Comments on B1: Learning and conceptual understanding: beyond simplistic ideas, what have we learned? (*Laurence Viennot)*

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Laurence Viennot has done us all a great service, with her careful dissection of what can be gleaned from thirty years of research on the teaching and learning of science. She is surely right to insist on avoiding a number of simplistic positions, without losing the essence of what each may have got right. It is indeed difficult, in this kind of work, to avoid the trap of "What is true is obvious, and what is not obvious is not true". The most important results, for example the prevalence of "linear sequential reasoning" to which Laurence Viennot draws attention, did not initially seem at all obvious to many of us, but, inevitably, came to seem so more and more as we encountered example after example. In other words, one difficulty with research into learning is that results have to be or become (perhaps only after some time) recognisable in experience to practitioners, and so in that sense to become "obvious". Laurence Viennot has steered a careful and deeply considered course between alternative views, showing in detail what each has to contribute, whilst being careful to avoid both empty generality and excessive simplicity. It is no surprise that life is complicated, but here we have that complexity deftly analysed and synthesised.

Whilst Laurence Viennot does not explicitly say so, it can be seen as a weakness in much of the research in science education that it is not deeply interested in specific content. She redresses the balance, by insisting that an important aspect of the design of teaching sequences is the "spotlighting" of particular content features, finding a point of view that brings out sharply some crucial but often hidden aspect of the content. In her own work she has chosen to focus on relatively mundane topics such as light rays, gas laws and friction, but revealing that even in these well-known and widely taught areas, there are unrecognised details that need but often do not get careful attention. The "wavy rays" in her Fig 1 are an excellent example. The same is surely true of larger topics: for example I suspect that much of the teaching of relativity founders on inadequate attention to the idea of "rest", which alters to mean "moving together". In this way, the chapter strikes another kind of balance, between the global understanding of what it takes for science teaching to succeed, and the particular, highly specific analysis of "critical details", without attention to which intellectual coherence is lost. It is specially worth noting the evidence that students accept such care over detail, even though their teachers predict that they will not – another case of something true that is far from obvious.

Perhaps Laurence Viennot might have made more of her critique of "context" or "relevance" as a source of motivation. She restricts herself to pointing out that it need not be the only source, and that – unfashionably – an insistence on rigour and careful coherent argument can also be motivating. It is left implied but unsaid that this also communicates an essential feature of the way science works – that from the everyday point of view scientists are remarkably pernickety, and necessarily so. One might also remark that the science that comes out of any chosen context or application is as difficult as it just happens to be. For example, whilst MRI scans and computer tomography have strong appeal, the physics behind them is really rather complicated, so that what is taught is likely to be simplistic, even incoherent. Choosing a motivating context is more difficult than it seems.