How to explain absolutely anything to absolutely anyone

The Art & Science of Teacher Explanation

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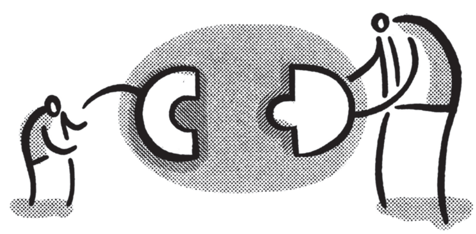
Contents

Introduction

"Daddy, in football, is a striker the same as a forward?"

"Daddy, why do we have wars?"

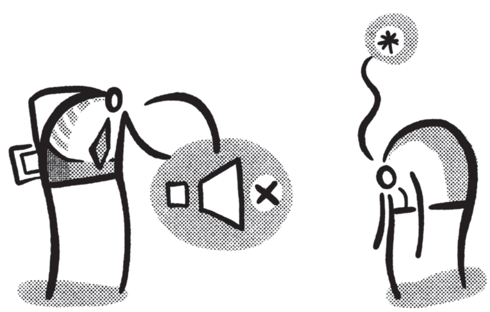
"Daddy, what would happen if all books were made of bacon?"



From the age of about two, children develop the intellectual ability to ask *why* questions. It is a vital developmental milestone. Their burgeoning curiosity about the world and their increasing proficiency with language means that they become desperate to learn more. To quench their new-found thirst for knowledge and understanding, they seek answers from the adults in their lives; their parents and teachers. They are becoming aware of what they do not yet know, or have not yet imagined, and they go on a tireless hunt for the further information and elaboration that might lift the veil on the mysteries of the universe. George, my 6-year-old son, asked me the three questions above over the period of time I spent writing this book. (Be assured, this book *is* suitable for vegetarians!)

Nothing could be more natural to human language and communication than explanation. Explanations have a range of purposes: to make something understandable; to clarify and expand an idea; to give the causes, context and consequences of a situation or event; or to show how facts and concepts are related and connected. The most straightforward definition of an explanation is 'the answer to a question'. As members of language communities, we provide and receive countless explanations every day, at work and at play. This is why the word 'because' is one of the most important in the English lexicon. If the question is 'why', the explanation finds its origin in 'because'.

It is near impossible to conceive of effective teaching without explanation. A teacher who does not explain is little more than a mute babysitter. However, classroom explanations – also known as 'instructional explanations' – are more problematic than those that occur spontaneously in the course of ordinary life. This is because the recipients of the explanation, our students, have not previously sought out the new information that we require them to learn. Sometimes, they are not aware of what they do not know. More troublesomely, they sometimes hold misconceptions which mean that they are completely convinced of an alternative and inaccurate 'truth' to the one we hope they will learn. Sometimes the problem lies in a lack of motivation, especially when students fail to see the relevance of the new material that we are trying to explain.



It would seem sensible, then, to assume that if young people are to learn about the nuances of tectonic shift or the finer details of atomic structure, their teachers should learn how to explain these ideas with clarity, precision, flair and agility. It would also seem sensible that a sizeable portion of teacher training and development be dedicated to helping teachers to improve their ability to explain these concepts. Sadly, this could not be further from reality. In recent years, teacher talk – the most efficient form of explanation known to man – has become the black sheep of the education world. In some schools, teachers have been encouraged to talk less so that their students can talk more. Group-work and student-to-student discussion have become the gold standard, lauded and applauded despite their considerable limitations when students are working with new material. Teachers have been discouraged from speaking for too long, and in some cases have been hung, drawn and quartered for doing so!

Thankfully, the tables are beginning to turn. Common sense and research evidence are converging to reassert the importance of the teacher's role in the classroom and, more significantly, the importance of the things that the teacher has to say. In 2014, teacher and writer Daisy Christodoulou's *Seven Myths About Education* methodically dismantled many prominent misconceptions about teaching and learning. In response to those who argue that teacher-led instruction is passive, Christodoulou wrote:

> **There is a reason why it took humans such a long time to discover the laws of nature, even though the evidence for such laws was all around them in the environment. We do not find it easy to learn new information when we have no or minimal guidance.**[1]

Each new generation stands on the shoulders of the last. Few young people can understand the theories of Charles Darwin and Albert Einstein, or fully appreciate William Shakespeare and Mary Shelley, without guidance and explanation from an expert teacher. It is essential that teachers feel confident enough to stand up at the front and teach such world-changing content without the accusation of being didactic or overly dominating. There is a time for teachers to talk; and there is a time for students to listen. Of course, there is also a time when the reverse is more desirable and students should be working independently and autonomously. But this should usually happen towards the end of a sequence of learning, not at the beginning. In most cases, teachers should first provide answers and then open the space for interrogation.

A wealth of empirical evidence supports the assertion that teacher explanations perform a crucial role in learning. Educationalist John Hattie systematically analyses the effectiveness of different influences on learning. At the time of writing, his most recent list of 252 separate influences placed 'teacher clarity' at a very significant number 24.[2] John Hattie and Gregory Yates have also shown that teaching is

1 Daisy Christodoulou, *Seven Myths About Education* [Kindle edn] (Abingdon: Routledge, 2014), loc. 1033.
2 See Sebastian Waack, Hattie Ranking: 252 Influences and Effect Sizes Related to Student Achievement, *Visible Learning*. Available at: https://visible-learning.org/hattie-ranking-influences-effect-sizes-learning-achievement/.

much more effective when teachers use methods that *activate* learning rather than methods that *facilitate* learning.[3] Put simply, students usually learn better when a teacher introduces new content rather than attempts to elicit it from them. Moreover, evidence from cognitive science reveals that the less prior knowledge a student has about a topic, the more teacher guidance they need. Human cognitive architecture is simply not designed to learn difficult new concepts independently.[4] Further evidence points towards the constructive influence of face-to-face interaction between teacher and student. For instance, one study shows that students' learning and persistence outcomes are better when they take in-person courses than when they take online courses.[5]

Needless to say, not all teacher talk is effective talk. Too often, simple concepts are made too complex and complex concepts too simple. Students can be left uninterested or overwhelmed. We must also stay vigilant against a pair of familiar adversaries: decreasing attention and wandering minds. Even though verbal explanations are a staple component of almost every lesson, it is also well-established that they do not always work for all students.[6] However, this does not mean that teachers should limit their talk; it means instead that they should learn how to talk better. Explanations are to teaching what penicillin is to medical practice: essential but not effective in every case.

