki and Wearden (2006), especially as researchers are not always explicit about what beliefs and experiences of their own may have influenced their interpretations.

Following several years of investigating and writing and the variety of conclusions and suggestions for further action and research, it is a challenge to capture 'contribution to knowledge' in a single sentence, which I have been challenged to do here. I have no doubt that this in itself will continue to evolve in my thinking and continued researching, as well as through challenges to it from others, but below is how I currently state it:

> regardless of their prior knowledge, expertise or misunderstandings and mis-information, the ways in which teachers think about, talk about and occasionally act upon knowledge of the brain in their working contexts is of essential value and significance in the development of educational neuroscience and its practical implications and should be regarded as an essential component of educational neuroscience research.

References

Aldridge, D. (2016) On the use of narratives from neuroscience and cognitive psychology to improve student motivation: noble lie or indoctrination? Presented at the British Education Research Association (BERA) Annual Conference, 14.9.18

Anderson, M. and Della Sala, S. (Eds) (2011) *Neuroscience in Education: the good, the bad and the ugly*. Oxford: Oxford University Press

Antaki, C., Billig, M., Edwards, D. and Potter, J. (2003) Discourse Analysis Means Discourse Analysis: a critique of six analytic shortcomings. *Discourse Analysis Online* 1(1):1-24.

Argyris, K., Stringaris, N. C., Medford, V., Giampietro, M. J., Brammer, M. and David, A. S. (2007) Deriving Meaning: distinct neuronal mechanisms for metaphoric, literal and non-meaningful sentences. *Brain and Language* 100(2), 150-162

Arrowsmith-Young, B. (2012) *The Woman Who Changed Her Brain*. London: Random House

Ashbury, K. and Plomin, R. (2014) *G is for Genes: the impact of genetics on education and achievement*. Chichester: Wiley Blackwell

Bates, T. (2012) Education 2.0: Genetically-informed models for school and teaching. In: Della Sala, S. and Anderson, M. (eds) *Neuroscience in Education: The Good, the Bad and the Ugly*. Oxford: Oxford University Press.

Battro, A. M., Fischer, K. W. and Léna, P. J (Eds) (2008) *The Educated Brain*. New York: Cambridge University Press

Beauchamp, C. and Beauchamp, M. (2012) Boundary as Bridge: An Analysis of the Educational Neuroscience Literature from a Boundary Perspective. *Educational Psychology Review* (2013) 25:47–67

Ben-Peretz, M. (2011) 'Teacher knowledge: What is it? How do we uncover it? What are its implications for schooling?' *Teaching & Teacher Education,* vol. 27, no. 1, pp. 3-9.

Bergenmar, J., Rosqvist, H. D. and Lönngren, A-S (2015) Autism and the Question of the Human. *Literature and Medicine*, Volume 33, number 1, Spring 2015

Blackwell, L.S., Trzesniewski, K.H. & Dweck, C.S. (2007) Implicit theories of intelligence predict achievement across an adolescent transition: a longitudinal study and an intervention, *Child development,* vol. 78, no. 1, pp. 246-263.

Blakemore, S-J. (2012) The Mysterious Workings of the Adolescent Brain. Available at: www.ted.com/talks/sarah_jayne_blakemore_the_mysterious_workings_of_the_adolsecent_brain?language=en (Accessed: 2.9.13)

Blakemore, S.-J. (2018) *Inventing Ourselves: The Secret Life of the Teenage Brain*. London: Transworld Publishers.

Blakemore, S-J and Choudbury, S. (2006) Development of the Adolescent Brain: implications for executive function and social cognition. *Journal of Child Psychology and Psychiatry,* vol.4, issue 3-4, pp. 296-312.

Blakemore, S-J and Frith, U. (2005) *The Learning Brain*. Oxford: Blackwell

Blevins, D.G. (2012) Brain Matters: Neuroscience and Creativity, *Religious Education,* vol. 107, no. 4, pp. 324-338.

Bonnier, C. (2008) Evaluation of early stimulation programs for enhancing brain development. *Acta Paediatrica* 97: 853–8.

Bowers, J. S. (2016) The Practical and Principled Problems with Educational Neuroscience. *Psychological Review*. Advanced publication online 3.3.16 http://dx.doi.org/10.1037/revooooo25 (accessed:12.7.16)

Bradbury, T. (2014) Multi-tasking Damages Your Brain and Career, New Studies Suggest. Available at https://www.forbes.com/sites/travisbradberry/2014/10/08/multitasking-damages-your-brain-and-career-new-studies-suggest/#1ab41bd956ee (Accessed 12.3.18)

Braun, V. and Clarke, V. (2006) Using thematic analysis in psychology. *Qualitative Research in Psychology*,3 (2) pp.77-101.

British Psychological Society (BPS) (2014) *Code of Human Research Ethics*. Leicester: BPS

British Education Research Association (2011) Ethical *Guidelines for Educational Research. Available at: http://content.yudu.com/Library/A1t9gr/BERAEthicalGuideline/resources/index.htm?referrerUrl=http%25253A%25252F%25252Fwww.yudu.com%25252Fitem%25252Fdetails%25252F375952%25252FBERA-Ethical-Guidelines-2011* (Accessed: 20.6.12)

Brocki, J and Wearden, A. (2006) A critical evaluation of the use of interpretative phenomenological analysis. *Qualitative Research in Psychology,* 3 (1) pp.87-108

Bruer, J.T. (2006) On the Implications of Neuroscience Research for Science Teaching and Learning: Are There Any? A Skeptical Theme and

Variations--The Primacy of Psychology in the Science of Learning, *CBE - Life Sciences Education,* vol. 5, no. 2, pp. 104-110.

Bruer, J.T. (1997) Education and the Brain: A Bridge Too Far, *Educational Researcher,* vol. 26, no. 8, pp. 4-16.

