TOM SHERRINGTON

TEACH NOW!
Science

The Joy of Teaching Science

A David Fulton Book

SERIES EDITOR: GEOFF BARTON

Teach Now! Science

The companion website for this series can be found at **www.routledge.com/cw/teachnow**. All of the useful web links highlighted in the book can be found here, along with additional resources and activities.

Being taught by a great teacher is one of the great privileges of life. Teach Now! *is an exciting new series that opens up the secrets of great teachers and, step by step, helps trainees to build the skills and confidence they need to become first-rate classroom practitioners.*

Written by a highly skilled practitioner, this practical, classroom-focused guide contains all the support you need to become a great science teacher. Combining a grounded, modern rationale for learning and teaching with highly practical training approaches, the book guides you through all the different aspects of science teaching, offering clear, straightforward advice on classroom practice, lesson planning and working in schools.

Teaching and learning, planning, assessment and behaviour management are all covered in detail, with a host of carefully chosen examples used to demonstrate good practice. There are also chapters on organising practical work, the science curriculum, key ideas that underpin science as a subject and finding the right job. Throughout the book, there is a wide selection of ready-to-use activities, strategies and techniques to help you bring science alive in all three main disciplines, including common experiments and demonstrations from biology, physics and chemistry, to engage and inspire you and your students.

Celebrating the whole process of engaging young people with the awe and wonder of science, this book is your essential guide as you start your exciting and rewarding career as an outstanding science teacher.

Tom Sherrington has been Head Teacher at King Edward VI Grammar School in Chelmsford for several years. He is moving on to become Head Teacher at Highbury Grove School in Islington, UK, and remains a practising science teacher. His blog, headguruteacher.com, has a very wide following, and he is a regular contributor to teacher training events around the country.

Teach Now!

Series editor: Geoff Barton

Being taught by a great teacher is one of the great privileges of life. *Teach Now!* is an exciting new series that opens up the secrets of great teachers and, step-by-step, helps trainees to build the skills and confidence they need to become first-rate classroom practitioners. The series comprises a core text that explores what every teacher needs to know about essential issues such as learning, pedagogy, assessment and behaviour management, and subject specific books that guide the reader through the key components and challenges in teaching individual subjects. Written by expert practitioners, the books in this series combine an underpinning philosophy of teaching and learning alongside engaging activities, strategies and techniques to ensure success in the classroom.

Titles in the series:

Teach Now! The Essentials of Teaching
Geoff Barton

Teach Now! History
Becoming a Great History Teacher
Mike Gershon

Teach Now! English
Becoming a Great English Teacher
Alex Quigley

Teach Now! Science
The Joy of Teaching Science
Tom Sherrington

Teach Now! Modern Foreign Languages
Becoming a Great Teacher of Modern Foreign Languages
Sally Allan

Teach Now! Mathematics
Becoming a Great Mathematics Teacher
Julia Upton

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Tom Sherrington

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For Deb, Daisy and Sam

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Series editor's foreword

What is this series about and who is it for?

Many of us unashamedly like being teachers.

We shrug off the jibes about being in it for the holidays. We ignore the stereotypes in soap operas, sitcoms, bad films and serious news programmes. We don't feel any need to apologise for what we do, despite a constant and corrosive sense of being undervalued.

We always knew that being criticised was part of the deal.

We aren't defensive. We aren't apologetic. We simply like teaching.

And whether we still spend the majority of our working week in the classroom or, as senior leaders, we regard the classroom as a sanctuary from the swirling madness beyond the school gates, we think teaching matters.

We think it matters a lot.

And we think that students need more good teachers.

That's where 'Teach Now!' started as a concept. Could we – as a group of teachers and teaching leaders, scattered across England – put together the kind of books we wish we had had when we were embarking on our own journeys into the secret garden of education.

