HOW TO TEACH

Respiration is not breathing!

Secondary Science

CATRIN GREEN

EDITED BY PHIL BEADLE

HOW TO TEACH

Respiration is not breathing!

Secondary Science

CATRIN GREEN

EDITED BY PHIL BEADLE

Independent Thinking Press

First published by

Independent Thinking Press
Crown Buildings, Bancyfelin, Carmarthen, Wales, SA33 5ND, UK
www.independentthinkingpress.com

Independent Thinking Press is an imprint of Crown House Publishing Ltd.

First published 2016.

Edited by Phil Beadle

British Library Cataloguing-in-Publication Data
A catalogue entry for this book is available
from the British Library.

Print ISBN 978-1-78135-241-0
Mobi ISBN 978-1-78135-258-8
ePub ISBN 978-1-78135-259-5
ePDF ISBN 978-1-78135-260-1

Printed and bound in the UK by
Bell & Bain Ltd, Thornliebank, Glasgow

FOREWORD BY PHIL BEADLE

'Open your books at page 34. Do exercises 1 through to 17 and shut up while you're doing them!'

I've sat in on some quite poor science lessons in my time (two in a row, in fact, where one of the key words was 'bucket'). The 'not really trying very hard' version of these lessons always seemed to be orientated around a stained textbook. The kids were guided through a reasonable enough practical activity but were *always* forced to follow this up with a series of drab comprehension questions that the students answered entirely perfunctorily, all the time studiously ignoring the teacher's vain and frustrated wish that they write in full sentences. We didn't learn much. But the time passed. And we were, all of us, one day nearer the day we got out of this dump.

It was a shame that this brilliant subject was marginalised as the blind, impotent witch in the triumvirate of important things to know (maths, English and the other one). I remember thinking a decade ago that it could be so much more than it was at that time.

Enter Teach First. Enter Catrin Green.

The first time I sat in a science lesson and thought, 'Oh, *this* is how it should be done,' was in a knackered lab in an academy in the outer reaches of Croydon. Here, a young woman, the author of this book, was taking risks, expecting the kids to understand difficult things, playing with the form. It was relatively early on in her first term as a teacher and she was already really, really good. So good, in fact, that they offered her the head of science post before the end of the second term. (I believe she said no as she wanted to focus on being as good a teacher as she could be.)

But it was not just the lesson, profoundly impressive as it was, or the kids' achievement and enjoyment, which was tangible, that impressed. It was in the feedback afterwards, in which Catrin, fizzing with intelligence, started questioning some of the Ofsted tropes and some of the thoughtless givens of 'fashionable' pedagogy at the time. I recall thinking that if Catrin Green was in any way representative of the kind of teacher Teach First were bringing into the profession, then I would have to put my cynicism about it away.

Science teaching has, I feel, improved a lot since I spent much of my life sitting at the back of other people's lessons ticking and crossing silly boxes. Things move on. And Catrin is no longer a talented ingénue sparking with potential. The book you have in your hands is written by a seasoned and talented teacher with nearly 10 years' experience of getting kids in Croydon to learn science, to love science and to love learning science. There will be bits that you disagree with, and there might be points at which you throw the book across the room (Catrin's approach is – dare I say – quite 'progressive' at points); but what you have here are the thoughts and ideas of an excellent practitioner who always finds a better way of doing things than, 'Open your books at page 34. Do exercises 1 through to 17 and …'

CONTENTS

Chapter 1

THE IMPORTANCE OF THE BIG PICTURE

'BUT WHAT HAVE PARTICLES GOT TO DO WITH REAL LIFE?!'

> The science curriculum can appear as a 'catalogue' of discrete ideas, lacking coherence or relevance. There is an over-emphasis on content which is often taught in isolation from the kinds of contexts which would provide essential relevance and meaning.
>
> Robin Millar and Jonathan Osborne[1]

To engage students in learning we provide them with a peg on which to hook their new learning – usually background knowledge from day-to-day life, from the previous lesson or from a prior topic. What a student already knows about a subject has a much greater impact on achievement than both the interests of the student and the skill of the teacher,[2] and whilst it is not possible for a teacher to fully influence a student's background knowledge, one of the most important factors in its acquisition in the first place is the

1 R. Millar and J. F. Osborne, *Beyond 2000: Science Education for the Future* (London: King's College London, 1998), p. 3.

2 See K. Halikari, N. Katajavuori and S. Lindblom-Ylänne, 'The Relevance of Prior Knowledge in Learning and Instructional Design', *American Journal of Pharmaceutical Education* 42(7) (2008): 712–720. Daniel T. Willingham's *Why Don't Students Like School? A Cognitive Scientist Answers Questions About How the Mind Works and What It Means for the Classroom* (San Francisco, CA: Jossey-Bass, 2010) provides an easy-to-read and interesting overview of the impact of background knowledge on learners.

number of opportunities that we provide students with to understand the content and how we find ways of linking the science to real life.