Buchanan, R. (2015) Teacher identity and agency in an era of accountability, Teachers and Teaching, 21:6, 700-719, DOI: 10.1080/13540602.2015.1044329 (Accessed 25.11.18)

Burgess, L. G., Riddell, P., Fancourt, A. and Murayama, K. (2017) Investigating similarity in motivation between friends during adolescence. Paper presented at *American Educational Research Association (AERA) Annual Meeting*. 27.04.17–01.05.17

Burgess, L. G., Riddell, P., Fancourt, A. and Murayama, K. (under review) The role of social contagion in influencing child and adolescent education: A review. *Mind, Brain and Education*.

Burt, C. (1957) Inheritance of mental ability. *The Eugenics Review* 49(3): 137-9.

Burton, D. (2007) Psychopedagogy and Personalized Learning. *The Journal of Education for Teaching: International Research and Pedagogy*, Vol. 33, no.1 pp. 5-17

Butler-Kisber, L. (2010) *Qualitative Inquiry*. London: Sage

Byrnes, J. P. (2001) *Minds, Brains and Learning: understanding the psychological and educational relevance of neuroscientific research*. New York: The Guildford Press

Campbell, S.R. (2011) ‘Educational Neuroscience: Motivations, methodology, and implications’, *Educational Philosophy & Theory,* vol. 43, no. 1, pp. 7-16.

Carter, J. (2015) *Carter Review of Initial Teacher Training (ITT)*. London: Crown Copyright

Catani, M. and Ffytche, D. H. (2005) The Rises and Falls of Disconnection Syndromes. *Brain*, vol.128, issue 10, pp.2224-2239

Chartered College of Teaching (2018) The Science of Learning, *Impact*, February 2018 available at: https://impact.chartered.college/issue/issue-2-science-of-learning/ (Accessed: 10.3.18)

Choe, J., Coffman, B. A., Bergstedt, D. T., Ziegler, M. D & Phillips, M. E. (2016) Transcranial Direct Current Stimulation Modulates Neuronal Activity and learning in Pilot Training. *Frontiers in Human Neuroscience*.

Available at: http://dx.doi.org/10.3389/fn-hum2016.00034 (Accessed: 7.3.16)

Choudbury, S., Blakemore, S.-J. and Charman, T. (2006) Social cognitive development during adolescence. *Social Cognitive and Affective Neuroscience* 1(3): 165–71.

Churches, R., Dommett, E. and Devonshire, I. (20170 *Neuroscience for Teachers*. Carmarthen: Crown House Publishing Ltd.

Cortese, S., Kelly, S., Chabernaud, C., Proal, E., Di Martino, A., Milham, M. P. and Castellanos, F. X. (2012) Towards systems neuroscience of ADHD: A meta-analysis of 55 fMRI studies. *The American Journal of Psychiatry* 169(10): 1038–55.

Costandi, M. (2013) *50 Ideas You Really Need to Know: The Human Brain*. London: Quercus.

Coyle, A. (2006) *Research Methods in Psychology: Interviewing*. London: Sage

Creswell, J. W. (1994) *Research Design: Qualitative and Quantitative Approaches. Thousand Oaks*: Sage

Creswell, J. W. (2007) Qualitative Enquiry and Research Design: choosing among five approaches. Thousand Oaks: Sage Publications.

Creswell, J.W. (2009) *Research Design: qualitative, quantitative, and mixed method approaches 3rd edition.* London: Sage

Creswell, J. W. and Miller, D. L. (2009) Determining Validity in Qualitative Inquiry, *Theory into Practice, Volume 39, number 3,* summer 2000, pp. 124-130

Crossland, J. (2010) ‘Working Memory and Learning’, *School Science Review,* vol. 92, no. 338, pp. 105-112.

D'Angiulli, A., Van Roon, P.M., Weinberg, J., Oberlander, T.F., Grunau, R.E., Hertzman, C. & Maggi, S. (2012) Frontal EEG/ERP correlates of attentional processes, cortisol and motivational states in adolescents from lower and higher socioeconomic status, *Frontiers in Human Neuroscience,* vol. 6, pp. 306-306.

Daniels, H. and Warmington. P. (2007) Analysing third generation activity systems: labour-power, subject position and transformation. *Journal of Workplace learning, Vol. 19 No. 6*

Dekker, S., Lee, N. C., Howard-Jones, P., and Jolles, J. (2012). Neuromyths in education: prevalence and predictors of misconceptions among teachers. *Front. Psychol.* 3:429. doi: 10.3389/fpsyg.2012.00429

Delazer, M., Ischebeck, A., Domahs, F., Zamarian, L., Koppelstaetter, F., Siedentopf, C.M., Kaufmann, L., Benke, T. & Felber, S. (2005) Learning by strategies and learning by drill—evidence from an fMRI study, *NeuroImage,* vol. 25, no. 3, pp. 838-849.

Denzin, N. K. (1989) *Interpretative Interactionism*. Newbury park, California: Sage

Department for Education (2012) *Teachers' Standards*. London: Crown Copyright

Dewey, J. (1938/1963) *Experience and Education*, New York: Collier Books

Doidge, N. (2007) *The Brain That Changed Itself*. New York: Penguin

Donoghue, G. M. and Horvath J. C. (2016) Translating neuroscience, psychology, and education: An abstracted conceptual framework for the learning sciences. *Cogent Education* 3(1): article number 1267422 (21.12.16).

Düvel, N., Wolf, A. and Kopiez, R. (2017) Neuromyths in Music Education: prevalence and predictors of misconceptions among teachers and students. *Frontiers in Psychology 8.629 doi10.3386/fpscg2017.00629* (Accessed:5.6.17)

Dweck, C. S. (2012) *Mindset*. London: Robinson

Ebbinghaus, H. (1885) Memory: a contribution to experimental psychology. New York: Dover

Edelenbosch, R., Kupper, F., Krabbendam, L. and Broese J. E. (2015) Brain-Based Learning and Educational Neuroscience: Boundary Work. *Mind, Brain and Education, Volume 9 issue 1, pp. 40-49.*

Edwards, A. (2005) Relational Agency: Learning to be a resourceful practitioner, *International Journal of Educational Research,* vol. 43, no. 3, pp. 168-182.

