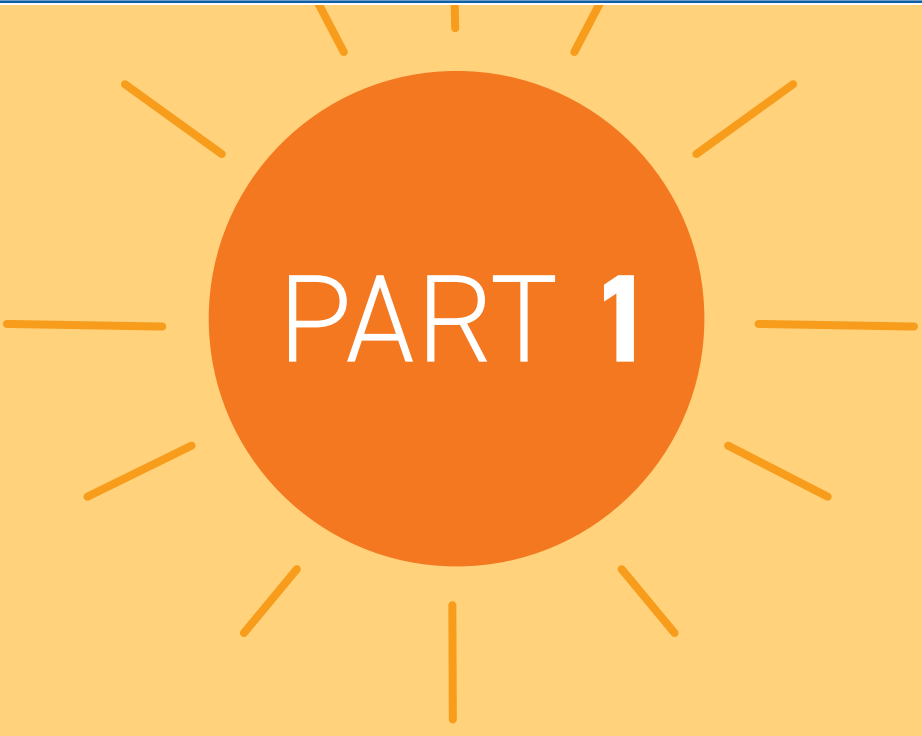
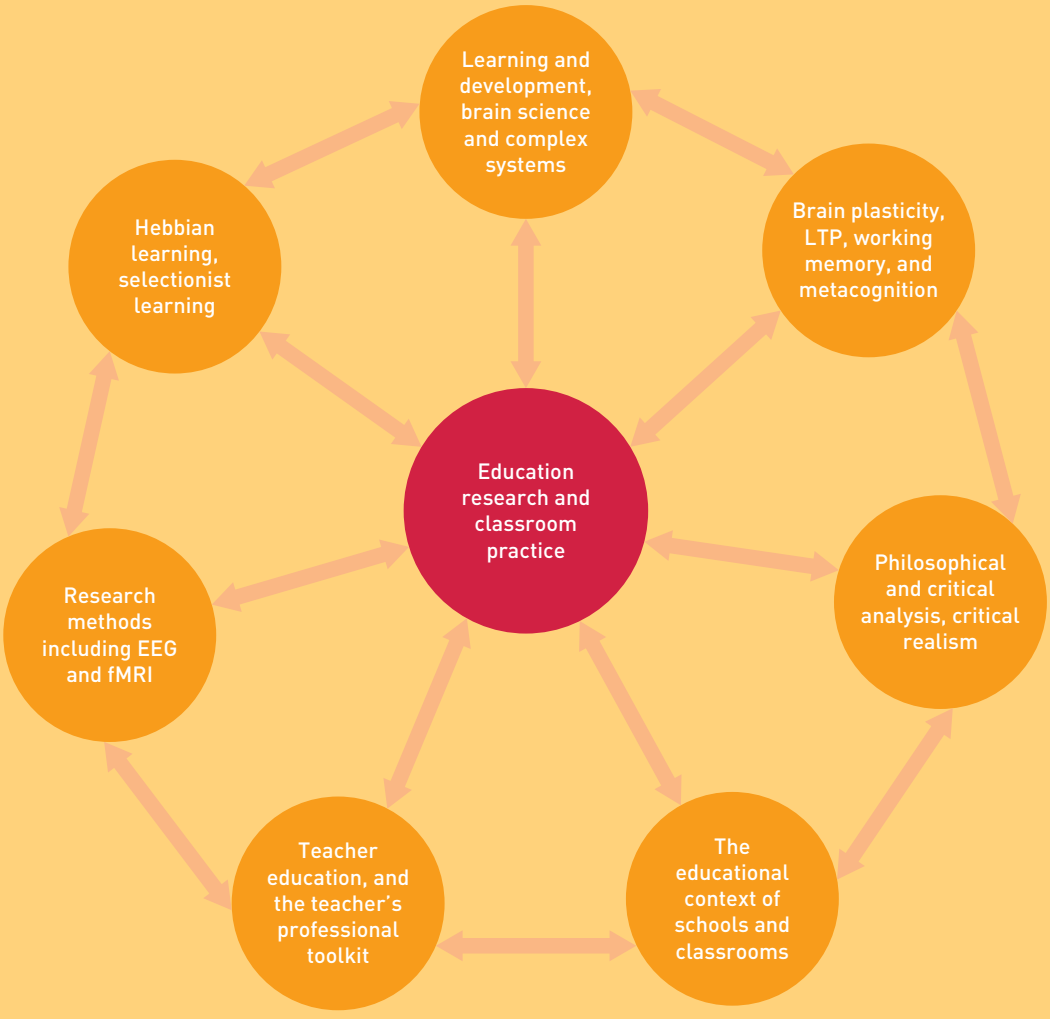