TELLING THE STORY

Although we would probably all agree that science is an awe inspiring subject, scientists (science teachers included) need to become much better at communicating this awe to those who are not yet scientists. All students are curious – no matter how apathetic they may initially appear – and the trick is to find the hook with which to engage them. One of the best ways of doing this can be to bring the science to life with a story. This isn't a new idea, of course, as linking knowledge to a story and creating a narrative has long been a key way of developing knowledge and learning. Not only does a story allow students to interconnect ideas they might already have about science, but it also allows them to place their knowledge in a wider context.

Storytelling is perceived as central to learning in English or history lessons, and whilst it might seem slightly more difficult (or even counterintuitive) in science, it's actually pretty easy. Think about any science documentary you've ever seen on TV – this is always the method they use to introduce new topics. Not only is it engaging but it also provides an anchor for the new knowledge. Additionally, provided they are not too bogged down in unnecessary detail, stories are easy to remember: psychologists believe they are treated differently in the memory to any other kind of material.[3] Students often struggle with the fine detail, so if we launch straight into the nitty-gritty of any topic they will quickly ask, 'Why are we doing/learning this?' Showing them the bigger picture and leading them towards being interested

3 This article provides a good review of the research: D. T. Willingham, 'Ask the Cognitive Scientist', *American Educator* (summer 2004). Available at: http://www.aft.org/periodical/american-educator/summer-2004/ask-cognitive-scientist.

is a good start point. Then the students will start to ask questions: 'Yes, but how?' or 'What next?' You might wonder what this has to do with learning, but studies have shown that teaching students the cognitive strategy of asking questions results in significant gains in comprehension.[4] A random list of 10 numbers with no connections is difficult to learn, but link the numbers to things in your own life and suddenly it's not quite so hard after all.[5] Therefore, a student who is simply taught what electrons, protons and neutrons are (without any surrounding context) may struggle to understand their relevance, but a student who has been taught about how our understanding of the basic building blocks of life has evolved has a connection between the different ideas and gets why they are studying it and how it is relevant to them.

HOW CAN I GET IT RIGHT FROM THE START?

A simple idea to start introducing stories into your teaching is to think pretty hard about the title of your lesson. So, a lesson that might otherwise be called 'The atom', could be 'What are we really made of?' or 'What is the smallest thing we know about?' Bill Bryson's *A Short History of Nearly Everything* is a fantastic place to start if you need some inspiration for stories.[6]

---

4 See B. Rosenshine, C. Meister and S. Chapman, 'Teaching Students to Generate Questions: A Review of the Intervention Studies', *Review of Educational Research* 66 (1996): 181–221.

5 Read Ed Cooke's *Remember, Remember: Learn the Stuff You Thought You Never Could* (London: Viking, 2008) for ways to memorise lots (like the whole of the periodic table – it would really impress your students. Disclaimer: I cannot do this!).

6 B. Bryson, *A Short History of Nearly Everything* (London: Black Swan, 2003).

Choose the most interesting sections of the story, litter it with some little side facts that spark interest and employ photos and diagrams to illustrate.[7]

Here are some examples of how to storify science for students.

Biology: 'Are we really 97% the same as chimpanzees?'

Evolution can be a tricky topic to teach, mainly because students walk into your classroom with existing ideas and misconceptions about what it is. Starting with evolution as a story is a really good way in: I begin this subject with the story of Darwin during his time at Cambridge. I tell them that he was so curious by nature that he used to eat owls and hawks, and that one of the results of this curiosity was his trip to the Galapagos Islands. At this point, it's important to note that a story doesn't have to be told just by you but can be investigated through group work and projects. For instance, allocate each group of students a different segment of Darwin's story: one group could be given information on his journey, another what he discovered on Galapagos with regards to finches, another how he tried to convince the public and so on. Get them to present these in date order.

7 Check out this article by Martin Robinson for tips on how to tell a story like a pro: 'Classroom Practice: Don't Just Talk at Them, Spin a Ripping Yarn', *TES* (14 February 2014). Available at: https://www.tes.com/article.aspx?storyCode=6403314.

Biology: 'Why do I have to have that injection?'