Eigenbrode, S. D., O'Rourke, M., Wulfhorst, J., Althoff, D. M., Goldberg, C. S., Merrill, K., Morse, W., Nielsen-Pincus, N., Stephens, J. and Winowiecki, L. (2007) Employing philosophical dialogue in collaborative science. *BioScience* 57(1): 55–64.

Ely, M., Vinz, R., Downing, M. and Anzul, M. (1997) *On Writing Qualitative Research: living by words*. London: Routledge/Falmer

Engeström, Y. (1987) *Learning by Expanding: an activity- theoretical approach to developmental research.* Helsinki: Orienta-Konsultit

Engeström, Y. (1999) Innovative learning in work teams: analysing cycles of knowledge creation in practice, in Engeström, Y., Miettinen, R. and Punamäki, R-L., *Perspectives on Activity Theory*. Cambridge: Cambridge University Press.

Engeström, Y. (2001) Expansive Learning at Work: toward an activity theoretical reconceptualization', *Journal of Education & Work,* vol. 14, no. 1, pp. 133-156.

Epstein, R. (2017) The empty brain. Available at: https://aeon.co/essays/ your-brain-does-not-process-information-and-is-not-a-computer (accessed 26.10.17).

Eraut, M. (2007) Learning from Other People in the Workplace', *Oxford Review of Education,* no. 4, pp. 403.

Evans, P. (2009) Reliability and Validity in Qualitative Research by Teacher Researchers in Wilson, E. (ed) *School-Based Research*. London: Sage

Farah, M.J. (ed) (2010) *Neuroethics: an introduction with readings*. Cambridge, MA: MIT Press

Findlay, H.J. (2012) Cognitive Neuroscience Learning Theories Coupled with Technologies: A Conduit for Deep and Lasting Learning, *Journal of Applied Learning Technology,* vol. 2, no. 1, pp. 27-31.

Fischer, K.W., Goswami, U. & Geake, J. (2010) The Future of Educational Neuroscience, *Mind, Brain & Education,* vol. 4, no. 2, pp. 68-80.

Foulkes, L. and Blakemore, S.-J. (2018). Studying individual differences in human adolescent brain development. *Nature Neuroscience* 21(3): 315–23.

Frank, C., Land, W. M., Popp, C. and Schack, S. (2014) Mental representation and mental practice: Experimental investigation on the functional links between motor memory and motor imagery. *PLoS ONE* 9(4): e95175.

Fraser, C., Kennedy, A., Reid, L. & McKinney, S. (2007) Teachers' continuing professional development: contested concepts, understandings and models', *Journal of In-Service Education,* vol. 33, no. 2, pp. 153-169.

Foddy, W. (1993/1998) *Constructing Questions for Interviews and Questionnaires*. Cambridge: Cambridge University Press

Führmann, D., Knoll, L. J. and Blakemore, S-J. (2015) Adolescence as a Sensitive Period of Brain Development, *Trends in Cognitive Sciences, vol. 19 no 10, pp. 558-566*

Fullan, M.G. (1993) Why teachers must become change agents, *Educational Leadership,* vol. 50, no. 6, pp. 12.

Fullan, M. (2007) *The New Meaning of Educational Change*. Oxon: Routledge

Fullan, M. & Hargreaves, A. (1992) *What's worth fighting for in your school?: working together for improvement.* Buckingham: Open University Press in association with the Ontario Public School Teachers' Federation, 1992.

Gambling Commission (2018) Young people and gambling. Available at: https://www.gamblingcommission.gov.uk/news-action-and-statistics/Statistics-and-research/Levels-of-participation-and-problem-gambling/Young-persons-survey.aspx (Accessed: 26.11.18)

Garrison, J. (1995). Dewey's philosophy and the experience of working: labour, tool and language. *Synthese*105: 87-114.

Garrison, J. (2001). An introduction to Dewey's theory of functional "Trans-Action": An alternative paradigm for activity theory. *Mind, Culture & Activity* 8(4), 275-296.

Glassman. M. (2001). Dewey and Vygotsky: Society, experience and inquiry in educational practice. *Educational Researcher* 30(4), pp.3-14.

Geake, J. G. (2011) Position Statement on Motivations, Methodologies, and practical Implications of Educational neuroscience Research: fRMI studies of the neural correlates of creative intelligence. *Educational Philosophy and Theory*, vol. 43, no.1, pp. 43-47

Geake, J. G. (2009) *The Brain at School,* Open University Press, GB.

Geake, J.G. & Hansen, P.C. 'Neural correlates of intelligence as revealed by fMRI of fluid analogies', *NeuroImage,* vol. 26, pp. 555-564.

Goldacre, B. (2006) *Bad Science: Name and Shame*. Available at: https://www.badscience.net/2006/03/the-brain-drain (accessed: 6.5.12)

Goleman, D. (2013) *Focus*. London: Bloomsbury.

Golsworthy, R. and Coyle, A. (2001) Practitioners' accounts of religious and spiritual dimensions in bereavement therapy. *Counselling Psychology Quarterly*, 14, pp.182-202

Goswami, U. (2006) Neuroscience and Education: from research to practice? *Nature Reviews Neuroscience* 7(5), pp.406-411

Goswami, U. (2008) Principles of Learning, Implications for Teaching: A Cognitive Neuroscience Perspective, *Journal of Philosophy of Education,* vol. 42, no. 3, pp. 381-399.