Research into effective teaching also reveals some fascinating and quite counterintuitive insights. In the US, Professor Siegfried Engelmann has compiled over half a century of evidence supporting Direct Instruction, a model of teaching that involves scripted explanations. Engelmann argues that what children learn is totally consistent with the input they receive from a teacher. Direct instruction involves precise clarity of wording, the use of carefully designed examples, and the teaching of rules and 'misrules' – all delivered through a systematic trickle of new information. Direct Instruction is a mastery approach to learning, which means that 85% of lesson time is devoted to practising material that children have

3 John Hattie and Gregory Yates, *Visible Learning and the Science of How We Learn* (Abingdon: Routledge, 2014), p. 73.

4 Paul A. Kirschner et al., Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching, *Educational Psychologist*, 41(2) (2006): 75–86.

5 Eric Bettinger and Susanna Loeb, Promises and Pitfalls of Online Education, *Evidence Speaks Reports* 2(15) (9 June 2017). Available at: https://www.brookings.edu/research/promises-and-pitfalls-of-online-education/.

6 See Jörg Wittwer and Alexander Renkl, Why Instructional Explanations Often Do Not Work: A Framework for Understanding the Effectiveness of Instructional Explanations, *Educational Psychologist* 43(1) (2008): 49–64.

already covered, while only 15% involves weaving in new material.[7] A nine-year longitudinal study called Project Follow Through found that students who received Direct Instruction had significantly higher academic achievement, better problem-solving skills and higher self-confidence and self-esteem than students receiving any other type of instruction.[8] Engelmann's slow and careful methods are a far cry from the rush and clamour of the way the curriculum is delivered in primary and secondary schools in England.

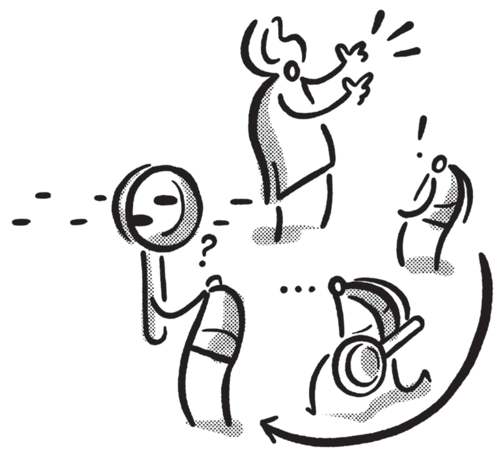
Before we start to explore the how, let's take a moment to think about what we might be trying to achieve each time we launch into an explanation. Chris Anderson, the curator of the non-profit organisation TED, gives this advice to would-be public speakers: "Your number-one mission as a speaker is to take something that matters deeply to you and to rebuild it inside the minds of your listeners."[9] This 'rebuilding' metaphor is essential to our understanding. The most effective explanations are designed and crafted with subtlety. As with the most robust physical structures, explanations should be built to last. The content we teach – whether it's quadratic equations or the respiratory system or dramatic irony – is not only for understanding and admiring now, but also for storing away for the future. A new fact, concept or idea is a gift for life, not a short-term loan.

There are many different types of instructional explanation. Teachers routinely explain facts, concepts, procedures, moral and aesthetic truths, metacognitive strategies and more. Each type of explanation comes with its own distinctive set of tricks and skills and a corresponding collection of hitches and hazards. We will explore these in full as we move through the book.

Explanation is an art form, albeit a slightly mysterious one. We know when we hear and see a teacher unravelling a great explanation. It has something to do with their effortless subject knowledge, the simplicity and directness of their language and the sense of assurance they exude. Nevertheless, we struggle to describe the intricacies of the craft. Just *how exactly* are they doing it? Invariably, we attribute good

7 See Shepard Barbash, *Clear Teaching: With Direct Instruction, Siegfried Engelmann Discovered a Better Way of Teaching* (Arlington, VA: Education Consumers Foundation, 2012).
8 See https://www.nifdi.org/what-is-di/project-follow-through.
9 Chris Anderson, *TED Talks: The Official TED Guide to Public Speaking* [Kindle edn] (New York: Houghton Mifflin Harcourt, 2016), loc. 262.

explanation to elements of a person's character or talents: "they're so confident" or "they explain things really clearly" or "they know their subject really well". However, these assumptions are unhelpful because they suggest that the ability to explain is a God-given gift; a form of tacit knowledge that some possess and others do not. In fact, explanation involves a set of intricate tools that anyone can master with a little patience and practice.



To unveil these hidden mysteries we will dip our toes into several forms of evidence. We will draw from educational research, from curriculum theory, from cognitive science, from the study of linguistics, from communication studies, from ancient philosophy and from the expertise of great teachers. We will look at how the most effective speakers, presenters and writers can transform even the most messy, complicated idea into a thing of wondrous crystalline clarity. And lastly, I will share some anecdotal accounts from my own English lessons of how I have attempted, often clumsily, to improve the way in which I explain new ideas in my classroom.

The idea of writing this book came to me on a rainy Saturday afternoon when I was halfway through the first chapter of Carlo Rovelli's *Seven Brief Lessons on Physics*.[10] I had wanted to read a book about physics for a while; it is a subject I know very

10 Carlo Rovelli, *Seven Brief Lessons on Physics*, Simon Carnell and Eric Segre (trs) (London: Penguin, 2015).

little about and one that has always somewhat intimidated me. I was struck immediately by the way in which Rovelli welcomed me into this new and potentially hostile world. Suddenly, the theory of relativity – for so long the impenetrable playground of wiry-haired science types – was something that even I, in my limited way, could begin to grasp. But more than that, it was lucid, strange and enticing. Beautiful even. I wanted to find out more.

How did Rovelli paint this new world so vividly? Let's begin with his bluntly put first sentence: "In his youth Albert Einstein spent a year loafing aimlessly."[11] Immediately, Rovelli opens a gap between expectation and reality by disrupting our conventional beliefs about Einstein: he seems more like a conventional teenager than a prodigious genius-in-waiting. Rovelli then plants us in a very specific time and place: Italy at the turn of the nineteenth century. Success stories are driven by obstacles that stand in the way of the protagonist's goal, and Albert's story as it progresses is no different: "his theory of relativity did not fit with what we know about gravity, namely how things fall".[12] In fact, Einstein had found himself – theoretically at least – pitted against a titanic foe: Isaac Newton, the godfather of Western physics.

After framing his narrative, Rovelli pops himself into the story. He recounts the moment on a sunny beach in Calabria where, in the pages of a mouse-gnawed book, he finally appreciated the magnitude of Einstein's theory. Looking up from the book and out to sea, Rovelli envisaged "the curvature of space and time"[13] as Einstein described it. This is an emotional and finely drawn epiphany – note the wonderful contrast between the tatty, nibbled book and the unimaginable greatness of the cosmos.