THE SCIENCE OF LEARNING AND DEVELOPMENT IN THE TWENTY-FIRST CENTURY

This book does not require any prerequisite knowledge of the science of learning and development, and it is very likely that teachers will find much in the book that is new. The main aim of Part 1 is therefore to start at the very beginning, assuming little more than a commitment to the professional practice of teachers. Teachers are fully aware they need to know how children and adolescents learn and develop. Traditionally within education, that process has been informed by a mix of speculative and scientific theory. However, the past quarter of a century has witnessed a massive growth in new scientific knowledge that can add considerably to teachers' professional knowledge regarding their students' learning and development and that also needs to be incorporated into future education research.

The centrality of education research and practice in this textbook, and the importance of this for teacher education, is explored at the start of Chapter 1 and also indicated in Concept map 1. All eight key concepts explored in the first five chapters are introduced In Chapter 1 using a light-touch approach, inviting readers to feel at home in this new field of study. A working definition of the science of learning and development as conceived in this textbook



Concept map 1 The science of learning and development

is stated early in Chapter 1, which also introduces the notion of the teacher's professional toolkit, as well as discussing the interplay between science and philosophical, critical analysis and the notion of critical realism that underpins this text.

The relationship between education and the science of learning is reinforced in Chapter 2 by focusing on the work of Donald Hebb (1949), a school teacher who became a distinguished brain scientist and laid down the foundations of synaptic plasticity that continues to underpin current research in the science of learning. Most of the learning occurring in schools today is Hebbian learning. Readers discover that those surrounding Hebb also made highly formative contributions to the science of learning, including Karl Lashley, Wilder Penfield (1958) and Hebb's doctoral student, Brenda Milner. Chapter 2 also provides an introduction to the basic anatomy of the brain, synaptic functioning, long-term memory and long-term potentiation (LTP).

Whereas Chapter 2 mainly refers to the science of *learning,* Chapter 3 focuses on the science of *development* and the major change that has occurred in developmental science over the past quarter of a century, with the introduction of dynamic systems theory (DST). This change has major implications for educational research and practice, not least because it challenges many of the theoretical assumptions that have guided education over the past 60 years, or so. The origins of DST in mathematics, chemistry, physics and meteorology are briefly explored as a means of introducing non-specialist readers to the core concepts of DST, including the idea that children are complex, emergent, self-organising beings.

Following the first three largely introductory chapters, Chapters 4 and 5 apply what has been learnt about the science of learning and development to two main educational concerns. Chapter 4 introduces the notions of working memory, executive functioning and metacognition, which are increasingly recognised as key to learning in schools. This chapter also provides readers with an introduction to research using the electroencephalogram (EEG). Chapter 5 focuses on the science of language, literacy and numeracy. The chapter details the origins of these fundamental areas of learning and locates where they occur in the brain and how they develop. The chapter ends with a discussion of how the science of learning and development is able to inform educational debate in the areas of literacy and numeracy. Picking up on the discussion of brain plasticity in Chapter 2, it also explores how plasticity is bringing new hope in remedying brain impairments such as dyslexia.