Goswami, U. (2009) Mind, Brain and Literacy: biomarkers as useable knowledge for education. *Mind, Brain and Education* 3(3), pp.176-184

Grandin, T (1995/2006) Thinking in Pictures. London: Bloomsbury Publishing PLC

Grandin, T. (2008) *The Way I See It: a personal look at autism and Asperger's*. Arlington: Future Horizons

Grandin, T. and Attwood, T (2012) *Different…Not Less*. Arlington: Future Horizons

Grandin, T. and Barron, S (2004/ revised 2014/2017) Unwritten Rules of Social Relationships: decoding social mysteries through autism's unique perspectives. Arlington: Future Horizons

Grandin, T. and Panek, R. (2014a) *The Autistic Brain*. London: Rider Books

Gray, D.E. (2009) *Doing Research in the Real World.* London: Sage.

Griffiths, M. D. and Hunt, N. (1998) Dependence on computer game playing in adolescents. *Psychological Reports* 82, pp. 475-480.

Griffin, S. (2015) Learning to learn: consultancy, internal agency and the appropriation of learning theory in English Schools. Ed.D thesis submitted at the University of Leicester

Grüsser, S. M., Thalemann, R., Albrecht, U. and Thalemann, C. N. (2005) Excessive computer usage in early adolescence – results of a scale assessment. *Weiner Klinische Wochenschrift* 117, pp.188-195

Guba, E.G. and Lincoln, Y. S. (1981) *Effective Evaluation*. San Francisco: Jossey-Bass

Habermas, J. (1968) *Knowledge and Human Interest*, London: Heinemann

Hamzelou, J. (2015) Scans prove there's no such thing as a 'male' or 'female' brain. *New Scientist*, 30.11.15.

Harland, J. & Kinder, K. (1997) Teachers' continuing professional development: framing a model of outcomes', *Journal of In-Service Education,* vol. 23, no. 1, pp. 71.

Heidegger, M. (translated by Macquarrie, J. and Robinson, E.) (1927/1962) *Being and Time*. Oxford: Blackwell

Hinton, C. & Fischer, K.W. (2008) Research Schools: Grounding Research in Educational Practice, *Mind, Brain & Education,* vol. 2, no. 4, pp. 157-160.

Hinton, C., Miyamoto, K. & Della-Chiesa, B. (2008) Brain Research, Learning and Emotions: implications for education research, policy and practice, *European Journal of Education,* vol. 43, no. 1, pp. 87-103.

Holloway, I. and Todres, L. (2003) The Status of Method: flexibility, consistency and coherence. *Qualitative Research*, vol.3(3), pp.345-357

Hooton, A. (2017) Can Barbara-Arrowsmith Young's cognitive exercises change your brain? *The Sydney Morning Herald*, April 22nd 2017

Horvath, J. C., Donaghue, G. M., Horton, A. J., Lodge, J.M. and Hatties, J. A. C. (2018) On the Irrelevance of Neuromyths to teacher Effectiveness: Comparing Neuro-Literacy levels Amongst Award-Winning and Non-award Winning Teachers *Front. Psychol.* 9:1666. doi: 10.3389/fpsyg.2018.01666 (accessed 18.9.18)

How neuroscience can improve leadership' (2011) Editorial, *Leader to Leader,* vol. 2011, issue 61, pp. 56-57.

Howard-Jones, P. (2010) *Introducing Neuroeducational Research* Abingdon: Routledge

Howard-Jones, P. (2008a) Philosophical Challenges for Researchers at the Interface between Neuroscience and Education, *Journal of Philosophy of Education,* vol. 42, no. 3-4, pp. 361-380.

Howard-Jones, P. (2008b) Potential Educational Developments That May Arrive by 2025, *Beyond Current Horizons*, December 2008

Howard-Jones, P and Fenton, F. (2010) *Brains, Minds and Teaching with Immersive Games*. Bristol: NEnet.

Howard-Jones, P. A., Franey. L., Mashmoushi, R. and Liao, Y.-C. (2009) The Neuroscience Literacy of Trainee Teachers, paper presented at the Annual British Education Research Association Conference, Manchester, UK.

Husserl, E. (1913) *Ideas* (translated by W. R. Boyce Gibson). London: George Allen and Unwin Ltd

Hyatt, K. J. (2007) Brain-Gym®: building stronger brains or wishful thinking? *Remedial and Special Education,* 2007, Vol. 28(2), pp.117-124

Illes, J., Moser, M.A., McCormick, J.B., Racine, E., Blakeslee, S., Caplan, A., Hayden, E.C., Ingram, J., Lohwater, T., McKnight, P., Nicholson, C., Phillips, A., Sauvé, K.D., Snell, E. & Weiss, S. (2010) Neurotalk: improving the communication of neuroscience research, *Nature Reviews Neuroscience,* vol. 11, no. 1, pp. 61-69.

Ionescu, T. and Vasc, D. (2014) Embodied cognition: Challenges for psychology and education. *Procedia – Social and Behavioural Sciences* 128: 275–80.

Iran-Nejad, A. (1998) *Brain-based Education: A Reply to Bruer*.

Jaarsma, P. and Welin, S. (2012) Autism as a Natural Human Variation: Reflections on the Claims of the Neurodiversity Movement. *Health Care Analysis*, (20), 1, p.20-30.

James, W. (1907) The Energies of Men. *The Philosophical Review* 16(1): 1–20.

Jarrett, C. (2015) *Great Myths of the Brain*. Chichester: John Wiley.

Johansson, A and Gotestam, K. G. (2004) problems with computer games without monetary: similarity to pathological gambling. *Psychological Reports* 95, pp. 641-650

Kacinik, N. and Chiarello, C. (2007) Understanding Metaphors: is the right hemisphere uniquely involved? *Brain and Language* (100)2, 188-207

Katzir, T. and Paré-Blagoev, J. (2006) Applying Cognitive Neuroscience Research to education: the case of literacy. *Educational Psychologist*, 41(1), 53-74

Kent, A. (2013) Synchronization as a Classroom Dynamic: A Practitioner's Perspective. Mind, Brain, Education, vol. 7 no1, p.13-18

Knox, R. (2016) Mind, Brain and Education: A Transdisciplinary Field. *Mind, Brain and Education* vol.10 Issue 1, pp. 4-9

Koizumi, H. (2011) Brain-Science Based Cohort Studies, *Educational Philosophy & Theory,* vol. 43, no. 1, pp. 48-55.