As he moves more deeply into scientific theory, Rovelli brings the mysteries of reality alive through metaphor. Space is described as a "gigantic flexible snail-shell", the earth as "a marble that rolls in a funnel". Other sentences are written with remarkable economy: "The gravitational field is not diffused through space; the gravitational field is that space itself".[14]

Rovelli's short chapter includes many of the tools vital to a great explanation: an interesting story; a clear context; an unsolved problem; a personal involvement; a

11 Rovelli, *Seven Brief Lessons on Physics*, p. 1.
12 Rovelli, *Seven Brief Lessons on Physics*, p. 2.
13 Rovelli, *Seven Brief Lessons on Physics*, p. 4.
14 Rovelli, *Seven Brief Lessons on Physics*, p. 6.

journey from the concrete to the abstract; the precise use of metaphor to capture hard-to-imagine concepts; and a vividness and economy of language. Teachers can certainly learn a lot about the art of explanation from reading books on complicated topics written for a lay audience, like Rovelli's.

Needless to say, skilful classroom explanation is about much more than word choice and the odd deft figure of speech. For example, students arrive in our classrooms with widely differing prior knowledge, which then influences how much they can comprehend and commit to memory. Furthermore, the language of many subjects, such as mathematics, goes far beyond spoken and written English. Images, diagrams, graphs and visual organisers are part and parcel of the symbolic code of learning. We should also be clear that explanations are *not* lectures. Ideally, they involve a dialogic process that involves active listening and participation from every person in the room.

A teacher's use of language also has a wider purpose: to induct students into the academic discourse of each subject. Think of each subject as having its own *grammar*; its own language world. This is a set of language conventions – involving phraseology, syntax, vocabulary and idiomatic expressions – that reflects the kind of thought processes inherent to the discipline and used with ease by subject experts. Consider the importance of conditional clauses – *if … then* clauses – to scientific thinking: *if* you freeze water, *then* it becomes a solid. Or the way in which English literature relies on tentative and exploratory language: the poet *seems to hint* that power dissipates and fades with time. Only students from academic families are likely to already be familiar with these language worlds. Unless we actively and purposefully model the implicit grammar of our subjects, we will struggle to improve our students' thinking, speaking or writing. Think of yourself as a member of an exclusive language club. How will you equip all your students to get past the bouncers on the door so they can join you inside? This task is even harder for primary teachers, whose role it is to induct students into multiple subjects and multiple language worlds.

Good teacher talk also improves students' vocabulary. This is particularly relevant at the time of writing as the new knowledge-rich primary and secondary curriculums in England require students to acquire an ever-deeper knowledge of words. Unfortunately, one in five children in England join secondary school unable to read to a standard that enables them to access the curriculum.[15] Of 24 OECD countries, England is the only one where 16–24-year-olds have lower literacy skills than 55–65-year-olds.[16] Knowledge of words and syntactical conventions (the arrangements of words and phrases in sentences) is not only vital to the development of reading competency, but also the key to unlocking academic success. A student will only build their vocabulary through regular and repeated exposure to new words, ideally through lots of reading. However, as only just over one-third of schoolchildren in England read at home every day, a teacher's deliberate and targeted use of words can go some way towards providing this exposure.[17]

In the chapters that follow, we will explore seven key principles for explanation that apply to every subject, age group and educational phase. These are:

Chapter 1: Subject knowledge

Your subject knowledge is both your magic bullet and your Achilles heel.

Chapter 2: Credibility and clarity

All explanation is also an act of persuasion.

Chapter 3: Explanation design

Too much new information at once can reduce learning. Less is usually more.

Chapter 4: Concepts, examples and misconceptions

Abstract concepts should be supported by concrete examples.

Chapter 5: Metaphor and analogy

Connections should be forged between students' prior knowledge and the material to be learnt.

Chapter 6: Storytelling

Your students are pre-wired to learn from storytelling.

15 Department for Education, *Reading: The Next Steps: Supporting Higher Standards in Schools*. Ref: DFE-00094-2015 (London: Department for Education, 2015). Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/409409/Reading_the_next_steps.pdf, p. 13.

16 OECD, *Country Note: England and Northern Ireland (UK): Survey of Adult Skills First Results*. Available at: http://www.oecd.org/skills/piaac/Country%20note%20-%20United%20Kingdom.pdf, p. 4.

17 Liz Twist et al., *PIRLS 2011: Reading Achievement in England* (Slough: NFER, 2012). Available at: https://www.nfer.ac.uk/publications/PRTZ01/PRTZ01.pdf, p. 73.

Chapter 7: Elaboration

Explanations are only effective when students are also given the opportunity to think about the new material.

The conclusion explores ways in which you can hone and practise your explanations, and how to support other teachers in improving theirs.

Ultimately, the purpose of this book is to introduce and explain a series of concepts and processes that will help you to think differently about the way in which you introduce and explain new knowledge and skills. Each section also provides very simple and practical strategies that you can put into action straight away.

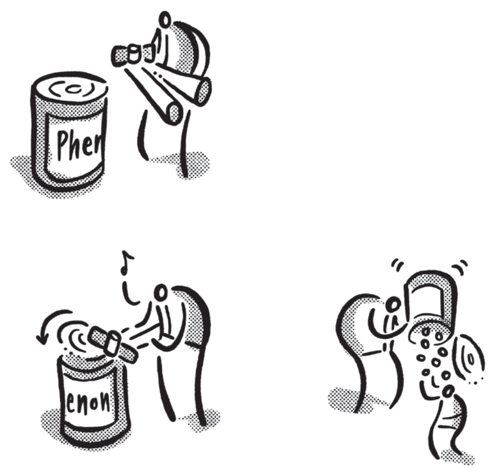
We will examine both the art and the science of explanation, and I will argue that to be most effective it requires a judicious blend of poetry and precision.

Let us begin.

Chapter 4

Concepts, examples and misconceptions

Abstract concepts should be supported by concrete examples.



Tyler is an ordinary 15-year-old at an ordinary secondary school. It is Friday. In his maths lesson, he subtracts algebraic fractions. In English, his class discuss tragic structure in Shakespeare's Macbeth. In biology, he looks at communicable and non-communicable diseases, while in geography he covers population density in the UK. And in the final lesson of the day, PE theory, Tyler studies the scientific principles that underpin planning a personal fitness training programme.