For an account of Edward Jenner, who pioneered the smallpox vaccine, start with a picture of someone suffering from the later stages of smallpox (warn the students first!) and it is likely you will inspire the awe that you are seeking. Continue by painting the story of how deadly smallpox was (some estimates suggest that between 300–500 million people have died of the disease – a higher fatality rate than both world wars combined[8]). Next – and this is a great opportunity to show how medical advances can come from thinking outside of the box – explain how Jenner went from hearing that milkmaids who had contracted cowpox almost never contracted smallpox and that this led him to try inoculating subjects with cowpox before exposing them to smallpox to test his hypothesis. Continue this into the present day by observing that smallpox could be used in bio-terrorism and why it is essential that students do not listen to any of the scare stories regarding vaccinations (after all, your students will be parents one day).

Biology: 'Why do 100,000 people die of cholera every year but I've never heard of it?'

John Snow's (no, not the guy from *Game of Thrones*) discovery of cholera in 1849 was incredible given that he couldn't see bacteria. Cholera was originally thought to be airborne until Snow looked into a particular case in Soho, London. Show students the same maps that he looked at of where people had been infected and prompt them with some questions. What patterns can they see? Would this pattern support the theory that the infection was

8 D. Perlin and A. Cohen, *The Complete Idiot's Guide to Dangerous Diseases and Epidemics* (Indianapolis, IN: Alpha, 2002).

airborne? Why/why not? How else could it have been spread (it's best if students already have a bit of background on communicable diseases first)? Once students have suggested that it could be spread through water, show them a second map with locations of the various water wells and see if they can identify the one on Broad (now Broadwick) Street as the source of the infection. Follow this up with similar exercises into recent epidemics (e.g. the Zika virus or Ebola).

Biology: 'How can babies have three parents?'

This is a great way to introduce a Key Stage 4 genetics topic. Teach the role of the mitochondria through the process and ethics of allowing three person babies.[9] Start the lesson by providing pairs of students with any news clippings you can find about this type of a story (differentiate your material here – some pairs will be able to understand *The Guardian* or *The New Scientist*; others might better engage with a clip from the BBC website). Next, split the pairs so that one student has to oppose the idea whilst the other one agrees. Give them time to prepare before getting them to debate in a 'debating ring' (see Chapter 3).

---

9 Mitochondria are organelles found in eukaryotic cells which contain a small amount of DNA which are responsible for respiration. (This is due to their interesting history: they so closely resemble bacteria that one theory suggests they were formed through the symbiosis of a eukaryotic and prokaryotic cell, hence they contain the DNA which originated from the bacteria.) Mitochondria are normally inherited from the mother (so you are genetically ever so slightly more similar to your mother than your father), but if the mother carries a genetic disease in her mitochondrial DNA, it is possible to have this DNA donated by a third party through a modified version of in vitro fertilisation (IVF). This results in a fertilised egg cell formed from the DNA of three 'parents'.

Biology: 'Why am I like my parents?'

The impact that the discovery of DNA has had on our understanding of inheritance is best started with a clip from *Jurassic Park* (the original one, obviously – there's nothing wrong with showing your age). The film can be used to explain how the park brought dinosaurs back from extinction. Use a think–pair–share activity (see Chapter 2) to ask students if they think this would ever be possible and then get them to brainstorm what they already know about DNA. This is important because aspects of this topic are part of everyday life, so you shouldn't assume the students have little background knowledge. A good activity here is to produce a student timeline at the front of the classroom. Start with a student Charles Darwin at one end of the room (get them to make a Darwin sign to hold up) and ask them to explain what Darwin told us about evolution. The next student along from Darwin should act as Gregor Mendel and should explain his pea experiments (have some YouTube clips up your sleeve to remind the students if they are rusty). Now you need to skip to the 1950s, so leave a largish gap and choose four students to be the pioneers of DNA, using them to play the roles of Rosalind Franklin, Maurice Wilkins, James Watson and Francis Crick. (As an aside, the lack of a Nobel prize for Franklin is a great discussion point to engage the girls.) It's worth finishing with a task regarding environment and genetics which will allow the students to conclude just how much (unfortunately) they are like their parents.

Chemistry: 'How have we got such a range of materials?'

Tell the story of the turning points in chemistry, starting with Aristotle believing that the only four elements were fire, earth, air and water through to the modern day and new wonder materials such as graphene. This is a good way to start teaching elements and compounds before introducing students to the periodic table. Hand out some Lego and ask the students to make simple structures (e.g. house, truck, skyscraper). Then ask them why it is possible that a number of different objects can be made from the same building blocks. Use this analogy to illustrate the difference between elements and compounds (and for those who grasp it quickly, molecules). Then you can finish the lesson by looking into how close we are getting to some of the technologies in *Iron Man*.

Chemistry: 'Why is there always a periodic table in my homework planner?'