Of course, there were lots of books around then. Nowadays there are even more – books, plus ebooks, blogs and tweets. You can hardly move on the Internet without tripping over another reflection on a lesson that went well or badly, another teacher

extolling a particular approach or dismissing another craze or moaning about the management.

So we know you don't necessarily think you need us. There's plenty of people out there ready to shovel advice and guidance towards a fledgling teacher.

But we wanted to do something different. We wanted to provide two essential texts that would distil our collective knowledge as teachers and package it in a form which was easy to read, authoritative, re-readable, reassuring and deeply rooted in the day-to-day realities of education as it is – not as a consultant or adviser might depict it.

We are writing, in other words, in the early hours of days when each of us will be teaching classes, taking assemblies, watching lessons, looking at schemes of work and dealing with naughty students – and possibly naughty teachers.

We believe this gives our series a distinctive sense of being grounded in the realities of real schools, the kind of places we each work in every day.

We want to provide a warts-and-all account of how to be a great teacher, but we also each believe that education is an essentially optimistic career.

However grim the news out there, in our classrooms we can weave a kind of magic, given the right conditions and the right behaviour. We can reassure ourselves and the students in front of us that, together, we can make the world better.

And if that seems far-fetched, then you haven't seen enough great teachers.

As Roy Blatchford – himself an exceptional teacher and now the Director of the National Education Trust – says in his list of what great teachers do:

> The best teachers are children at heart
> Sitting in the best lessons, you just don't want to leave.
>
> (Roy Blatchford, *The 2012 Teachers' Standards in the Classroom*, Sage, 2013)

We want young people to experience more lessons like that – classrooms where the sense of time is different, where it expands and shrinks as the world beyond the classroom recedes and where interest and passion and fascination take over; places where whatever your background your brain will fire with new experiences, thoughts and ideas; where whatever your experience so far of the adult world, here, in this classroom, is an adult who cares a lot about something, can communicate it vividly and, in the way she or he talks and behaves, demonstrates a care and interest in you that is remarkable.

We need more classrooms like that and more teachers to take their place within them.

So that's what we have set out to do: to create a series of books that will – if you share our sense of moral purpose – help you to become a great teacher.

You'll have noticed that we expect you to buy two books. We said we were optimistic. That's because we think that being a great teacher has two important dimensions to it. First, you need to know your subject – to really know it.

We know from very good sources that the most effective teachers are experts in what they teach. That doesn't mean they know everything about it. In fact, they often fret about how little they feel they truly know. But they are hungry and passionate and eager – and all those other characteristics that define the teachers who inspire us.

So we know that subject knowledge is really important – and not just for teaching older students. It is as important when teaching Year 7s, knowing what you need to teach and what you can, for now, ignore.

We also believe that subject knowledge is much more than a superficial whisk through key dates or key concepts. It's about having a depth of knowledge that allows us to join up ideas, to explore complexity and nuance, to make decisions about what the key building-blocks of learning a subject might be.

Great teachers sense this and, over a number of years, they build their experience and hone their skills. That's why we have developed subject specialist books for English, mathematics, history, modern foreign languages and science. These are the books that will help you to take what you learnt on your degree course and to think through how to make that knowledge and those skills powerfully effective in the classroom.

They will take you from principles to practice, from philosophy deep into pedagogy. They will help to show you that any terror you may have about becoming a teacher of a subject is inevitable, and that knowing your stuff, careful planning, informed strategies – that all of these will help you to teach now.

Then there's *Teach Now! The Essentials of Teaching*, which is the core text because we also believe that even if you are the best informed scientist, linguist or mathematician in the universe, that this in itself won't make you a great teacher.

That's because great teachers do things that support and supplement their subject knowledge. This is the stuff that the late, great educator Michael Marland called the 'craft of the classroom'. It's what the best teachers know and do instinctively but, to those of us looking on from the outside, or in the earliest stages of a teaching career, can seem mysterious, unattainable, a kind of magic.

It's also the kind of stuff that conventional training may not sufficiently cover.

