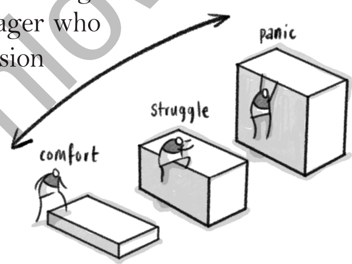
Contents

CHAPTER 1

Challenge

Challenge can be described as the provision of difficult work that causes students to think deeply and engage in healthy struggle. This can be problematic for all teachers but there are particular issues that make this especially difficult for science teachers. During any one lesson, science teachers will have up to thirty students in their laboratory, all of whom will have different prior knowledge of scientific ideas, different levels of understanding of the scientific ideas being explored and different scientific misconceptions. Alongside this, their level of interest in the subject will also vary widely, ranging from the super-keen science fanatic, who has always been fascinated by dinosaurs, the solar system and exciting chemical reactions, to the surly teenager who appears to have a complete aversion to the subject. It is our job to synthesise all of this information and then push each student just enough to keep them in the struggle zone.



Comfort zone	Struggle zone	Panic zone
Low challenge. Low stress. Limited thinking. Limited learning.	High challenge. Low stress. Thinking required. Effective learning.	Very high challenge. High stress. Cognitive overload. Limited learning.

Challenge is slightly different from the other five principles. While there are specific teaching strategies that can be employed to ensure that challenge is appropriate for all the students we teach, the principle is more about an approach to teaching. Challenge is a long-term venture and should run through everything we do as science teachers – like the lettering that runs through a stick of rock. It's about the culture that we create in our science laboratories and the expectations that we have of the students we teach. The objective is always to try to keep students in the struggle zone, as shown in the previous diagram. This requires students to be thinking hard enough to support learning, but not so much that they reach cognitive overload and slip into the panic zone, where learning will be limited. Similarly, the work should not be easy, resulting in students remaining in the comfort zone.

The best science teachers create this culture by getting to know the students they teach, taking a genuine interest in their progress, making them believe that they can achieve beyond their own expectations and then supporting them – through the other five principles – to meet these expectations. Their science laboratories are places of interest, warmth and safe challenge where students feel secure enough to push and challenge their own thinking.

So, let's explore some strategies that we can put in place to start growing this culture.

Challenge Strategies

1. Curriculum first

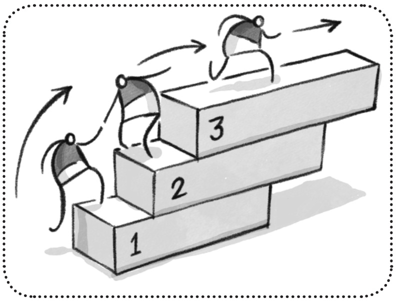
Our starting point as secondary science teachers should be a challenging and interesting curriculum. We should scale up our Years 7 to 9 curriculum to ensure that students are being exposed to challenging material – for example, rather than simply teaching students about particles in Year 7, why not teach them about subatomic particles and the arrangement of electrons in shells? Provided that we scaffold their learning carefully, most students will rise to the challenge and enjoy being exposed to these difficult ideas.

When asked to describe what he had been learning about in science, Jude, a Year 7 student at Durrington High School, responded:

> *We had a great science lesson today. Mr Canavan was telling us about subatomic particles. Electrons move around the outside of the atom in shells – shells are like lanes on a running track – the first shell holds two electrons, but then the others hold eight. They orbit the nucleus, which contains protons and neutrons. Protons have a positive charge and neutrons have a neutral charge. The electrons have a negative charge.*

This student response, while perhaps not perfect, simply wouldn't have been possible if the science department at the school hadn't reviewed their Years 7 to 9 curriculum and scaled up the content. The important point is that the students are being exposed to more demanding ideas. The challenge is then to do the same in Years 10 to 12. By exposing students to material that is just beyond the expected level of the curriculum specification, the hardest content they will be exposed to will make the hardest content they have to remember for the exam seem easier by comparison.

2. Talk like a scientist

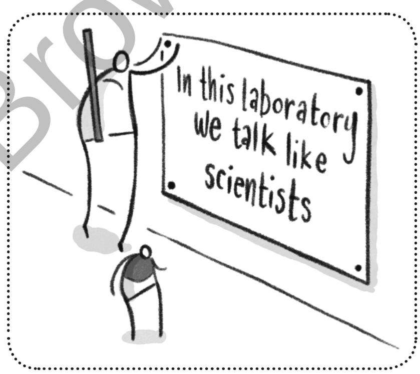


When thinking about vocabulary, we should consider the three different levels of words, as outlined by Dr Isabel Beck:[1]

- Tier 1 – high-frequency words, including objects and adjectives. These are rarely taught in school as they tend to be acquired preschool (e.g. book, chair).
- Tier 2 – cross curricular and often descriptive. Usually these can be explained using easier and more familiar words – for example, "fortunate" is a more mature way of describing being lucky. These are words that are useful across subjects and in various situations (e.g. variables, method, theory, structure, interpretation). Students are likely to encounter these words through exposure to written texts and are unlikely to come across them in day-to-day discussion.
- Tier 3 – low-frequency words. These are subject specific and are not encountered a great deal in everyday language; when they are, they tend to be particular to a subject (e.g. respiration, refraction, molecule). If students don't understand the meaning of these words, and so can't use them appropriately, their academic achievement will be limited.

1 Isabel L. Beck, Margaret G. McKeown and Linda Kucan, *Bringing Words to Life: Robust Vocabulary Instruction* (New York: Guilford Press, 2002).