Tyler is also very busy at the weekends. On Friday evening, he watches an episode of the cult series *Breaking Bad* (even though he is underage) and pops out to the shop to buy some paracetamol for his younger sister who is curled up on the sofa with a cold. On Saturday, Tyler goes for a run in the

countryside on the outskirts of the city where he lives (he is a middle distance runner and is training for a meet next weekend). On Sunday, he finishes his maths homework.

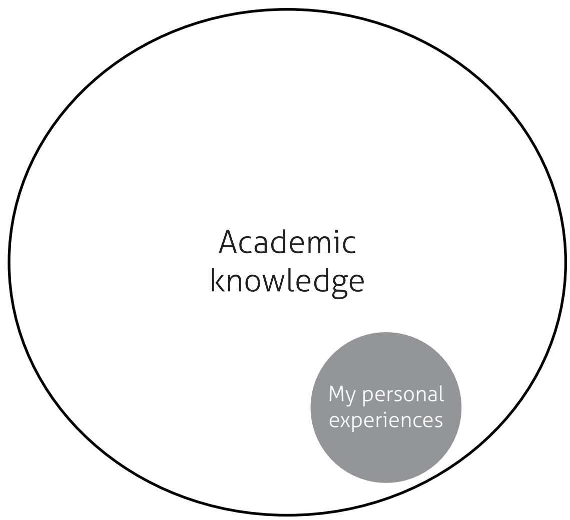
Tyler is an archetypal teenager whose understanding of the world is formed by a combination of school and home life. You have probably already noted the parallels between the academic material he has covered in school and the experiences he has outside it: the TV series *Breaking Bad* echoes the structure of a Shakespearean tragedy through the tragic hero's descent into tyranny; his sister's common cold is an example of a communicable disease; his decision to run in the countryside rather than in the city is influenced by the sheer density of the urban population; and his training programme, designed and insisted upon by his athletics coach, has been informed by the principles of frequency and intensity. His maths learning – on subtracting algebraic equations – has been reinforced through the homework task he has completed.

In short, there is no clear dividing line between the classroom and the world: life is mirrored by education, and education is mirrored by life. However, there are some essential differences between the knowledge gained from personal experience and the abstract knowledge of school. Each student brings very different knowledge into the classroom – some bring more than others and, sometimes, this knowledge is wrong or only partially right.

Linked to this is the reality that the more proficiency a student has in a particular domain (or area of learning), the less mental effort they will need to exert in solving problems in that domain. A fluent reader, for example, can read a Victorian novel or a science textbook without having to decode complex, multisyllable words. A fluent reader can transfer this skill from one subject to another and from one topic to another.

The teacher's central task at all stages of education, then, is to introduce students to knowledge that transcends the individual and the context. We call this conceptual knowledge, and the more academic concepts you can master, the more successfully you will navigate the education system. Concepts also create efficiency; they become intellectual lodestones. By forming the building blocks and reference points of the curriculum, they then support the learning of new and harder concepts.

A concept allows for abstraction. It allows us to generalise from a specific context to many other similar contexts – for example, from population density in the immediate vicinity of Tyler's house to population density in cities across the world. The logical linking together of these abstractions forms the basis of conceptual thought. In many ways, the purpose of school is to help students to see the distance between their personal lives and their academic learning – to understand that their personal, concrete experience is merely a drop in a multitudinous ocean.



However diverse and vibrant our personal experiences, and however observant and insightful we are, we are unlikely to grasp an academic concept in its fullness and intricacy without some effortful study. And usually this will be introduced by a teacher through a spoken, visual or textual explanation.

Alongside conceptual knowledge, we should also consider the other types of information that students encounter in a school curriculum. Some subjects, such as mathematics and physics, are already abstract and intangible in nature, whereas others, such as geography and biology, are already supported by concrete, everyday examples.

Some of the types of knowledge students have to learn include:

- **Factual knowledge:** true statements about the world – for example, the Battle of Hastings took place in 1066; the radius and ulna are in the forearm; Christians believe that Jesus Christ is the son of God.
- **Scientific knowledge:** a fact that has been acquired through scientific method – for example, the average human body carries ten times more bacterial cells than human cells; the earth is not flat; the earth orbits the sun.
- **Moral knowledge:** our understanding about right and wrong behaviour (relative to the situation and the social group we are part of, and often based on hypothetical thinking) – for example, it is wrong to hurt others; it is right to help those who are less fortunate than ourselves; it is right to treat others as we would like to be treated ourselves.
- **Aesthetic knowledge:** our private understanding of what makes something beautiful or not – for example, to be moved or horrified by Picasso's Guernica; to appreciate the perfection of a Shakespearean sonnet; to find insights in the way the world is understood differently in the French language.
- **Procedural (practical) knowledge:** knowledge required to perform a skill – for example, to know how to bowl a cricket ball; how to set out a formal letter; how to solve a geometry problem.
- **Metacognitive knowledge:** knowledge required to think about one's own learning more explicitly – for example, strategies for planning, monitoring and evaluating extended writing; strategies for revising in the lead-up to an exam.

These types of knowledge have differing levels of significance depending on the subject. If the purpose of a subject is to provide a window to some kind of scientific, moral or aesthetic 'truth', then the search for this truth takes many different paths. All subjects are supported by factual knowledge and require the development of procedural knowledge, whereas subjects like English literature and art hinge upon aesthetic judgement, and RE is formed from moral and ethical principles. Needless to say, it takes an incredibly skilled teacher to help a child to transform their perception of beauty or influence their moral judgement of a situation.

Put simply, the inherent nature of conceptual understanding is different between and within every subject. For instance, a successful piece of narrative writing in English requires a well-developed appreciation of different types of knowledge, and the ability to explore the following questions:

- Is the setting and context of my writing true to the *factual* and *scientific* world?
- To what extent do my characters comply with or break the *moral* conventions of society?
- Is the style and structure of my story *aesthetically pleasing*?
- Do I know *how* to structure a story in a successful way?
- How will I *plan* my writing before I start and *evaluate* it after I have finished?

In the rest of this chapter, we will explore practical ways to help students untangle their personal experiences from the factual, scientific, moral, aesthetic, procedural and metacognitive concepts that they must master in our classrooms. The Russian psychologist Lev Vygotsky once wrote: "with the help of the concept, we are able to penetrate through the external appearance of phenomena to penetrate into their essence".[1] If we explain these concepts well, then we will not only transform the way in which students view the everyday world, but also their chances of academic success.

Why are examples so important?