We're talking about how to open the classroom door, knowing where to stand, knowing what to say to the student who is cheeky, knowing how to survive when you feel, in the darkest of glooms, intimidated by preparation and by marking, that you have made a terrible career choice.

These two texts combined – the subject specialist book and the core book – are designed to help you wherever you are training – in a school or academy or on a PGCE course. Whether you are receiving expert guidance, or it's proving to be more mixed, we hope our ideas, approaches and advice will reassure you, and help you to gain in confidence.

We hope we are providing books that you will want to read and re-read as you train, as you take up your first post and as you finally shrug off the feelings of early insecurity and start to stretch your wings as a fully fledged teacher.

So that's the idea behind the books.

And throughout the writing of them we have been very conscious that – just like us – you have too little time. We have therefore aimed to write in a style that is easy-to-read, reassuring, occasionally provocative and opinionated. We don't want to be bland: teaching is too important for any of us to wilt under a weight of colourless eduspeak.

That's why we have written in short paragraphs, short chapters, added occasional points for reflection and discussion, comments from trainee and veteran teachers, and aimed throughout to create practical, working guides to help you teach now.

So thanks for choosing to read what we have provided. We would love to hear how your early journey into teaching goes and hope that our series helps you on your way into and through a rewarding and enjoyable career.

Geoff Barton
with Sally Allan, Mike Gershon, Alex Quigley, Tom Sherrington and Julia Upton
The *Teach Now!* team of authors

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I'm very grateful for the input of my colleagues at King Edward VI Grammar School. Kirsten Smith, Sandra Naish and David Hall have helped by contributing ideas for science experiments; Bill Wheeler gave useful advice about the philosophy of science section. Technicians Peter Oxford, Barbara Basso-Bert and Paul Strudwick have supported me superbly in my teaching at KEGS, and the sections on science as a practical subject owe a great deal to them.

Finally, I would like to thank my wife, fellow science teacher and school leader, Deb O'Connor. We've shared our life as science teachers for over twenty years, living and breathing our passion for teaching. Many of the ideas in this book have developed from our discussions. My hope is that the *Teach Now!* series goes some way to helping new teachers become as effective and inspiring as she is.

Tom Sherrington
December 2013

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1 The joy of teaching science

I love teaching; I love being a teacher; I love working in schools. I especially love teaching science.

I initially entered the profession with some trepidation, unsure of where it would lead, but it has proven to be a highly rewarding occupation, offering boundless opportunities for personal development and enjoyment. I've found that teaching science can be, in turn, intellectually stimulating, creative, experimental and highly rewarding in terms of developing relationships with students.

It's just wonderful to be the one who gets to introduce a class of young people to the idea of natural selection and reveal the extraordinary story of evolution; or to excite students by making their hair stand on end with a Van der Graaf generator, bringing the theory behind electricity off the page; or to be the person who makes the carbon ooze out of a flask of sugar with concentrated sulphuric acid to show how extraordinary chemical reactions can be.

There really is no job quite like it. Of course, it isn't always easy; in fact, sometimes it can be really tough. But, with the right spirit and the right tools, for the most part, the rewards are enormous, and teaching science is a great joy.

Teaching is also learning

A recurring theme in this book is that the ideas that make up the subject of science are at the heart of the joy of teaching it. I have found, over the years, that teaching has deepened my understanding and my passion for science, often in ways that have surprised me. In my own specialist area, physics, I have learned so much about gravity, waves and fundamental particles through teaching. As a general science teacher for many years, I've had to learn a lot more about genetics and evolution than I'd covered in my biology O level, and, in chemistry, I now have a much more sophisticated understanding of the link between chemical structures and material properties and the range of chemical reactions that can be performed in a school laboratory.

The process of continuing to learn the subject is a passion that most science teachers share. For example, at a recent physics department meeting at my school, we were trying out some new experiments to show our students.

