That’s funny…

Introduction

Whenever I’m asked to explain or describe my approach to practical work, I always feel rather self-conscious. I wonder if I’m just re-inventing the wheel; I worry that I’m not actually doing anything very clever or very original, because, well, it just doesn’t seem very clever or original. It always strikes me as blindingly obvious that this is how to do it, that this is the way science should be taught.

Yet it hasn’t always been obvious to me, and my experience of running training courses for biology teachers from all over the country is that, actually, no, this is not how it is usually done. Instead, practical work, if done at all, is largely used as a way of illustrating something that has already been learned, or, worse, used an optional bit of fun at the end of a lesson. It is so easy to fall into the trap of believing that teaching is about telling students *everything*. Good teachers, most teachers, will enliven this process with games and songs and model-making and formulaic practical work, and that’s fine as far as it goes. Lessons should be varied and unpredictable and enjoyable. But, and this is my key point, *it’s not science*.

I’ve lost count of the number of people, including my wife, who said they didn’t enjoy Biology at school because they couldn’t see the point of the practicals. After all, what’s the point in doing something when you know what’s going to happen? Or what’s supposed to happen? Science is about the excitement of discovery. I try, as far as possible, to replicate this process within my lessons.

Kidney Dissection

The GCSE kidney is a good, simple example of where I’m coming from. Many teachers just don’t bother with a kidney dissection. After all, it’s not a very challenging or interesting activity, it takes the students all of 5 minutes to do and there’s a profound sense of anti-climax. Is that it? The best reaction you’re likely to get is, “oh, it looks just like the picture in the textbook”. This is because the whole topic has been done the wrong way round. If you start by telling them everything and showing them everything and explaining everything, there’s nothing left to explore.

But turn it on its head, and everything is transformed. I *start* this topic with the kidney dissection. I tell them what plane to cut it in and once they’ve done this, to make a large (A4 sized) drawing of what they can see. The work they will produce is stunning – beautifully observed, detailed drawings of the different regions of the kidney. I let them add colour. I suggest they drop hydrogen peroxide over the cut surface and rub off the frothy residue with a gloved finger to reveal the thousands of parallel lines radiating out from the hub.

It’s a marvellous process of discovery – they’ve never seen the insides of a kidney before, never looked closely and in detail, nor attempted to actually draw it. They’ll happily spend half an hour doing this and take enormous pride in the finished work. In doing so, they remember the gross structure far better and there’s now a framework to fit the detail into – kidneys are an organ of excretion, so somehow this structure, this arrangement of tissues, those white striations, are vital for that function. Let’s find out how!

I do the same with nearly all microscope work. Apart from telling them what the specimen is, they don't know what to expect when they look down the lens. Year 7s drawing cork tissue or onion cells or spermatogenesis in testes, Year 9s drawing cross-sections of the small intestine, Year 11s finding and drawing white blood cells from blood smears. It improves all kinds of skills – microscopy, observation, drawing – but for me it is the mystery, the equivalent of unwrapping a Xmas present, that makes it so exciting and motivational.

Enzymes

Introducing Year 9s to Enzymes can be done in exactly the same way. Rather than starting with, "Today we're going to learn all about enzymes! Enzymes are biological catalysts. They work a bit like a lock and key….", I get them to carry out a series of experiments* that just ask them to describe what happens and make a few simple deductions. By the end of the lesson, they've seen that a variety of different cells share a curious ability to speed up the breakdown of hydrogen peroxide. They've also seen that boiling the cells removes their ability to do this. And they've seen that extremes of pH have a similar effect. They've done this all by themselves and now want to know what on earth is going on. Lock and key theory and the basics of denaturing fall readily into their receptive brains.

Benedict's

What about Benedict's test for reducing sugars? I could explain what it is, show them how to do it, and get them to test a variety of different foods. Lots of colourful fun with Bunsen burners, but not very challenging, and not finding out anything new – after all, they could just look at the food label. So this year, as part of the Cells topic with Year 7, I asked the students to demonstrate that apple juice contains sugar. All they had was a mysterious blue liquid (the name can come later), some sugar, some apple juice and some distilled water. It worked brilliantly. Initially, they were baffled, but also up for the challenge. Yet slowly, through trial and error, they discovered that heating apple juice with the blue liquid produce a lovely brick red colour. They then realised that they had to use other tests to eliminate the other possible explanations for this result. In other words, they designed a controlled experiment without ever being told about controls.

