National Teaching Fellowship update

Mathematical Techniques and Problem-Based Learning

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Most people who drive do not understand how a car engine works; they probably do not understand how the brakes work or what the clutch is for. This does not necessarily make them bad drivers, certainly not as long as the conditions are what they are used to. Do scientists who use mathematics need to understand it? Let's see. For how many does it matter that $\sqrt{2}$ is not just 'about 1.414' (or about 1.4 if you are doing astrophysics)? My own answer used to be that it does, because if you do not have this to build on you have no hope of understanding what $i = \sqrt{-1}$ is. My own answer also used to be that science students have one chance of acquiring some mathematics instead of just mathematical techniques, and we should not lose this. Experience seems to show how wrong I was. In practice, we do not have the time or effort to distinguish if students understand the construction of complex numbers or if they just know how to manipulate $e^{i\theta}$.

So we got into the mode of teaching mathematical skills to science students in the way that skills are generally taught: by constant repetition and coverage of all possible variants of a given problem, eventually to the extent that mathematics becomes indistinguishable from pattern matching. And the sad thing is that you know it works – at least until you change the context and start asking for applications of the techniques in unfamiliar surroundings (like physics or chemistry). One can tweak things a bit, as we have done, by getting rid of lectures and using text, workshops and tutorials to try to obtain some extra engagement. But it still does not exactly encourage students to feel an affection for the mathematics, which they know they have to grind out because it might prove useful later. Nor does it help, in my experience, to teach mathematical techniques on-the-fly 'in their scientific context', partly because the context is often unfamiliar (partial derivates **and** Maxwell relations!?), but also because the techniques are supposed to be useful precisely because they apply in a variety of contexts.

Why then should we be optimistic about the possibilities for change. Part of the answer is one word: technology; more specifically your favourite symbolic manipulation program. In Roman times long division was a topic studied at university. Technology, in the shape of '0', came to the rescue, and, more recently, in the form of 1s and 0s (or calculators). Why would a science student want to endlessly practice differentiation of $x^3 \sin 7x^2$ and its relatives if one can tap it into M.... (should the need ever arise)? This allows us to concentrate on the understanding of differentiation and use symbolic programs for the technical stuff.

So far, so not very new. The next part of the answer, as I hope to explore it, will be coupling this with problem-based learning (PBL) in which engaging problems posed at the start of a course unit are used to motivate learning, not to test it. The specific context is our new degree programme in interdisciplinary science, which is a three or four year programme of specially constructed modules, each involving one or more interdisciplinary science problems, and taught by PBL. Despite our initial plans it now seems odd to single out the mathematical techniques modules as the only non-PBL parts of the course. Thus, our project is, over time, to develop a PBL mathematical techniques module using a symbolic program for the manipulations and the problems to motivate understanding. In due course we shall be interested to see whether this will be generalisable to the needs of single discipline degrees. Watch this space.