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Reflections on Teaching and Learning Physics

The strange case of the balloon that stuck to an uncharged wall

"success is all about making the right connections"
(Tierney, 2006)

There is well-known 'party trick' that involves rubbing an inflated balloon on a jumper, and then pressing it against a wall. The balloon remains attached to the wall, and may do so for some time. Most people have seen this 'trick', although few could probably explain the physics involved. Secondary level students would probably recognise this as an example of 'charging by friction', and know that some insulators charged in this way can attract dry hair or small pieces of paper.

However, the charging of the balloon is clearly only part of the story, as nothing needs to be done to the wall for there to be enough attraction between the charged balloon and the apparently uncharged wall to allow the balloon to become 'stuck'. A charged object is being attracted to a neutral one.

I have asked sixth-form students to suggest why the balloon can be attached to the wall. This is not something that is generally taught, and unsurprisingly the students tend not to be able to offer an acceptable explanation. In some cases the students are clearly surprised and frustrated that they had never thought about the physics behind this familiar phenomenon!

Alice had completed a year of her (A level) college course when I asked her about a number of different phenomena. Alice was familiar with the balloon 'trick', and explained this in terms of "some sort of interaction with the electrons and things, and you have a positive and negative charge, which allows a glue effect, attraction between two areas, one of positive and one of negative."

So for Alice this was a simple case of electrostatic attraction between oppositely charged objects. She explained that the balloon would be charged as "when you're rubbing the balloon, you're transferring electrons either onto it or away from it". The balloon would stick to the wall "because you've got opposite charges, you've got the, say, negatively charged balloon, and then your positively charged wall". Alice had to acknowledge that the wall "hasn't had anything done to it as such", and so it was not clear why it should be charged. Here, however, Alice had a creative proposal.

Alice suggested that "maybe *in comparison to* your very negatively charged balloon, it's still likely to attract." Alice agreed that she was suggesting that "it's relative", that because *the neutral object is positive by comparison with the negative object*, they're effectively both charged. Alice was technically wrong: neutral objects are not attracted to charged objects on the basis of being more positively charged *than if* they been negative charged!

Making the wrong connection

Teaching involves making the unfamiliar familiar. One way we do this is by offering direct experience of novel phenomena. However, more often our job is to build up new understandings based on the learners' existing experiences and knowledge. This means that a lot of teaching involves using potent metaphor, or drawing analogies to make new material familiar by presenting it in terms of comparisons with existing robust knowledge and understanding (Muldoon, 2007).

This of course just builds upon the natural cognitive processes that we all use spontaneously – we come to understand new ideas and information by interpreting it through our existing 'conceptual frameworks'. But this is a fallible process as it might well make 'connections' that are misleading.

When using teaching analogies we have to carefully steer learners to the intended comparisons (Taber, 2001). However, when students make spontaneous connections, there may be no teacher on hand to advise on the suitability of the comparison. An unhelpful comparison can become a well-established aspect of the learner's thinking before the teacher has an opportunity to challenge it.

Students' learning difficulties in science can be categorised into a number of common 'causes' and one of these when the student draws an unhelpful association. Alice's suggestion might be interpreted this way as *an electrical potential of +50V volts is negative* compared to a potential of +75V, and would provide the potential difference to drive current. Assuming a parallel effect with charge might seem very reasonable.

So Alice's suggestion is certainly credit-worthy as an idea. However it does not match a physically acceptable explanation. The wall is neutral, but contains negative charges that are not entirely fixed, so that the charge distribution can be influenced by an applied electric field (say, from an approaching charged balloon), that leads to polarisation. That in turn produces a difference in the net forces between (a) balloon and 'wall-protons', and (b) balloon and 'wall-electrons', so attracting the balloon towards the wall until an equilibrium state is reached. We would probably be impressed by the student who developed such an explanation spontaneously.

Missing the right connection

One of the other topics I asked Alice about was how solid materials were held together. Alice explained about van der Waals' forces, where there was "an electron cloud surrounding each molecule, and as these clouds don't stay in one fixed place, there's always going to be momentary areas of dipole. And that's where you get your positive and negatives attracting each other again."

Just as one of the common causes of learning difficulties in science can be making inappropriate associations, another is not recognising links that as teachers we hope students might make. Alice had the basic conceptual understanding to see how neutral objects could be electrically attracted, but did not make a connection between the origin of van der Waals' forces and the balloon 'trick'.

One area that interests me is the various means by which learning can 'go wrong', as understanding this can help us to anticipate these 'mistakes' and plan teaching to channel thinking towards the accepted scientific models. Missing intended connections, and making unhelpful connections are just two of the possibilities (https://science-education-research.com/teaching-science/diagnostic-assessment/science-learning-doctors/).

Alice's failure to understand the balloon trick is not surprising, but her attempt to conjecture a mechanism reflects an intelligent and articulate student who could offer detailed (and physically valid) explanations of other complex phenomena. In addressing the balloon trick, Alice failed to make the (appropriate) connection between apparently unrelated aspects of her science knowledge, but instead drew upon a different (inappropriate) way of thinking that worked for another aspect of the same topic area. Once again we are reminded of the challenges of learning physics and the importance of teachers who can act as 'learning doctors' to monitor, diagnose and guide students' developing thinking in the subject.

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