If conceptual knowledge is so pivotal to learning, then why should we concern ourselves with examples? Why should we waste our time on factual information when an understanding of the general principle is the greater goal? Cognitive scientist Daniel Willingham distils many years of research findings into one sentence: "We understand new things in the context of things we already know, and

1 Quoted in Jan Derry, *Vygotsky: Philosophy and Education* (Chichester: Wiley-Blackwell, 2013). p. 21.

most of what we know is concrete."[2] He goes on to write that the best way "to help students understand an abstraction is to expose them to many different versions of the abstraction".[3] In other words, surface-level examples are crucial to the development of deep-level processing and understanding.

It is almost impossible to 'get' a new concept without first being exposed to an example of that concept at work in the real world. This is why the concept of revolution in history is best taught through historical events and contexts: the French Revolution, the Russian Revolution or even the Industrial Revolution. In the early stages of learning, the more concrete the example, the better. This does not mean that we should avoid abstractions altogether. Instead it means that we should explain mysterious objects, forces and phenomena in a way that would make them tangible. To do this, we must pepper our explanations with real-world referents.

There are two possible ways of guaranteeing that this happens. The first might be to ensure that students learn through direct, first-hand experiences – for example, through field trips and museum visits. As enjoyable as these experiences can be, sadly this direct approach would be an incredibly expensive and impractical way of running an education system. Trips are only ever an added bonus. So the second approach is to ensure that students experience the real world through indirect experiences. Virtual experiences of learning – through personal reading or a teacher-initiated episode – can be as powerful as direct experiences. A trip to the forest will allow for many beautiful and powerful sensory experiences: the dank aroma of leaf mould, the spongy brilliant-green of moss, the trilling tune of a wood warbler … But, ultimately, learning is a result of the thinking that occurs in the working memory. With good teaching, children can learn about the ecosystem of a forest in the classroom too.[4]

2 Willingham, *Why Don't Students Like School?*, p. 67.
3 Willingham, *Why Don't Students Like School?*, p. 67.
4 See Robert J. Marzano, *Building Background Knowledge for Academic Achievement: Research on What Works in Schools* (Alexandria, VA: Association for Supervision and Curriculum Development, 2004) for an interesting discussion on the impact of direct experiences and indirect experiences.

The perfect example

Designing good examples is an art form in its own right. The perfect example is simple and self-contained; it provides an effortless shortcut to understanding. Effective examples not only bring insight and clarity, but also accentuate the inherent personality of the material too. They can inject a topic with emotion, humour, absurdity, poignancy or a sense of the unexpected. They breathe new life into potentially stagnant ideas. It takes many years for an expert teacher to nurture and prune their collection of examples, but once they have, teaching becomes a craft performed with wonderful deftness and ease.

So, what makes for a good example?

- It should connect to what a student *already knows.*
- It should be as *simple* as possible.
- It should appeal to the *senses*.
- It should be easy to *transfer* to new contexts.
- It should be *memorable*.
- It should come in *multiples*.
- It should aim to provoke an *emotional* response.

The writer Bill Bryson puts each of these principles to work with aplomb in *A Short History of Nearly Everything*, a science book for beginners. To explain the conservation of mass, for example, Bryson gives the example: "If you burned this book now, its matter would be changed to ash and smoke, but the net amount of stuff in the universe would be the same."[5] This little sentence provided something of a Eureka moment for me. It used something tangible – the book I was holding. It was simple. It was tactile. And it helped me to transfer the concept of conservation of mass to other objects: my own body after death, for example. Matter is indestructible, and so the atoms that make up my body will simply take on new arrangements in new places; they will not be lost forever.

5 Bill Bryson, *A Short History of Nearly Everything: A Journey through Space and Time* (London: Black Swan, 2016), p. 134.

Later in the book, Bryson helps his reader to imagine the unimaginable: the fact that at sea level and at 0° Celsius, one cubic centimetre of air (the size of a sugar cube) contains forty-five billion billion molecules:

> **Think how many cubic centimetres there are in the world outside your window – how many sugar cubes it would take to fill that view. Then think how many it would take to build a universe. Atoms, in short, are very abundant.**[6]

Again, Bryson's example is perfect in its simplicity: everyone can picture the size of a sugar cube; it hinges on a visual representation and is an instantly memorable image.

However, these examples do not capture the entirety of the concepts that are being explained. This is worth noting and is especially relevant to teachers whose students work with very complex concepts. A single example only provides a simplified and partial representation of the whole. An isolated example can lead to a situation where students struggle to fully separate the concept from the presentation. This causes the surface features of the representation to become muddled with the deep structure of the concept, or problem, at hand. For example, the Bill Bryson examples could lead some readers to develop misconceptions: that molecules are only present in the air or that conservation of matter only occurs when an object is burnt, for example. In these cases, the example has provided a useful bridge between current knowledge of the world and the strange new world of the unfamiliar academic idea, but it has also caused mislearning of the essential principle.

A way to counterbalance this problem is to always come armed with multiple examples. In fact, evidence from the science of learning suggests that students are more likely to be able to transfer learning to new contexts when they are given two examples rather than one.[7] Once a student has grasped the basics of a new idea, they have to discern the defining aspects of the concept so that they can build the depth and accuracy of their understanding. The broader the range of contrasting and interesting examples, the easier they will find it to make accurate generalisations and extrapolations.

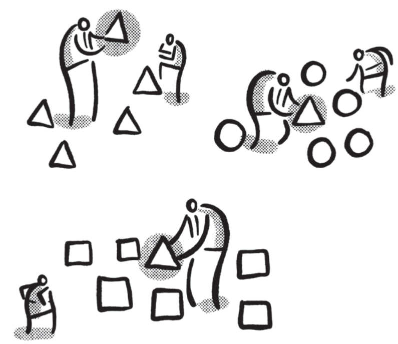
6 Bryson, *A Short History of Nearly Everything*, p. 176.

7 See this guest blog post for more: Althea Bauernschmidt, Two Examples Are Better Than One, *The Learning Scientists* [blog] (30 May 2017). Available at: http://www.learningscientists.org/blog/2017/5/30-1.

There are many useful methods for improving the way in which you present multiple examples. One is to present the same concept across a *range of very different contexts*. This helps students to understand when and where the concept can be generalised. Another is to present *small and subtle variations* on the same concept to tease out exceptions and subtle nuances. For example, an English teacher might present these two sets of examples when introducing the possessive apostrophe:

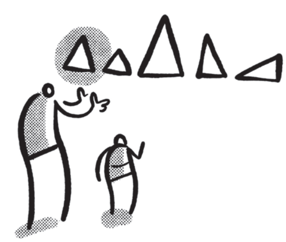
Set 1 – range of contexts

- Kathryn's gloves were soaked.
- My dog's bark is very deep.
- The cat's eyes gleamed wickedly.
- The tree's height was extraordinary.
- My mum is my great-grandfather's son's daughter.