CHAPTER 1

INTRODUCING THE SCIENCE OF LEARNING AND DEVELOPMENT IN EDUCATION

LEARNING OUTCOMES

By the end of this chapter, you will:

- Understand what is meant by the science of learning and development and start to appreciate its relevance for education research and practice
- Understand the relationship between theory and the interweaving of research and practice in education, and the importance of cross-disciplinary collaboration
- Be aware of quite recent paradigm changes in our understanding of learning and development, and know about some main conclusions of recent research
- Understand the importance of adopting a critical yet humanising approach to your studies in the context of education

Why the *science* of learning and development in education?

Everybody knows a lot about learning and development. We have all been learning and developing since before we were born, and we will continue until the day we die, so why do teachers (and parents) need to know about the *science* of learning and development? Because, strange as it might seem, it has all been happening in our brain, and we can only *know* about the brain by investigating it scientifically. All learning occurs in the brain and all development is related to changes occurring in the brain (Smith, 2009) – a brain that is massively complex, containing some 86 billion nerve cells (neurons) and just as many glia cells (Figure 1.1). Unlike neurons, glia cells do not produce electrical impulses; rather, they provide protection and support for neurons. Neurons are quite sparsely interconnected at birth, but they become massively interconnected in the early years, forming pathways that will be strengthened or weakened (or completely pruned) as the individual child learns and develops.

Figure 1.1 An adult human brain weighs around 1.5 kg with approximately 86 billion massively interconnected nerve cells (neurons) and just as many glia cells, which basically protect and support the neurons

You and your learning, developing brain

Who we are, as individual persons or 'selves', is largely a product of all that we have previously experienced on life's journey, starting when we were a foetus in the womb. But there is also a *constant interplay* between life's many and varied experiences and the genes that we inherited from our parents. Genes provide constraints on development; they ensured that when you came into the world and started to develop, you were on a human genetic trajectory and not the trajectory of a cat or dog. All of us are a product of the constant interplay between the physical impact on the brain of all that we experience, whether good or bad, and the influence of genes we inherited. Notice the emphasis on a *constant interplay* between our genes and experiences. This contrasts with the outdated claim that we are the product of a dichotomy that positions nature (genes) and nurture (experience) as opposites that are then said to somehow 'interact'. There really is no such dichotomy of opposites, though you will often find it repeated in textbooks.

That outdated dichotomy is partly based on a previous belief that genes are not impacted by environmental factors. Developments this century in the field of epigenetics show that idea to be false (Shenk, 2010). Genes are 'turned on or off' by environmental factors or 'markers' (Pembrey et al., 2006). The **nature/nurture dichotomy** can also lead to the false impression that somehow our genes are our destiny. If we have an unfavourable gene for some

nature/nurture dichotomy: a view of development that separates the biological and environmental influence and postulates how they are said to interact

condition such as **dyslexia**, for example (explored further in Chapter 5), it has often been thought there is nothing that can be done to remedy the condition. But that is simply not the case (Geake, 2009), as we will discover in Chapter 2 when considering the therapeutic prospects that are emerging from current understandings of brain plasticity.

dyslexia: an impairment with reading and spelling despite having the ability to learn. The 'central difficulty for a student with dyslexia is to convert letter symbols to their correct sound (decode) and convert sounds to their correct written symbol (spell)' (Australian Dyslexia Association, 2021).

Another important point to note is that brains do not exist in isolation from everything else that makes you who you are, your body and your personal thoughts and feelings. Brains are intrinsically *embodied* (Immordino-Yang, 2016), biologically integrated within the body. Indeed, the primary role of the brain is to constantly monitor all that is happening in the body, keeping it all in metabolic balance, a process called **homeostasis** (Damasio, 2018), through a feedback sensing process called **interoception** (Barrett, 2017), which we examine in Chapter 11. Thus, the primary role of the human brain is not, as some philosophers seem to assume, to provide human persons with conscious self-awareness. The achievement of consciousness or conscious self-awareness is very much a Johnny-come-lately phenomenon in the evolutionary story of the brain, found not only in humans, but also in the higher apes, dolphins and elephants, and perhaps even capuchin monkeys (de Waal, 2009; Sankey & Kim, 2016).

homeostasis: 'the coordinated and largely automated physiological reactions required to maintain steady internal states in a living organism' (Damasio, 1999, p. 39)

interoception: the 'brain's representation of all sensations from your internal organs and tissues, the hormones in your blood, and your immune system' (Barrett, 2017, p. 56)

So your brain is very much part of your body – it's an organ of the body, as are your heart and your lungs. Moreover, your embodied brain is also physically, socially and culturally *embedded* (Figure 1.2). For better or worse, as embodied brains we are inevitably situated in multiple physical and social environments that constantly impact what we do and who we become. As Linda Smith (2009, p. 82) notes in regard to learning and development, 'It's a brain in a body in a world that matters.' But please note that this is not a one-way process, because what we do and who we become impact the multiple environments in which we are situated.