One was a slow-motion camera that could shoot 1,000 frames per second. We used it to film a balloon filled with water at the moment of its being burst with a pin. The result was fabulous to see: the rubber balloon parts flew off, leaving the water in a completely formed balloon shape, before, eventually, it fell apart. This illustration of intermolecular forces in water was fascinating, fun to produce and completely new to me.

We also looked at a large-scale capacitor made from two layers of unrolled aluminium foil, about 1 m long, separated by a thin plastic sheet and attached to a high-tension (5 kV) supply. The result was a series of high-voltage discharges through the plastic, accompanied by some impressively loud bangs. In my subsequent lessons, the students found these demonstrations extremely engaging: they generated a wide range of interesting questions, and we all learned something and had fun in the process. For me, this is the joy of teaching science, and I hope it will be for you too.

The learning obviously isn't confined to the content of the subject; it is also the professional learning that goes with being a teacher. Over time, new pedagogical ideas emerge; there are all kinds of fads and trends and new directives, but, even without all of the circus hoop jumping that goes on in schools, there are still so many different ways to explain ideas and to make connections between theory and practice.

As the book develops, I hope you will be able to explore your own ideas about some of the fundamental concepts in science and how they all fit together, in some kind of order that will allow you to make sense of it for your students.

It is likely that any group of science teachers in a school will have arrived via different routes, with different degrees and science specialisms. Depending on your school's structure and philosophy, it may be that you only teach physics, chemistry or biology. Certainly, it is very common for teachers to teach just one of these subjects to A level; it is also very common up to GCSE. However, at Key Stage 3 (KS3) and very often at GCSE, teachers are expected to share the teaching of science, irrespective of their degree specialisms.

I have argued in the past that a strong general science teacher is far more use to a student than a weaker specialist. However, subject knowledge certainly does make a difference in drilling down to the deeper concepts at the highest attainment levels. In writing this book, I am going to attempt to strike a balance by addressing issues relevant to all teachers of science in general, with examples and specific ideas from physics, chemistry and biology woven in.

To get you thinking about what you know, here are some questions. Think about what a one-line answer would be, and then what a 'four mark' answer might be. Go deeper and deeper – asking 'why?' – until you just don't know:

- Why do magnets attract or repel each other?
- Why does your heart beat faster during exercise?
- How does a rainbow work? And what about a mirage? What is that?

- What exactly does double-glazing do?
- Why is a hypothermia blanket shiny on both sides?
- Why is diesel fuel less flammable than petrol but doesn't need a spark plug to ignite?
- Is it true that whales and hippos are closely related? How is this possible?
- Why are spiders so clever, the way they spin those webs? (Trick question)
- How do we get iron from rocks?
- Why do we bend our knees when jumping down from a wall?
- How do plants know what the seasons are?
- Why do astronauts seem weightless in a space station, when they are still in orbit?
- How far is it to the next nearest galaxy? How do we know?
- Why is graphene so flexible and strong, when it is only one molecule thick?
- Which way do the electrons move in a bolt of lightning?
- What is fire? Exactly . . .
- Why is potassium metal so reactive in water?

ACTIVITIES

If you are unsure about any of these answers, do some research, talk to colleagues in your school and develop your own scientific knowledge and understanding. It is so much easier to teach a topic where you feel really confident in the subject matter.

All science teachers have areas of relative strength and lots of gaps. Work out what your gaps are and start to fill them!

Science is all about posing good questions and searching for the answers.

Scientific thinking: thinking like a scientist

Another of the pleasures of teaching science is the opportunity to engage with the 'real' science community, past and present, both experimental and theoretical, involving students in the process of thinking like a scientist.

This takes many forms. At a basic level, there is the 'how stuff works' dimension: this applies to the properties of everyday materials and machines, cooking food, plant responses, diseases, teeth, ears, the heart, magnets, motors and the weather. How do they work, and how do we know that?