Set 2 – small variations

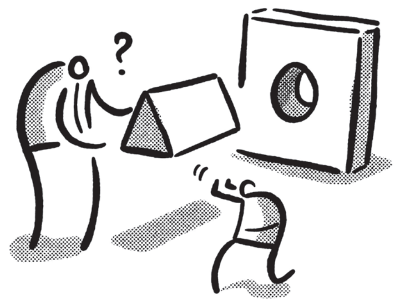
- They were Andrew's gloves.
- The gloves were Andrew's.
- We visited Andrew's house.
- I'm going to Andrew's tonight.
- There were two Andrews living there.



Set 1 shows us that apostrophe of possession rules hold fast in a range of scenarios. Set 2 presents a number of subtle variations on the same theme and allows the teacher to pre-empt areas of potential confusion and exceptions to the rule. For example, in the fourth sentence, although the word 'house' is missing, it is implied – and so the apostrophe of possession rule should still be applied.

Perhaps a golden rule for teachers is to always have as many examples as possible at the ready. With simple concepts, the whole class or individual students will need only one or two; with tricky concepts, they may need many more.

Examples and non-examples



If there is one strategy in this chapter that will help all students to learn better, it is this: introduce new concepts through contrasting examples *and* non-examples. According to Wragg and Brown, 'not-examples' (or non-examples) are "cases which do not meet the criteria of the concept, but then, by comparison, illustrate what the real criteria for inclusion in the concept actually are".[8] Non-examples are particularly useful because they prevent students overgeneralising and encourage them to discriminate between similar concepts. All teachers and parents will be familiar with the tendency among novice learners to overgeneralise. We see this when a young child misuses the past tense '-ed' rule with an irregular verb: "I *knowed* you would do that!" Or perhaps in maths when a child believes that if 5 x 11 = 55 and 9 x 11 = 99, then 11 x 11 must be 111. We can all become better teachers if we learn how to avert misconceptions before they take root.

In my English lessons, I tend to introduce grammatical concepts, such as the correct use of the semicolon, through examples and non-examples. For example:

1 Tom was unhappy; Arsenal had lost that day. (tick)

2 The tiger is a ferocious predator; it can kill an animal twice its size. (tick)

3 The winter is the most depressing time of year; the summer is full of joy. (tick)

8 Edward C. Wragg and George Brown, *Explaining* (London and New York: Routledge, 1993), p. 33.

4 Julian is my closest friend; and I can never be apart from him. (cross)

5 Even though I am a Tottenham fan; I have a soft spot for Brighton & Hove Albion. (cross)

The non-examples are based upon the common mistakes and misconceptions that I see regularly in student writing. In example 4 the conjunction 'and' is redundant and in example 5 the semicolon has been used erroneously to separate a subordinate clause from a main clause.

Teachers often worry that by presenting accurate examples and misconceptions together the boundaries between right and wrong will become blurred and, in turn, that this will lead to students learning the misconception and not the rule – the so-called 'backfire effect'. We are right to be concerned about this – but there are some simple ways around the problem:

- Start by making it very clear why 'right is right'.
- Direct students towards the misconception and explain clearly why it is wrong – "This is incorrect because …"
- Circle back to the misconception as often as you can and ask students to explain to you why it is wrong.
- Design tasks that allow the class to discriminate between examples and non-examples – for example, using classification tasks or Venn diagrams.
- Design a memorable cue that reminds students of the common mistake.
- Encourage students to create their own examples and non-examples.

Must haves and may haves

Concepts are also defined according to 'must have' and 'may have' attributes. Must have attributes are those features that are critical to a concept; it cannot exist without them. For instance, a Shakespearean tragedy must end with a catastrophe; a pentagon must have five sides; a volcano must have an opening in the surface of the earth. On the other hand, may have attributes apply in some cases of the concept, but not all. Some Shakespearean tragedies are about thwarted love; some pentagons contain sides of irregular length; some volcanoes are conical in shape.

Wragg and Brown provide an incredibly useful framework for explaining concepts.[9] I call it the 'concept template' and it includes the following elements:

1. A label or name – the word (or words) used to name the concept.
2. A simple definition.
3. A list of attributes.
   i. must have
   ii. may have
4. A list of examples.
   i. illustrative examples
   ii. non-examples

9 Wragg and Brown, *Explaining*, p. 33.

The concept of 'mammals' might look like this:

Name	mammals
Definition	Mammals are animals such as humans, dogs, lions and whales. In general, female mammals give birth to babies rather than laying eggs, and feed their young with milk.[10]
Attributes	
must have	Hair or fur at some stage of the life cycle; mammary glands in females; single-boned lower jaws; warm-blooded metabolisms; diaphragms; four-chambered hearts; three-bones in the middle ear.
may have	Breast-feeding males (Dayak fruit bat); the ability to fly (bat); an aquatic habitat (whale); a land habitat; seven neck vertebrae; four legs.
Examples	
illustrative examples	Human beings; elephants; whales; bats; dolphins; hedgehogs; seals; platypuses; kangaroos.
non-examples	All birds; all fish; scorpions (arachnids); lizards (reptiles); frogs (amphibians); woodlice (isopod land crustaceans).

A template like this can be used to plan teacher explanations and questions. You might ask students to fill in a blank version before you teach a topic, to assess their prior knowledge and identify any misconceptions. Similarly, students can complete them once their knowledge and understanding becomes more proficient.

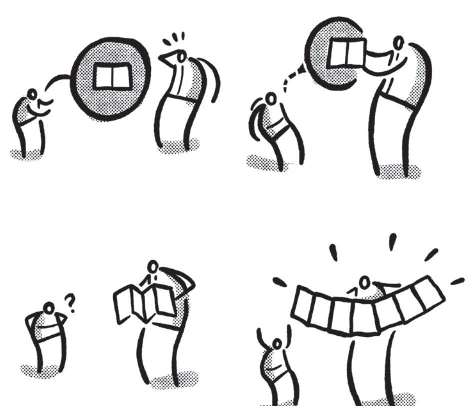
In less scientific subjects, such as English literature and history, the boundaries between concepts and ideas are sometimes very indistinct or open to interpretation. In these subjects, you might experiment with the layout and the wording of the template. For example, in my English literature lessons I put a different spin on

10 See https://www.collinsdictionary.com/dictionary/english/mammal.

this structure to help my students to investigate complex characterisation. To do this, we use these headings to explore each main character in a text: name, factual examples, always shows, sometimes shows, never shows.