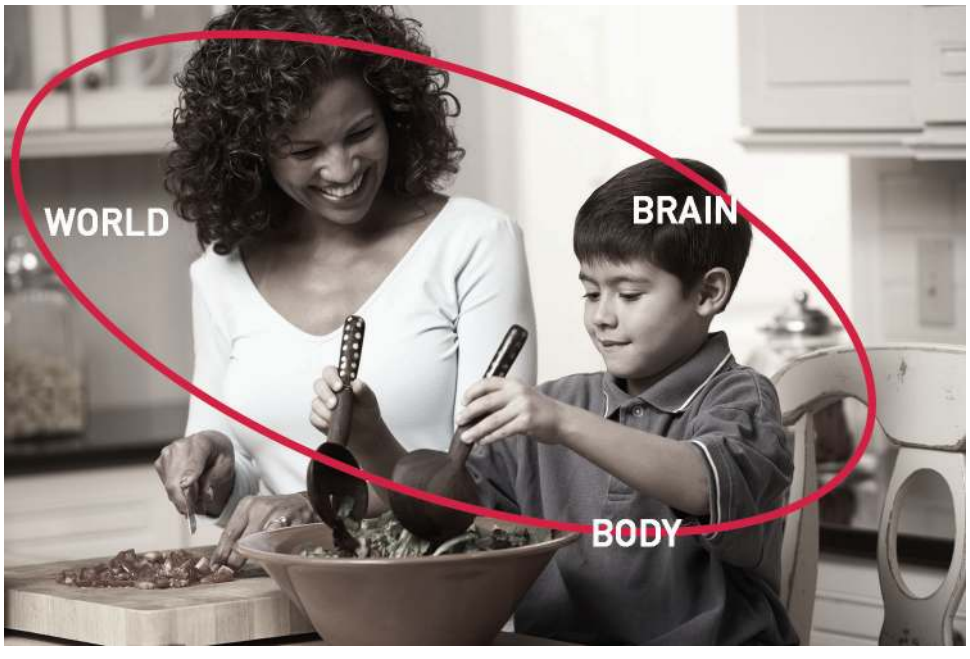


Figure 1.2 The *embodied* and physically, socially culturally *embedded* brain. In understanding learning and development, it's 'a brain in a body in a world that matters'.
Source: Concept from Smith (2009, p. 82).

Finally, as you will learn throughout this textbook, brains are highly dynamic and complex, and they are also fragile – both physically and emotionally. A key message for teachers is that in working with children, we are working with embodied and embedded brains. It is a massive responsibility. And, because brains are physically and emotionally fragile, such work needs to be done with the greatest of care.

From conventional wisdom and craft knowledge to science

Teachers and parents are especially aware of learning and development. Although they can't see what is happening in children's brains, they certainly see it happening in the achievements, personalities and behaviours of the children in their care. Beginning with the explorations and discoveries in the early years of infancy, through the stabilities and growth of the childhood years and then the turbulences of puberty and adolescence, teachers and parents are encountering and constantly responding to the joys, challenges and worries of children's learning and development, on a daily basis (Figure 1.3).

Figure 1.3 What's happening in this child's head as she investigates the world, and what's going on in your brain as you read this book?

However, although we may feel we know a lot about learning and development based on own experience and conventional wisdom, and even though teachers are especially aware of learning and development as a result of their professional practice and craft knowledge, there is a constant need to dig deeper by asking some difficult questions and trying to answer them. For example: *What are the processes involved in learning and development*, and *What is actually going on in the brain when students learn and develop?* Or, to make it up close and personal, *If all learning occurs in the brain and all development is a product of changes occurring in the brain, what's going on in your brain right now, and how is that contributing to your learning and development?*

To answer these and similar challenging questions, we need to delve into the science of learning and development, but what does that mean, and shouldn't it be the *science*s of learning and development? In using the singular term ('science') for the title of this book, we are emphasising *taking a scientific approach* to understanding learning and development in the context of education. In other words, we are placing an emphasis on scientific research. The two main areas of scientific research that are especially relevant to education, and which therefore form the focus of this text, are:

1. those aspects of brain science (especially the anatomy and functioning of the brain) that relate to learning and development, and
2. the science of complex, dynamic systems, or **dynamic systems theory (DST)** as it is known in developmental science.

dynamic systems theory (DST): a theoretical framework in developmental science that focuses on the origins and self-organisation processes of novel functions

The teacher's professional toolkit

The purpose of this book is to provide teachers with an up-to-date and accurate account of some of what we now know about the science of learning and development, and its relevance to education. This book is written in the belief that the science of learning and development should be an *essential part* of every teacher's professional toolkit, along with and interwoven into subject expertise and pedagogical knowledge and skills.