Then there is the 'fundamental truth' dimension – the big existential questions. How did life on Earth develop? How are living things connected, and how has that changed over time? What is energy, what is matter made of, and how does it all hold together? How can we get a sense of the scale of the subatomic world and of the universe, both in space and in time, and how does the living world interact with the physical world that it inhabits?

Of course, then we have the measurement and verification dimension. How do we construct experiments that allow us to measure variables in a controlled, systematic fashion, such that our analysis can lead to valid conclusions? Having the opportunity to work through all of these questions with a class of young people is wonderful.

The traditional and modern scientific approaches that have been employed over time are a constant reference point for gaining a perspective on the development of scientific ideas. The personal triumphs, disasters and accidental discoveries by scientific figures offer a dimension to the study of science that really helps to bring it alive. Whether we're talking about Galileo and the great 'ball drop' experiment, the painstaking work of Darwin and Wallace in arriving at the idea of natural selection, the arrangement of the

elements by Dmitri Mendeleev, or more recent breakthroughs with the human genome and the Higgs boson, the people are part of the story, alongside their discoveries and ideas.

Of course, one of the great assets to teachers of science faced with a cohort of teenagers immersed in social media and the latest technology is that our subject is continually being updated. Science is simultaneously timeless and cutting edge. Scientific ideas are in the news every week, and a great science teacher will find ways to weave the newest events and breakthroughs into the curriculum, to keep it alive, fresh and of the moment. Science doesn't stand still.

Science is multidisciplinary

For a lot of science teachers, one of the greatest joys is the massive variety of activities that you can engage in during lessons. Although there is a lot of time spent with theoretical concepts, thinking and writing answers to problems and performing calculations, much as you might do in many other subjects, science is also a practical subject, with a major 'hands-on' element.

As we will discuss later, it is really important to know how the practical work and theory work together – not all experiments help to explain basic concepts; they can actually make things a lot more confusing, because real life is messy. However, very often, the practical lessons and demonstrations are the best bits – and are certainly the things students remember long afterwards. As a science teacher, you have the opportunity to create some big bangs and blows – igniting the perfect oxygen–hydrogen mix in a balloon or methane bubbles in detergent; you can experience the messy but fascinating process of dissecting an eye, a heart or a set of sheep lungs; and, my personal favourites, you get to make motors and create all kinds of mischief with sound and light.

At a fundamental level, scientific thinking is all about matching theory with experiment, and we have ample opportunity to do this in the school laboratory. We can tell the story of our understanding of light as a wave and a particle and the development of our

knowledge of fundamental particles through the perspective of the history of ideas needing experimental verification and experimental discoveries looking for a theoretical underpinning. This applies to the story of natural selection and genetics and our observations of materials in all their glorious diversity, despite being made up of only a few common building blocks.

Of course, science is also an academic discipline that requires us to use research skills, to have the power to write explanations in good English and to produce an analysis of data using graphs and calculations. As teachers, these elements of the role are really important, not least because these skills are those that are relied on heavily during formal exams. Mainly, we need them to share our ideas within the class. There is a level of rigour required – accuracy and precision – alongside a certain flair and imagination.

We need to develop skills for using a range of weird and wonderful apparatus, and this takes time to master. From simple clocks, ammeters and voltmeters to baffling oscilloscopes, tricky microscopes and fiddly bits of glassware, there is a lot to learn. However, with technicians and teacher colleagues to support you, it soon becomes one of the pleasures of the job. Every year that I've been a science teacher, I've learned something new about a piece of kit or I've found a new way to measure something.

So, a science teacher needs to be a thinker, a mathematician, a writer, a technician, a storyteller, a historian – a veritable polymath. If you've never thought of yourself as a multitasker, you're about to be amazed.