A concept is similar to an iceberg. Often our students can only see the part that rises above the waterline; they do not realise that a deeper, fuller and usually more subtle truth lies beneath. Great explanation rests on a teacher's ability and willingness to guide students towards the murky, uncomfortable and sometimes contradictory nature of truth. Many concepts in education are hard to teach and hard to learn. Too often, teachers move too quickly through lessons and the curriculum without leaving time for real investigation. All teachers should heed the words of Friar Lawrence from Shakespeare's *Romeo and Juliet*: "Wisely and slow; they stumble that run fast."

The strategy of helping students to see the distinction between essential and non-essential elements is also driven by a moral imperative. It helps to challenge deep-rooted bias and promotes the kind of finely tuned discrimination that distinguishes balanced intellectual thinking from oversimplified thinking. Quite simply, not all snakes are venomous, not all teenagers are insolent and not all homeless people are drug addicts. Indeed the type of careful thinking we need from our students has taken on extra importance in recent years. In a world of deplorable fake news, ubiquitous smartphones and persistent xenophobia, it is essential that schools teach young people the disciplined habits of mind that will protect them from jumping to easy, simplistic and erroneous binary conclusions in their adulthood.



When exemplification goes wrong

Ultimately, the role of an example is to provide a stepping stone towards understanding and knowledge. Unfortunately, as with all aspects of teaching, an example can sometimes have a different effect to the one the teacher intended. An awkward example can cause shallow understanding and, in the worst cases, create confusion or lead to misconceptions. The table below explores some common errors and outlines ways to rectify them:

Error	Problem	Solution
Too few examples.	This can lead to a shallow understanding of the boundaries of the concept.	Start with simple, everyday examples to connect with prior knowledge. Then start to introduce less obvious cases, exceptions and caveats, before moving on to non-examples that appear to blur into related concepts at first glance.
Too little scrutiny of examples.	Sometimes teachers assume that students have fully understood a concept when they have not.	Your aim is to gain as much real-time feedback as you can of how the class (and individual students) are modelling the concept for themselves. Frequent questioning allows you to track their understanding and nip potential misconceptions in the bud. Stock questions and prompts might include: "Why is this right?" "Why is this wrong?" "How does x connect with y?" "Tell me what you don't understand."

Error	Problem	Solution
Examples are too compli-cated or abstract.	If examples refer to situations and scenarios way beyond a student's prior knowledge and experience, then it is very unlikely that they will be in a position to construct an accurate and true understanding of the concept.	Make sure your examples contain simple real-world referents. Ensure that these are likely to be within your students' frame of reference. While common cultural reference points – films, television, sport, etc. – are useful, remember that the interests and personal experiences of your students will be varied.
Concepts are too indistinct.	Students (and adults) get muddled between similar concepts – for example, area and perimeter in mathematics; simile and metaphor in English; stalactites and stalagmites in science.	In this common situation, the problem is caused by fuzzy boundaries between concepts rather than by the examples themselves. The trick here is to provide very distinct memory cues at the point of teaching. A recommended approach would be to: • Make the class aware from the start that the two concepts are often confused. • Teach a visual mnemonic to remember the difference – for example, stalactites hang from the ceiling of a cave like tights hanging on a washing line. • Ensure that students practise using the mnemonic so that it is not forgotten.

How concrete examples can improve memory retention

Fifty years of research shows us that human beings are more likely to remember concrete examples than abstract ones. For example, Gorman found that concrete nouns like 'button' were easier to remember than words like 'bound'.[11]

Weinstein et al. advise that as well as helping with retention, paired concrete examples help students to transfer their understanding to new contexts (the holy grail of learning):

> **providing concrete examples during instruction should improve retention of related abstract concepts, rather than the concrete examples alone being remembered better ... Having students actively explain how two examples are similar and encouraging them to extract the underlying structure on their own can also help with transfer.[12]**

A valid concern regarding the use of concrete examples is that playful, humorous or fun examples could prove to be counterproductive. In other words, the students remember your wonderfully delivered witty joke instead of the concept you were elucidating! The good news is that fun, or even risqué, examples do not appear to harm learning. In fact, as long as they are relevant to the concept and do not include too much extraneous detail, the evidence suggests that they provide an extra memory boost.[13] This is excellent news for teachers: it is a much-needed licence for creativity.

If you need help to find amusing and memorable examples, the Internet offers a smorgasbord of delights. In recent years, my teaching of grammatical concepts has

11 A. M. Gorman, Recognition Memory for Nouns as a Function of Abstractedness and Frequency, *Journal of Experimental Psychology* 61 (1961): 23–39.

12 Yana Weinstein et al., Teaching the Science of Learning, *Cognitive Research: Principles and Implications* 3(2) (2018): 1–17 at 11. Available at: https://cognitiveresearchjournal.springeropen.com/articles/10.1186/s41235-017-0087-y.

13 Weinstein et al., Teaching the Science of Learning.

become more vibrant and interesting with the use of examples that I have found online. To help students avoid dangling modifiers, I use these:

Early men hunted mammoths with spears.

I found my missing hat cleaning my room.

To help students to understand when an Oxford comma would be appropriate, we compare the following:

We invited the dogs, William, and Harry. (With the Oxford comma.)

We invited the dogs, William and Harry. (Without it.)

It is also important that we invest time in helping our students to memorise concrete examples. This process is often overlooked. The definition of a dangling modifier is "a grammatical error where the modifying word or phrase is attached to the wrong subject or where the subject is missing in a sentence".[14] This abstract definition is hard to conceptualise and even harder to apply to your own writing. Memorising it is a waste of time. It is far better to ensure that a student memorises a few examples (including the mammoth and hat ones) so that the next time they edit their own writing and notice a similar error they think: "Ah, that's like the mammoth example Sir showed us; I need to change this sentence." Ultimately, a concrete example provides us with a memorable support structure that helps us to reconstruct an abstract construct in our minds when we need to.

A useful tip is to conduct a pre-mortem for each lesson: if my students do not remember this in six months' time, what will have caused this? Planning distinct and lively examples is one of the first steps towards long-term retention.

14 See https://www.grammarly.com/blog/how-to-eliminate-dangling-modifiers-from-your-writing/.

Tackling misconceptions

We have already touched on the notion of misconceptions on a number of occasions in this chapter. Students come to lessons with pre-existing schemas (organised frameworks of knowledge) that represent the world as they see it; some of these are accurate conceptions, others are illogical or erroneous. Even though these alternative conceptions are frustrating for teachers, they are a natural part of life and learning and they often derive from common sense or intuitive thinking about the natural world. Misconceptions are prevalent in every subject, but they are especially rife in the sciences. Students often arrive in physics lessons believing that energy is created and then destroyed rather than being transferred from one form to another, or in chemistry lessons convinced that there is air between the particles in a gas. Thankfully, there are many common, shared misconceptions, like these two examples, that experienced teachers can learn to pre-empt.