The notion of a professional *toolkit* is a metaphor for the essentials needed to perform the professional role of the teacher. There may be many desirable things for teachers to learn in their professional education, but a sound and accurate understanding of how children and adolescents learn and develop should be professionally foundational. This book will be of considerable relevance to all teachers as they constantly strive to understand and teach students in their care, and also to the many parents who are interested in deepening their understanding of their children's learning and development.

REFLECTION

Using the metaphor of the teacher's professional toolkit, in addition to a sound and accurate understanding of how children and adolescents learn and develop, what other professional 'tools' do teachers need, as an absolute priority, to do their job effectively?

Theory and the interweaving of research and practice in education

Acquiring an understanding of how children and adolescents learn and develop might seem like a rather theory-driven enterprise; it has certainly tended to be so in the past. Books on the study of education seem to be inundated with theories of all kinds. However, ultimately education takes place in schools, in classrooms and other learning environments, and that should firmly link the study of *education* to *educational practice*. This book is not driven by theory, although it discusses some scientific theories; rather, it is motivated by a constant interplay between educational *practice* and scientific *research*, viewed as an *interwoven whole*.

Changing the emphasis from theory and practice to the interplay of *research and practice* contrast this text with many previous teacher education texts that embraced a '*theory into practice*' model. Student teachers, it was said, should first learn theory and then apply that *theory into practice* when planning lessons and addressing the pedagogical challenges they encounter in their classroom. If you think about it, this *theory into practice* model is a bit strange. It assumes that there exists a body of relevant theory that was generated independently of practice, but that somehow needs to be applied to educational practice and pedagogy. It seems to set up a dichotomy between theory and practice in order to knock it down. Surely, the most apposite educational theories are intimately related to practice and arise out of, and address, problems of practice. Or, to put it in a more straightforward way, aren't good teachers always *theorising* about their practice (Sankey, 1996)?

Another problem with the emphasis on 'theory' is that it deflects attention away from the key role played by research in the study of education. Theory often provides an important

conceptual framework for conducting educational research but, arguably, what newly qualifying and experienced teachers need most is a grasp of how evidence that is generated by ongoing research – including research into learning and development – relates to education. A holistic notion of the *interweaving of research and practice in education* is very compatible with a dynamic systems approach to learning and development – which, as you will learn shortly, isn't just one more theory to add to the list, but rather an overarching paradigm.

Education as a discrete science, informed by cross-disciplinary collaboration

A major problem with the **theory/practice dichotomy** in education is that it tends to position education as a discipline that is dependent on theories that arose when addressing problems in other disciplines, such as psychology or sociology. This carries the implicit assumption that education is not a science in its own right, but simply a derivative of other disciplines. If, on the other hand, the problems that arise in education are viewed as distinctively educational, requiring educationally relevant research in order to address them, the idea that education should be viewed as a discrete science in its own right follows closely behind. Moreover, this view suggests that research conducted in relation to the science of education should be based in educational practice, solving educational problems. Ideally, it should be school based, using the natural setting of the school and classroom rather than a laboratory.

theory/practice dichotomy: a view in education that theory and practice are two distinct entities

Nevertheless, disciplinary boundaries are a human construct and there is no need to create an additional dichotomy, separating the science of education from the remainder of science. Educational science should therefore work in cross-disciplinary collaboration with other sciences, particularly those related to the science of learning and development, incorporating relevant insights and using the same technologies, even though the *research focus remains directed towards education* and resolving its most pressing problems. With regard to advancing knowledge and understanding about learning and development in education, it is therefore highly likely that research will increasingly use brain imaging technologies such **functional magnetic resonance imagining (fMRI)** and the **electroencephalogram (EEG)** (Figure 1.4). As you will discover in Chapters 4 and 10, EEG is very well suited to school-based research.