Autonomy

Teaching wouldn't be fun at all if every lesson was prescribed, and you had to do exactly what you were told by someone else. We haven't come this far just to be vehicles for transmitting information. We're here to engage our students in a rigorous learning process, but also to make sure we are getting a lot out of it too. The more motivated and enthusiastic you are as a teacher, the

more likely you are to transmit those things to your students and to sustain yourself as a professional when things get tough. In this context, teaching science is brilliant, because, to a large extent, you have a high degree of autonomy.

Of course, there is a syllabus – and we will deal with planning a curriculum later. But, for any given idea or topic, there are hundreds of ways to organise a lesson to make things interesting and to suit your personal style.

In terms of autonomy, this means that, from day to day, you are doing what you decide to do. You might want to do a practical with all the students, or show a video clip you found, or run a demonstration. You might want students to work on their own, or to collaborate in pairs or groups; you might want them to produce a piece of extended writing or a multimedia product or simply to give extended oral presentations. You can use textbooks, some resources you have designed or borrowed or interactive online materials, or you can make up questions as part of an extended question and answer exchange.

Some methods might work better than others, and there are some important elements of pedagogy that you'll want to embed into your daily routines – aspects of formative assessment and questioning – but there are so many options, and you have the freedom to choose. If anything, the choice can be overwhelming, and, to begin with, you may start out with a solid borrowed framework that you embellish in your own way later on.

However, as many teachers will tell you, one of the aspects of the job that sustains them is the joy of closing the door and having a space where they can create whatever they want to with their students. As I always say: you don't need permission to be great!

Going off piste and being agile

Agility is the word I use to describe a key characteristic of a great teacher. It's all about the ability to adapt, to change course, to respond, to deal with multiple simultaneous demands, to keep

up with all the individual students' learning needs, to be spontaneous and flexible and to think on your feet; 'thinking on your feet' is a hugely important teacher skill.

I think it is safe to say that many really good lessons don't go according to plan. Why? Because, in truth, the plan is usually highly skeletal: it is just a rough outline of where to start and where the lesson will be going in general, but the details depend on what happens next at each stage. In an environment where I am challenging my students at a high level and trying hard to tease out their individual weak spots, I'm never exactly sure how students will respond or what questions they might ask. But, as an agile teacher, I'm ready for anything.

Sometimes, agility is needed to rescue a bad situation, like a goalkeeper pouncing, but, mostly, agility is about seeking out the most engaging, most challenging path to keep the flow of learning going . . . like an off piste skier. This is the part of being a teacher that I love the most. At a basic level, a routine, probing question and answer session is a great test of agility. This is the pedagogical equivalent of sparring. Great teachers love it, taking students' statements and questions and then returning more probing responses. With whole-class response methods, the challenge is greater, and so are the rewards.

An agile teacher will take any opportunity to make connections to current developments, scrapping the planned lesson if necessary. Venus is transiting the sun, the Higgs boson has been discovered, Richard III has been found and verified with carbon dating, there has been a tsunami: all these things are a reason to go right off at a tangent and bring learning into the real world. In fact, when these things happen, it is unforgivable not to.

Students and teachers find great joy in the kind of spontaneity that allows anyone in the room to express their puzzlement, their curiosity or their sheer love of the subject at any given time. Recent diversions in my lessons have led us to consider the James May 'milk first' tea-making theory based on temperature gradient and specific heat capacity, how a bullet-proof vest works (following the

input of a materials enthusiast in my A level class) and what might happen in terms of g-force if we could fly through the sun. Is it on the syllabus? Not exactly . . . but who cares?