Language has important implications for science teachers. First, we need to explicitly teach the subtle differences in meaning of a tier 2 word in a science context compared to its use elsewhere. For instance, the students' experience of "variable" would mean that something is or has been changing (e.g. "The weather has been highly variable this week"). But in science it has a more specific meaning. It is a factor in a science experiment that could change, but we either choose to keep the same measure or change it. Second, we need to expose them to tier 3 scientific vocabulary on a regular basis and repetitively. So rather than dumbing down our language (e.g. "The oil became more runny when it was heated"), we need to expose students to and teach them the correct meaning and use of scientific vocabulary (e.g. "As the oil was heated it had a lower viscosity, and so moved down the tile at a faster speed"). Having taught them tier 3 language, we then need to insist that they use it. Senior leader and education consultant Chris Moyse does this brilliantly by providing this poster for science teachers to put up on the walls of their laboratories:[2]



2 Chris Moyse, Talk Like … Resources (28 March 2016). Available at: https://chrismoyse.wordpress.com/2016/03/28/talk-like-resources/.

3. Surface then deep

John Hattie refers to the skill which means expert teachers know when to advance from surface learning to deep learning.[3] Surface learning is about knowing the key facts, whereas deep learning is about knowing how to relate, link and extend this knowledge. A common mistake that science teachers make is moving on to the deep learning before students have mastered the surface learning – the key knowledge that they need to master that topic. For example, before students can understand the idea of ionic bonding or covalent bonding (deep learning) they need to have a good understanding of atomic structure (surface learning). Atomic structure is the threshold concept. If they don't understand this, they cannot get to a profound understanding of ionic and covalent bonding. But simple descriptions of ionic or covalent bonding could also be viewed as surface learning because simply talking about the "sharing or transfer of electrons" does not really demonstrate deep learning. Deep learning would involve understanding bond breaking and bond making plus the energy changes involved. As science teachers we need to make sure students are clear on the surface learning before going deep, and that we are clear about what we expect of them in terms of deep learning. We can do this in a number of ways, such as hinge questions, quizzes or a simple question and answer session. It needs to be an essential part of our planning.

3 Hattie, The Science of Learning.

4. Think now

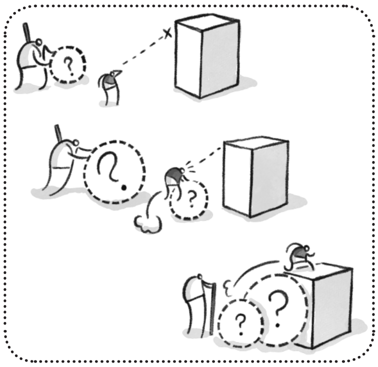
The anchor effect is one of the most robust findings in experimental psychology. In essence, it suggests that our perceptions are heavily influenced by the first piece of information we receive on a topic.[4] For example, if you see an piece of jewellery and an expert tells you it is worth $300, and you negotiate a price of $250, you will think you have a good deal based on the first price you were given. In reality it might only be worth $50, but you have anchored your expectations around $300. This has very significant implications for the science teacher. We need to ensure that the first thing students see and think about when they enter the science laboratory is challenging and will make them think. This will anchor in challenge from the start of the lesson, and as a consequence their perception of success from this point on will be based around this objective. Having a "think now" task ready at the start of the lesson can help to achieve this. This can take a variety of forms:

- A picture to promote thinking (e.g. a picture of different specialised cells with the students asked to describe and explain how the structure of each one helps it to do its job).
- A photo to promote thinking about a scientific issue (e.g. trees killed by acid rain, a parachutist descending to illustrate the forces acting on a falling object).
- A difficult question that will stimulate thinking.

As well as promoting thinking and anchoring in challenge from the beginning, "think now" tasks are also useful in terms of ensuring a calm and purposeful start to lessons.

4 Daniel Kahneman, *Thinking, Fast and Slow* [Kindle edn] (London: Allen Lane, 2011), loc. 1998–2180.

5. Think hard



Consider the following questions that might be asked in a science lesson:

Why do we need carbohydrates and fats in our diet?

Most students would be able to recall that these two are important because they release energy.

Why do we need protein in our diet?

Again – no problem. Most students would know that this is for growth and repair. Then there is this question:

What is the link between carbohydrates and protein in our diet?

A number of students will struggle with this. They will find it hard to link the two ideas – that is, the energy released from carbohydrates is used to build proteins for growth and repair. So, going back to Hattie, their surface learning is secure but their deep learning isn't.

What can we do about this? Plan into our lessons a "think hard" question. This is a question (or series of questions) that will require the students to think hard and make connections between ideas. More importantly, we should make it explicit that it's a "think hard" question by telling the students so or, for example, using a distinctive graphic on the PowerPoint slide along with the question.

Clearly, this is a pre-planned question that we should expect the students to respond to in writing. This is different from the verbal questioning that takes place all of the time in lessons, which can't be planned for as it is usually framed around student responses (and we all know how unpredictable they can be!). Obviously, by doing more structured "think hard" questions like this more frequently, the requirement for them to be thinking deeply should help their learning. It will also provide our brightest students with a regular diet of challenging questions.

It's important to make these questions explicit for a number of reasons:

- By telling students it's hard, we are also telling them that it's going to be okay to struggle with this – in fact, we'll struggle with it together and it will be alright!
- Focusing on these "think hard" questions in our planning will make us think about the surface learning that will need to be embedded in order for the students to answer them, so we should be more aware of the surface to deep tipping point.
- Experiencing success with these challenging questions will support their intrinsic motivation. Students don't just get motivated because we tell them to; they are motivated when they experience success and want to build on this further.