Kovas, Y, Malykh, S. and Petrill, S.A. (2013) Genetics for Education, in Mareschal, D., Butterworth, B. and Tolmie, A. (eds) (2013) *Educational Neuroscience.* Chichester: Wiley and Sons Ltd.

Kuriloff, P., Reichert, M., Stoudt, B. & Ravitch, S. (2009) Building Research Collaboratives Among Schools and Universities: Lessons from the Field, *Mind, Brain, and Education,* vol. 3, no. 1, pp. 34-44.

Krashen, S. (1977) Some issues Relating to the Monitor Model. In Brown, H., Yorio, C. and Crymes, R. (eds) *On TESOL* '77, pp. 144-158

Lalancette, H. and Campbell, S.R. (2012) Educational Neuroscience: Neuroethical Considerations, *International Journal of Environmental and Science Education,* vol. 7, no. 1, pp. 37-52.

Lakoff, G. (2015) *How Brains Think: The Embodiment Hypothesis*. Available at https://www.youtube.com/watch?v=WuUnMCq-ARQ. (accessed 14.6.18).

Lakoff, G. and Johnsen, M. (1980) *Metaphors We Live By*. Chicago: The University of Chicago Press.

Lee, D.S. (2012) Neuromyths in Education: Prevalence and Predictors of Misconceptions among Teachers, *Frontiers in Psychology,* vol. 3, pp. 429-429.

Legrenzi, P. and Umiltà, C. (Anderson, F. Translation) (2011) *Neuromania: on the limits of brain science*. Oxford: Oxford University Press

Lisberger, S. G. (2013) Sound the Alarm: Fraud in Neuroscience available at http://dana.org/news/cerebrum/detail.aspx?id=42870 (Accessed: 3.5.13)

Loh, K. K. and Kanai, R. (2014) Higher media multi-tasking activity is associated with smaller grey-matter density in the anterior cingulate cortex. *PLoS ONE* 9(9): e106698.

Lynch, T. (2014) Writing up your PhD (Qualitative Research). Available at: hhttps://www.ed.ac.uk/files/atoms/files/writing_ up_ your_phd_qualitative_research.pdf (accessed 14.7.17)

Mackey, A. (2014) What happens in the brain when you learn a language? Available at: www.theguardian.com/education/2014/sep/04/what-happens-to-the-brain-language-learning 04.09.14 (accessed 15.10.17).

Mareschal, D., Butterworth, B. and Tolmie, A. (eds) (2013) *Educational Neuroscience.* Chichester: Wiley and Sons Ltd.

May, B.P. 2008) Cultural historical activity theory and Dewey's idea-based social constructivism: Consequences for Educational Research, *Outlines. Critical Practice Studies,* no. 1, pp. 37.

McCabe, D.P. & Castel, A.D. (2008) Seeing is believing: The effect of brain images on judgments of scientific reasoning, *Cognition,* vol. 107, no. 1, pp. 343-352.

McConnell, M. J. et al. (2017) Intersection of diverse neural genomes and neuropsychiatric disease: The brain somatic mosaicism network. *Science* 356(6336).

McGill, R. (2015) The Cognitive Revolution in Teaching. Available at: www.teachertoolkit.me/2015/10/17/cognitiveteaching/ (Accessed: 17.10.16)

McNiff, J., Lomax, P. and Whitehead, J. (2003) *You and Your Action Research Project.* London: Routledge Falmer

Medina, J. (2008) *Brain Rules*. Seattle: Pear Press.

Melby-Lervåg, M. and Hulme, C. (2013) Is Working memory training Effective? A Meta-Analytic Review *Developmental Psychology* 2013, Vol. 49, No.2, 270-291

Merriam, S. (1998) *Qualitative Research and Case Study Applications in Education.* San Francisco: Jossey-Bass

Molloy, M (2016) Scientists discover how to 'upload knowledge to your brain' The Telegraph 1st March (online) available at: www.telegraph.co.uk/technology/2016/03/01/scientists-discover-how-to-downlaod-knowledge-to-your -brain/ (Accessed: 7.3.16)

Morehouse, R. E. (2012) *Beginning Interpretative Enquiry*. Abingdon: Routledge

Morris, T. T., Davies, M. N., Dorling, D., Richmond, R. C. and Smith, G. D. (2018) Testing the validity of value-added measures of educational progress with genetic data. *British Educational Research Journal*, Vol. 44, October 2018, pp. 725-747.

Morse, J. M. Barrett, M., Mayan, M., Olson, K. and Spiers, J (2002) Verification Strategies for Establishing Reliability and Validity in Qualitative Research. International Journal of Qualitative Methods 1(2): pp.1-19.

Mostert, M. P. and Crockett, J.B. (2000) Reclaiming the History of Special Education for More Effective Practice. *Exceptionality* 8(2), pp.133-143

Moustakas, C. (1994) *Phenomenological Research Methods*. Thousand Oaks: Sage

Nedergaard, M. and Plog, B. A. (2018) The glymphatic system in central nervous system health and disease: Past, present and future. *Annual Review of Pathology* 13: 379–94.

Neurobollocks (2014) Transcranial direct-current stimulation – don't try it at home. Available at: https://neurobollocks.wordpress.com/2014/06/07/transcranial-direct-current-stimulation-don't-try-it-at-home/ (accessed 6.11.15)

neurosciencenews.com (2017) Adult brains produce new cells in previously undiscovered area. Available at: https:neurosciencenews.com/neurogen-esis-ptsd-amygdala-7304/ (accessed 17.8.17).