Inspiring awe

Take a look at the image in Figure 1.1. It is the Hubble Ultra-Deep Field, photographed over several days in 2003–4. As explained by Professor Brian Cox, in this patch of sky, imagined on a scale the size of a thumbnail placed 75 feet away, there are over 10,000

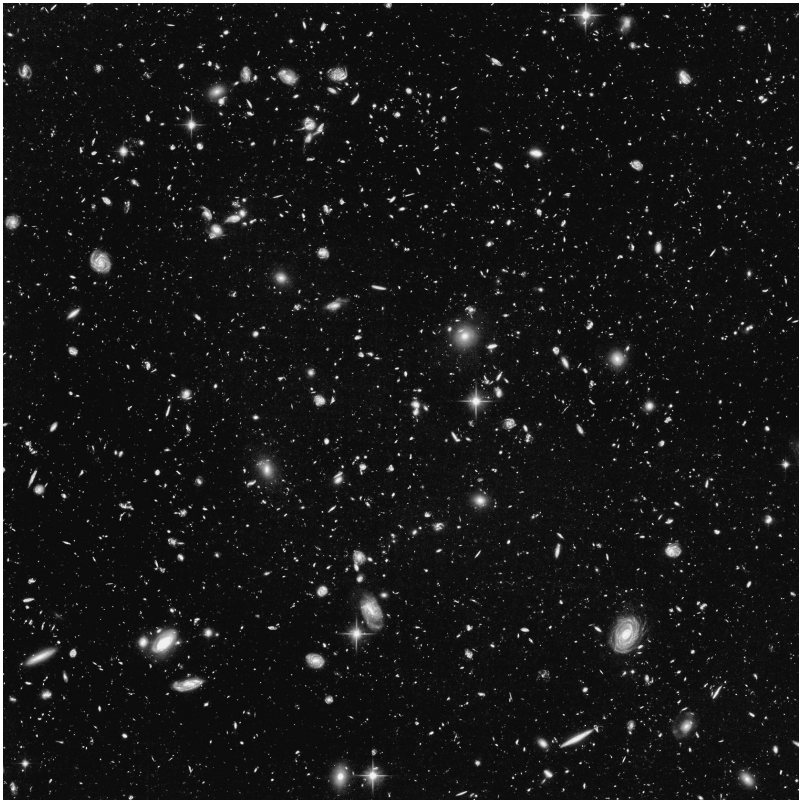

Figure 1.1 The Hubble Ultra-Deep Field
Source: Image Asset Management Ltd/Alamy

objects, invisible to the naked eye. Each object is not a star but a galaxy, each with hundreds of millions of stars.

The light from some of the objects has been travelling towards us almost since the beginning of time. So, looking at the image is like looking back into time, as well as into the enormity of space. For me, this is 'awesome' in the truest sense. It fills me with *awe*.

What does this mean exactly?

- It provokes an emotional response – it is beautiful, thrilling, magnificent.
- It forces me to rethink some fundamental conceptual ideas, to update my mental model.
- It creates a sense of scale that makes me look on my small world with a new perspective.
- It raises lots of questions and makes me curious to know even more.
- It is impressive as a human discovery, a human achievement.

This is *awe* . . . often experienced alongside its counterpart *wonder*. One of the joys of teaching science is being able to step back from time to time to contemplate the subject in hand, instilling a sense of awe. This is how the seeds of a deep-rooted love of learning are sown. We're not just learning this stuff because we have to, or because it is useful. We are learning it because it is just so fabulously, fascinatingly awe-inspiring. There is no greater motivation to learn than this.

Clearly, in a five-period day, with exams to prepare for and a pile of marking to look forward to, you may feel your inclination to inspire awe may be on the low side. But who else is going to do this if we don't?

In fact, we should aim to make it our default mode, our natural disposition, to seize every possible opportunity to fire our students' imaginations and to stoke their passions. This is as important to a school's contribution to social, moral, spiritual and cultural education as any number of assemblies. Is it unrealistic to think of

inspiring awe as a habit for any teacher? I don't think so – and, as science teachers, we certainly have plenty of material.

I naturally feel that most of our subject is awe-inspiring. Playing with a pair of magnets is a wonderful thing . . . just sensing that invisible, mysterious force. Seeing a simple current-carrying wire moving in between a pair of magnets . . . well that is extraordinary. Imagine Faraday's surprise and delight. The inner flower garden revealed by cutting open a fig – and the evolutionary story behind it – or, in chemistry, handling rocks that are millions of years in the making . . . it is all awe-inspiring, if we just take the trouble to create that moment of wonder in our lessons.