This is the story of Dmitri Ivanovich Mendeleev. As the students enter the room, ask them to find the periodic table in their planner and pose the title of the lesson to them. Use a snowball activity to find out what students think (see Chapter 2). Provide them with element cards identifying the key properties (most schools will have a set of these or they can easily be found on the Internet); if you can manage it, a sample of some of the elements is useful as well. Ask the students in pairs to sort them in any way they wish, as long as they can justify why they have grouped them together (e.g. they all have low melting points). Tell the students that the activity they've just completed is the essence of what Mendeleev did to come up with the periodic table and, at this point, go through a timeline activity (like the Darwin example above or get the students to use sequencing cards). For the more able, pose some challenging questions to help them think further (e.g. Why is hydrogen so lonely in the periodic table? Why are some periods cast out on their own?). Once the serious work is complete there are a lot of sing-a-long videos about the periodic table that can be found on YouTube that no student is ever too old or too cool for. Finish the lesson by asking the students the same starting question and perhaps get them to provide an exit pass explaining what they now think the answer is.[10]

Chemistry: 'What will my life be like in 2050?'

This is an opportunity to talk about global warming from the Industrial Revolution onwards. Begin the lesson with some photos on the students' desks to act as a stimulus for discussion (e.g. driverless cars, mock-ups of London flooded by rising sea levels, a nuclear power station, robots) and initially ask them to answer the question in the lesson title. Get them to think about what will have the biggest impact on their lives in 2050 (hopefully the pictures will help with the answers) and steer them towards the devastating impact that rising global temperatures might have on their lives. (The trailer for *An Inconvenient Truth* (2006) is a powerful start here.) Put students into groups and give each group a different stage of the timeline: the Industrial Revolution, the rise of nuclear power, new green technologies and possible future technologies. Give them time to research their area and prepare for feeding back to the class. Get the students to present their findings in date order. Complete the lesson(s) by asking the students to reflect on what may happen by 2050 if some new technologies to produce energy are not up and running in time.

10 An exit pass is an elaborate name for a sticky note on which the students write their name and answer, which they must give to you before they leave the classroom – it works best before break and lunch!

Chemistry: 'Why do people hate chemicals?'

People tend to try to avoid chemicals, whether in cleaning products or hair dyes, because they fear the repercussions (despite the fact that everything in the world is actually made from chemicals). We can start dispelling this myth when starting the topic of compounds by looking at how this thinking came about – from the use of lead based products to the assumed danger of E numbers. Start by asking the students if chemicals are safe and encourage them to give some examples of 'unsafe' chemicals (you'll get an odd selection here from CFCs and oil to arsenic and kryptonite!). Next, go through the definition of what a chemical is and ask them to re-evaluate their initial answers. Give groups of students different examples of chemicals that are perceived to be dangerous (or can be if used in the wrong way).

Some ideas of stories you might want to give your groups include:

- Images of Elizabeth I and old adverts for lead based make-up.
- Newspaper clippings on the effect of E102 and E110 on children.
- The impact of thalidomide in the 1950s.
- News articles on the presence of arsenic in many day-to-day foods (e.g. rice, cereals, fruit). Are these foods dangerous?
- Should we have fluoride added to our water? Give details on the debate.
- A newspaper article on the terrifying use of a chemical in our chips/carpet (whatever's been in the news recently – e.g. acrylamide in baby food).
- Provide students with everyday objects that contain 'chemicals' (e.g. shampoo, window cleaner, paracetamol, plastic lunch box). Get them to research any negatives about them.

So, you have a passion for your subject and you've been given the opportunity to work with some of the funniest, most surprising and exceptional students. But ...

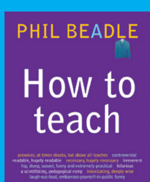
... teaching science isn't always a walk in the park. How do you get students to think scientifically, remember all of those key words and not get acid in their eyes?

Secondary Science is chock-full of workable ideas for the secondary science classroom. Ditch the stereotypical view of a science teacher: white coat, slides, teaching the limewater test to the same class for the fifth year in a row, and discover new and creative ways to inspire the next generation to use science.

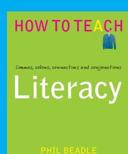
Catrin Green has always loved science and loved sharing that passion. She has been a head of science and now, as a deputy head, works in a school where the science department is at the forefront of teaching and learning. She is a Teach First Ambassador and runs science CPD as part of an academy chain.

@CatrinGreen

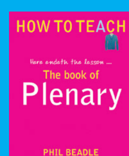
A proud member of Phil Beadle's How To Teach series



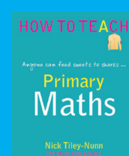
ISBN: 9781845903930



ISBN: 9781781351284



ISBN: 9781781350539



ISBN: 9781781351352

www.independentthinkingpress.com

ISBN: 978-178135241-0

9 781781 352410

Education