Neuroskeptic (2016) No, We Can't "Upload Knowledge To Your Brain" available at: http://blogs.discovermagazine.com/neuroskeptic/2016/03/06/we-can't-upload-to-your-brain/ (Accessed: 7.3.16)

O'Donoghue, T.A. & Punch, K. (Eds) (2003) *Qualitative educational research in action: doing and reflecting,* New York, London: Routledge/Falmer, 2003.

OECD (2002) *Understanding the Brain: Towards a New Learning Science*. Paris: OECD Publishing

Office for Standards in Education (Ofsted) (2018) Ofsted inspections: Myths. Available at https://www.gov.uk/government/publications/school-inspection-handbook-from-september-2015/ofsted-inspections-mythbusting (Accessed: 26.8.2018)

Ophir, E., Nass, C. and Wagner, A. D. (2009) Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences* 106(37): 15583–7.

Organisation for Economic Co-Operation and Development. (2002). *Understanding the brain: towards a new learning science.* Paris: OECD. Available Online From www.oecd.org (Accessed: 23.2.2012)

Packiam-Alloway, T. (2010) *Improving Working Memory: Improving Students' Learning. London*: Sage

Packiam-Alloway, T. and Alloway, R. G. (2014) *Understanding Working Memory*. London: Sage

Palghat, K., Horvath, J. C. and Lodge, J. M. (2017) The hard problem of educational neuroscience. *Trends in Neuroscience and Education* 6: 204–10.

Papadatou-Pastou, M., Haliou, E and Vlachos, F. (2017) Brain Knowledge and the Prevalence of Neuromyths Among Prospective Teachers in Greece. Frontiers in Psychology, 29th May 2017.

Pietkiewicz, I. and Smith, J. A. (2014) A practical guide to using Interpretative Phenomenological Analysis in qualitative research. *Psychological Journal*, 10, 1, 2014 pp.7-11

Polkinghorne, D. E. (1989) Phenomenological Research Methods. In Valle, R. S. and Halling, S. (Eds) *Existential-phenomenological Perspectives in Psychology*. New York: Plenum Press

Purdy, N. & Morrison, H. (2009) Cognitive neuroscience and education: unravelling the confusion, *Oxford Review of Education,* vol. 35, no. 1, pp. 99-109.

Ratey, J. (2007) *A User's Guide to the Brain*. London: Abacus

Rauscher, F. H, Shaw, G. and Ky, K. N. (1993) Music and Spatial Task

Performance in Nature 1993: 365: 611

Rauscher, F. H. and Shaw, G. (1998) Key Components of the Mozart Effect *Perceptual and Motor Skills* 1998 86

Research Schools Network (2017) *Six more research schools appointed*. Available at: https://researchschool.org.uk/2017/04/07/six-more-research-schools-appointed/ (Accessed 9.5.17)

Riddle, D. R. and Lichtenwalner, R. J. (2007) Neurogenesis in the adult aging brain. In: Riddle, D. R. (ed.) *Brain Aging: Models, Methods and Mechanisms*. Boca Raton, FL: CRC Press/Taylor and Francis

Ritchie, S. J., Cox, S. R., Shen, X., Lombardo, M. V., Reus, L. M., Alloza, C., Harris, M. A., Alderson, H., Hunter, S., Neilson, E., Liewald, D. C. M., Auyeung, B., Whalley, H. C., Lawrie, S. M., Gale, C. R., Bastin, M. E., McIntosh, A. and Deary, I. J. (2017) Sex differences in the adult human brain: Evidence from 5,216 UK Biobank participants. *BioRxiv*. Published ahead of print 4.4.17. https://doi.org/10.1101/123729

Rodriguez, V. (2014) *The Teaching Brain: The Evolutionary Trait at the Heart of Education*. New York: The New Press

Roth, W. & Lee, Y. (2007) Vygotsky's Neglected Legacy': Cultural-Historical Activity Theory, *Review of Educational Research,* vol. 77, no. 2, pp. 186-232.

Roth, W. & Yew-Jin Lee (2010) Cultural-historical activity theory and pedagogy: an introduction, *Pedagogies,* vol. 5, no. 1, pp. 1-5.

Ritchie, S., Della Sala, S., & McIntosh, R. (2012). Colored filters in the class-room: A 1-year follow-up. *Mind, Brain, and Education*, 6(2): 74–80.

Sacks, O. (1971) *The Man Who Mistook His Wife for a Hat* London: Picador

Saldaña, J. (2009) The Coding Manual for Qualitative Researchers. London: Sage Publications Ltd

Sargeant, J. (2012) Qualitative Analysis Part II: Participants, Analysis and Quality Assurance. *Journal of Graduate Medical Education 2012 Mar; 4(1):p 1-3* (accessed: 6.2.13)

Satel, S. & Lilienfeld, S. O. (2013) *Brainwashed: The Seductive Appeal of Mindless Neuroscience.* Philadelphia: Basic Books

Save the Children (2016) *Lighting Up Young Brains*. London: Save the Children.

Schenk, J. (2011) *Teaching and the adolescent brain*. New York; Norton

Schmidt, S.J. (2009) Development and Use of Visual Explanations: Harnessing the Power of the 'Seeing' Brain to Enhance Student Learning, *Journal of Food Science Education,* vol. 8, no. 3, pp. 68-72.

Schwartz, M. & Gerlach, J. (2011) The Birth of a Field and the Rebirth of the Laboratory School, *Educational Philosophy & Theory,* vol. 43, no. 1, pp. 67-74.

Seron, X. (2012) Can teachers count on mathematical neurosciences? In: Della Sala, S. and Anderson, M. (eds) *Neuroscience in Education: The Good, the Bad and the Ugly*. Oxford: Oxford University Press.

Shaywitz, S.E. & Shaywitz, B.A. (2008) Paying attention to reading: the neurobiology of reading and dyslexia', *Development and psychopathology,* vol. 20, no. 4, pp. 1329-1349.