functional magnetic resonance imagining (fMRI): a brain imaging technique that detects the changes in blood oxygenation and flow that occur in response to neural activity

electroencephalogram (EEG): a brain imaging technique that detects electrical activity in the brain using small metal discs (electrodes) attached to the scalp

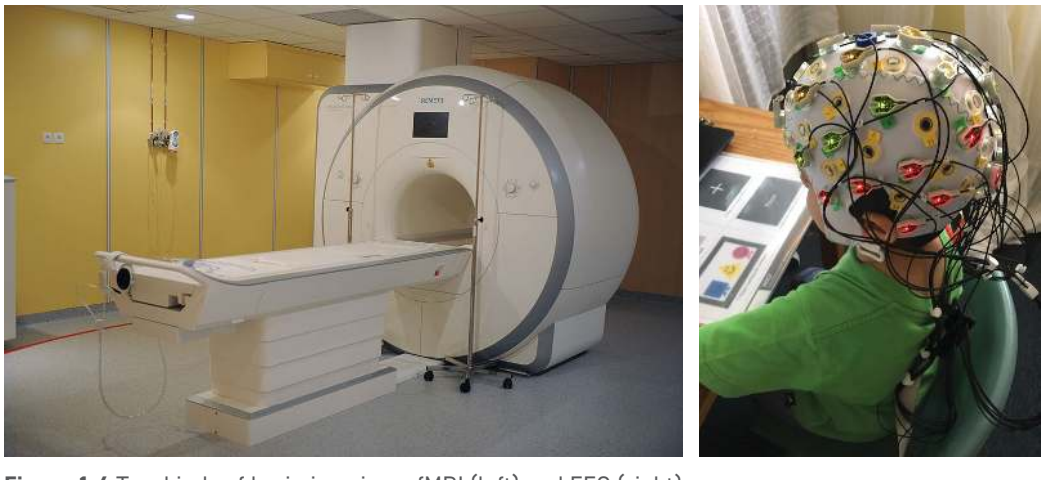


Figure 1.4 Two kinds of brain imaging – fMRI (left) and EEG (right)

The cognitive subconscious and other philosophical puzzles

In this text, we will also be interweaving the science of learning and development with philosophical issues, as they arise in context. Some of the scientific ideas we will encounter in this book raise very thought-provoking and educationally important philosophical questions that are relevant to teachers, especially as they relate to how we view children as learners. There are also important philosophical questions to be asked about the nature of science, the veracity (validity) of scientific evidence and what makes a scientific theory scientific. Moreover, Alva Noë (2004, p. vii) provided an important foundation for this text when he argued that science and philosophy are always closely interwoven: 'Philosophy flourishes in the midst of scientific research, not only because philosophical problems are in good measure empirical, but because scientific problems are in good measure philosophical.'

If science and philosophy are as closely interwoven as Noë suggests, then the ability to notice and articulate relevant philosophical questions related to the science of learning and development that arise in the context of education should also be part of each teacher's professional toolkit. As an example, consider the scientific research finding that much of our thinking, learning and development occurs below the level of conscious awareness, and therefore out of reach of conscious introspection. This is often referred to as the **cognitive unconscious** (Lakoff & Johnson, 1999), though this book uses the term **cognitive subconscious** (Sankey, 2006) because the word 'unconscious' could mistakenly imply a kind of coma, and that's completely the wrong idea.

cognitive unconscious: much of our thinking is operating below the level of conscious awareness and is therefore not available to conscious introspection

cognitive subconscious: an alternative term for the cognitive unconscious

To clarify the claim that much of our thinking is occurring below the level of conscious awareness, Lakoff and Johnson (1999, pp. 10–11) offer some examples of what is happening when holding a conversation:

- Accessing memories relevant to what is being said
- Comprehending a stream of sound as being language, dividing it into distinctive phonetic features and segments, identifying phonemes, and grouping them into morphemes
- Assigning a structure to the sentence in accord with the vast number of grammatical constructions in your native language
- Picking out words and giving them meanings appropriate to context
- Making semantic and pragmatic sense of the sentences as a whole
- Framing what is said in terms relevant to the discussion
- Performing inferences relevant to what is being discussed
- Constructing mental images where relevant and inspecting them
- Filling in gaps in the discourse
- Noticing and interpreting your interlocutor's body language
- Anticipating where the conversation is going
- Planning what to say in response.

The claim that much of our thinking is occurring below the level of conscious awareness has important implication for teachers in recognising that *the children we teach are both conscious and subconscious learners and decision-makers*. Teachers are therefore educating the conscious and subconscious understandings, beliefs and values of the children in their care