For me, and I hope for you too, this isn't superficial stuff. Inspiring awe is a core function for teachers: it's what we should be doing. We need to take every opportunity we can to communicate our own feeling that life is full of wondrous things that are there to be studied, discovered and enjoyed.

Relationships with students

Later on we will deal with the nuts and bolts of behaviour management, but, at a fairly basic level, your capacity to enjoy being a teacher will depend to a very large extent on how much joy you take from being around teenagers. Establishing relationships can be hard work; it can be emotional and, occasionally, very personal and painful, especially with a new class, when you're still on a steep learning curve. However, it is hard to imagine enjoying teaching if you don't enjoy the process of forming these relationships.

If this already sounds daunting, don't worry. It doesn't have to be 'up close and personal'. You don't have to be anything more than a professional person doing a serious job, and schools have all manner of support systems to fall back on when you need them. It takes time to develop the confidence you need to be at ease with any class and the maturity or experience to be thick-skinned enough not to be battered by every teenage mood swing that takes the shape

of a jibe in your direction. However, being around young people needs to be something you enjoy, once you've got things working the way you want them to.

When teachers look back on their work, they rarely talk about the great lesson they taught on osmosis in plant cells, or the superb scheme of work they wrote on hydrocarbons. Much more often they talk about the students they taught: the ones who made them laugh and cry; the ones who blew them away with their ideas or made a connection with them through their humour, their kindness or their dedication. Ultimately, we are not just teachers of science, we are teachers of students; the teaching and learning of science create the context for the relationships we forge. It is better to enjoy this as much as possible, as hard as it can be, because most of the time this is what makes the job worth doing.

Achievement is its own reward

In truth, there is something even better than the relationships. Joyful as it may be, forming relationships is actually a by-product of the process that is our core purpose: teaching science and creating the conditions for our students to learn and to achieve. You may teach students where your relationship has been fraught with tribulations and confrontations; you may teach students where every lesson was a giant love-in. Either way, the greatest rewards of all come when those students show you that they've got it, they've made a leap forward, the penny has dropped . . . the light bulb has gone on. Dah-da! Finally, Eureka!

When this happens, you don't need to give prizes: no stickers, stamps or house points. The joy that students experience – and that you feel in parallel, as the person who got them there – is greater than any token or reward. Achievement really is its own reward. It is also, by far, the greatest joy of teaching. All the hard work, all the sweat, the hours of preparation, the time spent giving carefully considered feedback, the inspiration and perseverance in the face

of the odds, the ups and downs of forming those relationships . . . all of that is paid off handsomely when students achieve, when they reach the far-away goals that you set them at the beginning. It's pure joy.

This can happen in small moments in a lesson – lots of micro-steps of progress towards a bigger goal. A student's smile as they give a great answer or hand in a great piece of work, the beaming pride a student shows when you praise them for doing something impressive that they had struggled over – these are the lovely moments that make your day and theirs and make it all worthwhile. It can also happen in a big way on exam results days – the elation of securing achievement: there is nothing like it.

As we go through the rest of this book, the theme of 'joy' will resurface. Most of the chapters are very practical, grounded in the reality of daily school life, but hopefully, you will engage with the ideas with a certain spirit that gives you more than just professional satisfaction. Teaching great science lessons is not just our professional responsibility; it is the most rewarding job I can think of. Teaching great lessons is a joy and a great, great privilege. So, let's get started . . .

TALKING POINTS

1 What is it about being a science teacher that you are most excited by or daunted by?
2 Which areas of science do you feel you need to explore much further to give you real confidence in the classroom?
3 Which ideas or phenomena in science are the ones you're really looking forward to sharing with the students in your classes?

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