Shaywitz, S.E., Shaywitz, B.A., Pugh, K.R., Fulbright, R.K., Constable, R.T., Mencl, W.E., Shankweiler, D.P., Liberman, A.M., Skudlarski, P., Fletcher, J.M., Katz, L., Marchione, K.E., Lacadie, C., Gatenby, C. & Gore, J.C. (1998) Functional disruption in the organization of the brain for reading in dyslexia', *Proceedings of the National Academy of Sciences of the United States of America,* vol. 95, no. 5, pp. 2636.

Shearer, C. B. and Karanian, J. M. (2017) The neuroscience of intelligence: Empirical support for the theory of multiple intelligences. *Trends in Neuroscience and Education* 6: 211–33.

Sheppard, P. (2005) *Music Makes Your Child Smarter*. Ivor Heath: Artemis Editions.

Shulman, L.S. (1986) Those Who Understand: Knowledge Growth in Teaching, *Educational Researcher,* no. 2, pp. 4.

Silverman, D. (2000) Doing Qualitative Research: a practical handbook. Sage: London

Silverman, D. (2001) *Interpreting Qualitative Data*. London: Sage

Silverman, D. (2013) *A Very Short, Fairly Interesting and Reasonably Cheap Book About Qualitative Research*. London: Sage

Smith, K. and Ulvik, M. (2017) Leaving teaching: lack of resilience or Sign of Agency? *Teachers and Teaching: Theory and Practice*, 2017 Vol 23(8), pp.928-945

Sparks, S.D. (2012) Teachers Need Lessons in Neuroscience, Experts Say, *Education Week,* vol. 31, no. 33, pp. 16-17.

Spaulding, L. S., Mostert, M.P. and Beam, A.P., (2010) Is Brain-Gym® an effective educational intervention? *Exceptionality, a Special Education Journal,* vol.18, 2010-issue 1

Stanovich, K. (2009) *What intelligence tests miss: The psychology of rational thought*. New Haven, CT: Yale University Press

Stephan, K. E., Marshall, J. C., Friston, K. J., Rowe, J. B., Ritzl, A., Zilles, K. and Fink, G. R. (2003) Lateralised cognitive processes and lateralised task control in the human brain. *Science* 301(5631): 384–6.

Stewart, L. (2008) Do musicians have different brains? *Clinical Medicine* vol. 8, no. 3, pp. 304-308.

Stickgold, R. and Walker, M. P. (2013) Sleep-dependent memory consolidation and reconsolidation. *Sleep Medicine* 8(4): 331–43.

Sylvan, L.J. & Christodoulou, J.A. (2010) Understanding the Role of Neuroscience in Brain Based Products: A Guide for Educators and Consumers, *Mind, Brain, and Education,* vol. 4, no. 1, pp. 1-7.

Tashakkori, A. and Teddlie, C. (1998) *Mixed methodology: combining qualitative and quantitative approaches.* Thousand Oaks, California: Sage

Taylor, B., Hershel, J. and Maclaughlin, D. (2013) Prevalence and Incidence Rates of Autism in the UK: time trend from 2004-2010 in children aged 8 years. *British Medical Journal Open*, volume 3 issue 10.

Teddlie. C. and Yu, F. Mixed Methods Sampling: A Typology with Examples *Journal of Mixed Methods Research* 2007; 1; 77

Thaut, M. (2008) *Rhythm, Music and the Brain* Abingdon: Routledge

Tibke, J. (2019) *Why the Brain Matters: a teacher investigates neuroscience*. London: Sage.

Thomas, M. (2018) how is neuroscience relevant to the classroom? Presentation at the *BrainCanDo* Conference, Reading, 15.3.18.

Thomas, M. S. C. and Knowland, V. C. P. (2009) Sensitive periods in brain development: Implications for education policy. *European Psychiatric Review* 2(1): 17–20.

Tokuhama-Espinosa, T. (2011) *Mind, Brain and Education Science*. New York: Norton

Tufford, L. and Newman, P. (2010) Bracketing in Qualitative Research. Qualitative Social Work

Varma, S., McCandliss, B.D. & Schwartz, D.L. (2008) Scientific and Pragmatic Challenges for Bridging Education and Neuroscience. *Educational Researcher,* no. 3, pp. 140.

Vul, E., Harris, C., Winkielman, P. & Pashler, H. (2009) 'Puzzlingly high correlations in fMRI studies of emotion, personality, and social cognition'. *Perspectives on Psychological Science,* vol. 4, no. 3, pp. 274-290.

Vygotsky, L. S. (1997). The collected works of L. S. Vygotsky, Vol. 4: The history of the development of higher mental functions (R. W. Rieber, Vol. Ed; M. J. Hall, Trans.). New York: Plenum Press. (Original work published 1941)

Wall, M. (2014) How Neuroscience is being used to spread quackery in business and education. The Conversation available at: www.theconversation.com/how-neuroscience-is-being-used-to-spread-quackery-in-business-and-education-30342 (accessed 26.8.14)

Walshaw, M (2010) The Researcher's Self in Research: confronting issues about knowing and understanding others. Mathematics Education Research Group of Australia https://files.eric.ed.gov/fulltext/ED520979.pdf (accessed 5.3.19)

Warren, J. (2008) How does the brain process music? *Clinical Medicine (London, England),* vol. 8, no. 1, pp. 32-36.

Warren, J. (2008) Medicine, music and the mind. *Clinical Medicine (London, England),* vol. 8, no. 1, pp. 7-8.

Wellcome Trust (2014) *Understanding learning: education and neuroscience*. Available at: www.wellcome.ac.uk/education-resources/education-and-learning/our-work/brains-and-thinking/wts040353htm (accessed 8.2.16).