On other occasions, individual students develop rather unusual or idiosyncratic misconceptions. I once taught a very high-achieving Year 11 student (who has since won a scholarship to a prestigious independent school) who was completely convinced that the word perhaps was spelt *prehaps* – even in the face of irrefutable dictionary evidence!

This introduces another common problem that teachers have to solve: that misconceptions are extremely tenacious and have extraordinary staying power. Chinn and Brewer describe seven different responses that people – children *and* adults – have when encountering anomalous data (that which cannot be explained by our pre-existing understanding of the world).[15]

These are:

1 *Ignore it* completely.

2 *Reject it* by arguing that the data is wrong or simply fraudulent.

3 *Exclude it* by conveniently segregating the theories learnt in school from everyday theories of how the real world works.

15 Clark A. Chinn and William F. Brewer, The Role of Anomalous Data in Knowledge Acquisition: A Theoretical Framework and Implications for Science Instruction, *Review of Educational Research* 63(1) (1993): 1–49. Available at: http://journals.sagepub.com/doi/10.3102/00346543063001001.

4 *Hold it* in abeyance by putting the problem to one side and assuming that someone will prove us right at some point in the future.

5 *Reinterpret it* by accepting the new data but explaining it according to our existing theory.

6 Make a *peripheral change* to our existing theory without destroying its core beliefs.

7 Change to a *new theory* and reject our existing hypothesis.

As you will have noticed, only the seventh option – theory change – produces a desirable outcome. Misconceptions are limpet-like. They are embedded onto the very fabric of our students' beliefs about the physical and cultural world they inhabit and, as such, they are devilishly difficult to budge. Even if a child's verbal answers and written work demonstrate surface-level understanding of the concept they have been taught, this does not necessarily indicate an ontological change in the way they now think about the world. Despite successfully answering the questions in a plenary quiz at the end of a lesson, they may skip down the corridor still holding the belief that the seasons are caused by the earth's distance from the sun rather than by the earth's axial tilt! The child's central beliefs, therefore, remain untouched by scientific proof.

How, then, can teachers get better at helping students to shed their misconceptions? First, many studies suggest that standard forms of teaching, such as lectures, discovery-based learning and simply reading a text, cannot be solely relied upon to effect conceptual change. More subtle methods, including the following, are more likely to be fruitful:[16]

- Before teaching a new topic, give students a task which helps to identify their pre-existing misconceptions. Once they have taken on board new concepts, they can then refer back to it to see how far they have come.
- Ensure that new theories are always presented with plausible and clear examples.
- Use model-based reasoning or thought experiments to help students to construct representations of the world outside their everyday experience.

16 See Joan Lucariello and David Naff, How Do I Get My Students Over Their Alternative Conceptions (Misconceptions) for Learning?, *American Psychological Association* [blog]. Available at: http://www.apa.org/education/k12/misconceptions.aspx for more detail.

For instance, Isaac Newton visualised a cannon being fired on top of a high mountain to show that gravity is universal and that it is a key force in planetary motion. Without the force of gravitation, the cannonball would shoot off in a straight line away from earth. Such hypothetical thought experiments give plausibility to potentially abstract concepts.

- Create cognitive conflict by presenting students with situations and scenarios that are incongruous with their current conceptions. You can do this by presenting a refutational text which introduces the misconception, refutes it and then provides the new and satisfactory theory. This should then lead to discussions and activities that allow the students to see the conflict between the two. However, some studies suggest that this method is more effective with higher-attaining than lower-attaining students, for whom a more traditional direct teaching approach is more successful.[17]
- As suggested throughout this chapter, use real-world case studies to bring concepts to life.[18]

All in all, the entrenched nature of misconceptions is one of teaching's greatest challenges. Teacher training and CPD is most effective when it retains a strong focus on the correction of common mistakes and misconceptions. Subject departments should make it their mission to identify the most problematic misconceptions in the discipline, record them centrally and share the most effective strategies for helping students to overcome them.

Chapter summary

- The end goal of teaching is the development of students' conceptual knowledge; however, this is best achieved though concrete, memorable real-world examples.
- Effective explanation of concepts involves the presentation of examples, non-examples and must and may have attributes.

17 Anat Zohar and Simcha Aharon-Kravetsky, Exploring the Effects of Cognitive Conflict and Direct Teaching for Students of Different Academic Levels, *Journal of Research in Science Teaching* 42(7) (2005): 829–855.

18 Yildizay Ayyildiz and Leman Tarhan, Case Study Applications in Chemistry Lesson: Gases, Liquids, and Solids, *Chemistry Education Research and Practice* 14(4) (2013): 408–420.

- Students' misconceptions are tenacious and stubborn. Teachers, departments and schools should maintain a relentless focus on helping students to overcome them.

First steps

- Design a concept template for a topic you are due to teach next half term. Alongside it, create a list of verbal questions you will use to assess and probe students' understanding of this concept.
- Make a list of the ten most common errors, misunderstandings and misconceptions you have noticed in your students' thinking.
- Start creating a list of useful and effective examples to overcome these. Ask experienced colleagues to contribute to this list.

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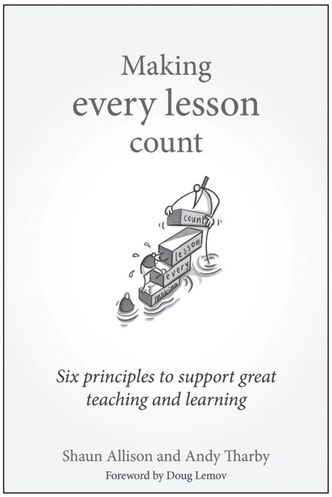

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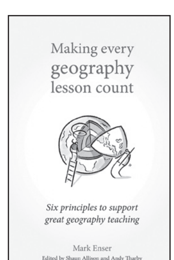

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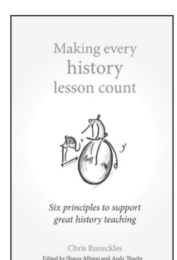

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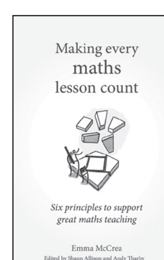

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Andy Tharby is a practising English teacher with over a decade's classroom experience at a secondary school in West Sussex. He is co-author of the award-winning *Making Every Lesson Count* and the author of *Making Every English Lesson Count.* Andy is also interested in helping fellow teachers enhance their practice through engagement with research evidence.

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