And so on…

The more I experiment with this kind of approach, the more seems possible. Year 9s can figure out the basics of diffusion for themselves. I just give them a big agar block stained with purple indicator and some 1M HCl. They can design their own experiments to work out a)the definition of diffusion, and b)how the rate of diffusion changes with concentration gradient, temperature and surface area/volume ratio. Sure, it needs a bit of structure and a bit of guidance**, but it's worth the effort. Alice, in Year 9, commented on her Subject Evaluation form, *"I learn so much better when I find things out for myself. Every teacher should teach like Dr Weeks."*

The "that's funny" approach is particularly important for topics like Photosynthesis that most students loathe with an almost visceral, reflex intensity. Yet it's a topic that has so many brilliant practical activities. I kick off in a fairly low key way, a week or so before I actually need to start teaching it, by just getting them to plant the seeds of some rapid cycling brassicas (given how much students hate learning about plants, it's amazing how much they enjoy planting them!). I don't make a big fuss about where the pots are put – some end up under the light bank, the rest just around the edge of the lab. When we finally get them back and compare them a few weeks later, the students are genuinely startled by the difference – the significance of *light* to plant *growth*, something they so often just can't get their heads around when they're just told, is vividly apparent, and is the perfect springboard into the topic. They actually *want* to know how it all works.

There are lots more excellent ideas for plant experiments on the SAPS website – one of my favourites is the leaf discs in light/dark/water/glucose solution experiment***. At A-level, students can use CO_2 probes to determine the effect of light intensity on the rate of carbon fixation by geranium levels. By plotting their own data, they end up with a perfect limiting factor graph, which they can set about researching and explaining. It's great – they end up teaching themselves.

Ownership of results, in other words having their own data to analyse, is another vitally important factor in student practical work (is there anything more depressingly boring than analysing somebody else's data?). My Year 13s breed fruit flies (sex linked eye colour cross is a good one). Not knowing what to expect, they are hugely motivated to not just count the phenotypes of the offspring, but also teach themselves the Chi2 test in order to compare the predicted ratios to their observed numbers.

This kind of learning through discovery, i.e. being scientists, needn't be limited to practical investigation. Year 10 students can "discover" the balanced chemical equation for aerobic respiration through creative use of Molymods. I draw an A-level glucose molecule on the board and get each pair of students to make it – a sort of advanced Lego biochemistry. I then give each pair of students 10 Molymod oxygen molecules (the 10 is important, as you will see). Now I ask them to completely oxidise the glucose molecule, converting it to water and carbon dioxide, using as many oxygens as they need. Then let them count it all up. One glucose has turned into six waters and six carbon dioxides…. But they've forgotten how many oxygens they used – never mind – how many are left over? Oh, right. We used six. They have effectively worked out the stoichiometry for themselves; and they never forget the formula as a result.

Measuring success

As a starting point, I would like all my students of whatever age, ability or aspiration to enjoy their Biology lessons and to ultimately fulfil their potential at whatever level they choose to take the subject. Georgia, in Year 9, probably won't choose Biology A-level, but she's clearly had a good year: *"Thank you for teaching me Biology this year! You, incredibly, made me understand the subject – yay! I have thoroughly enjoyed your lessons each week and I have found them engaging and exciting. You're the best teacher I've ever had."*

So not every student will go on to study Biology at university. But more of them should and I measure the success of the department not just in terms of A-level uptake and public exam success, but by how many students are sufficiently inspired to put Natural Sciences/Biological Sciences on their UCAS form. Since I took over the department 7 years ago, the numbers have risen from a mean of 3.2 (n = 9, range 1-5) to a mean of 9.17 (n=6, range = 7-12). Why? Well, Ellie, now studying Natural Sciences at Cambridge, wrote, *"thank you for everything you have done for me over the past 4 years. I've never had a teacher whose lessons have been so amazingly interesting, hilarious and inspiring. I've had a brilliant time and I'm really sad that it's all over. Every time I get to see (and do!) some* *really cool biology over the course of my career, I will always think back to how you helped to go out and do what I love so much."*

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