Weisberg, D. S., Keil, F. C. and Gray, J. R. (2008) 'The Seductive Allure of Neuroscience Explanations'. *Journal of Cognitive Neuroscience 20(3): pp. 470-477*

Willig, C. (2008) *Introducing Qualitative Research in Psychology: adventures in theory and method.* Buckingham: Open University Press

Willingham, D. (2008) Brain-based education: fad or breakthrough? Available at: www.danielwillingham.com/videos.html (Accessed: 7.3.12)

Willingham, D. (2009) Why Don't Students Like School? San Francisco: Jossey-Bass

Wilson, A. D. and Golanka, S. (2013) Embodied cognition is not what you think it is. *Frontiers in Psychology* 4. doi: 10.3389/fpsyg.2013.00058

Wolfe, P. (2001) *Brain Matters: translating research into classroom practice*. Alexandria, VA: ASCD

Zambo, D. & Zambo, R. (2011) Teachers' Beliefs about Neuroscience and Education. *Teaching Educational Psychology,* vol. 7, no. 2, pp. 25-41.

Zull, J. E. (2011) *From Brain to Mind*. Sterling, VA: Stylus Publishing.

Appendices

Appendix 1: Semi-structured interview Questions (Interviews one to five)

1. Can you identify any sources for your knowledge of the brain, whatever your knowledge may be?
2. Which of these do you consider to have had the most influence on your thinking and/or on your classroom practice?
3. What do you consider to be the impact of these on your teaching? (if not evident in response to question 2)
4. What do you hold to be the evidence that this makes a difference?
5. Where, if at all, would you say educational neuroscience fits into the culture of and practice of your department/school? How does this appear in practice?
6. In what context do you think it might be helpful for children to have some understanding of learning and the brain?
7. From a teacher's perspective, what do you most want educational neuroscience to assist with?

Appendix 2: Confirmation of Ethical Approval

19 December 2013

Our Ref: IC/SB

Jon Tibke
Faculty of Education, Arts and Business
Bowerham Road

University of Cumbria
Research Office
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Dear Jon

Request for Ethical Clearance – Our Ref 13/05
Project: The Case of Teachers and Neuroscience: how do professionals mediate public information?

Thank you for your revised application regarding the issues that required addressing. The Panel are now able to give approval for your project and wish you well.

Yours sincerely

Dr Ian Convery
Chair
Ethics Advisory Panel

Appendix 3: Participant Consent Form Sample

ETH09/04a

Title of Investigation

Participant Consent Form

Please answer the following questions by circling your responses:

Have you read and understood the information sheet about this study? YES NO

Have you been able to ask questions about this study? YES NO

Have you received enough information about this study? YES NO

Do you understand that you are free to withdraw from this study at any time, and without having to give a reason for withdrawal? YES NO

Your responses will be anonymised before they are analysed.

Do you give permission for members of the research team to have access to your anonymised responses? YES NO

Do you agree to take part in this study? YES NO

Your signature will certify that you have voluntarily decided to take part in this research study having read and understood the information in the sheet for participants. It will also certify that you have had adequate opportunity to discuss the study with an investigator and that all questions have been answered to your satisfaction.

Signature of participant:.. **Date:**................

Name (block letters):...

Signature of investigator:.. **Date:**................

Please keep your copy of the consent form and the information sheet together.

Researcher Contact Information: Jon Tibke

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Appendix 4: Participant information Sheet

ETH09/04

University of Cumbria

Title: The case of teachers and neuroscience: how do teachers mediate knowledge of the brain?

Participant Information Sheet

About the study
This research aims to provide insight into teachers' understanding of neuroscientific information that they encounter from a variety of sources and to examine in what ways they believe this influences their work. With a sample of case study teachers, this will be explored through interviews. In addition, a survey will provide wider data from a wider group of participants. The research will form the basis of the researcher's PhD thesis.

Some questions you may have about the research project:

Why have you asked me to take part?
Potential participants have emerged either through interest in the project or conversely through scepticism about the project.

What will I be required to do?
You may be asked to fill in a questionnaire, be interviewed and or take part in discussion.

Where will this take place?
This is negotiable - interviews can be conducted in a venue convenient to you. The questionnaire is online.

How often will I have to take part and for how long?
Interviews may last up to 60 minutes and are likely to occur at two points during the academic year 2013-14 and possibly beyond. Questionnaires should take about 20 minutes. There will be no requirement for you to miss any teaching time in school.

When will I have the opportunity to discuss my participation?
With the researcher at any point prior to, during or after data collection.

Who will be responsible for all the information when the study is over?
The researcher (Jon Tibke)

Who will have access to it?
The researcher
How long will data be kept and where?
The data will be archived on a password protected computer

What will happen to the information when this study is over?
Data will be analysed by the researcher, findings written up in his PhD thesis and in other articles which will be disseminated to participants on request. Findings will be presented at academic conferences. At all times pseudonyms will be used and anonymity maintained. No school names will be recorded or used.

How will you use what you find out?
We will use the findings to draw up recommendations and implications for schools, teachers and the wider teacher education and neuroscience in education communities.

Will anyone be able to connect me with what is recorded and reported?
We will make every effort to maintain anonymity so that you will not be identified. Pseudonyms will be used. No school names will be recorded or used in any context.

How long is the whole study likely to last?
Data will be gathered during the academic year 2013-14 and beyond, with on-going analysis and a target of the thesis being completed by the summer of 2015.

How can I find out about the results of the study?
Contact the researcher, details below. He will be pleased to forward you copies of the research findings.

What if I do not wish to take part?
Your participation in the study is entirely voluntary.

What if I change my mind during the study?
You are free to withdraw from the study at any time without having to provide a reason for doing so. In addition you will have certain editing rights during the recorded interview, for example if you wish to retract something you have just said, it will be wiped from the recording.

Will I need to sign any documentation?
You will be asked to sign a consent form before participating in the study.

Whom should I contact if I have any further questions?
Please contact the researcher directly (details below).

Complaints
All complaints from the participants are in the first instance to be directed to the Director of Research Office and Graduate Studies, University of Cumbria, Bowerham Road, Lancaster, LA1 3JD

Researcher Contact Information:

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