REFLECTIONS ON TEACHING AND LEARNING PHYSICS

TEACHING
LEARNING

Lessons for physics teachers based on Einstein's wisdom

'To punish me for my contempt for authority, fate made me an authority myself.'

Albert Einstein

As readers of *Physics Education* will know, 2005 marks the centenary of the publication of the five papers that made Albert Einstein's scientific reputation. Although his expertise was in physics and not pedagogy, Einstein was not above commenting on broader matters, such as the nature of science and the progress of scientific thinking. In honour of Einstein Year, I consider how some of his comments could be reinterpreted by a physics educator citing him as an authority. I have sourced the quotes from *A Dictionary of Scientific Quotations* [2].

'Common sense is nothing more than a deposit of prejudices laid down by the mind before you reach 18.'

Here Einstein is pointing out that the job of the physics teacher is difficult, because students come to classes already holding a range of common-sense ideas about the world. These ideas often seem to work when applied in everyday situations. Yet, they are often inconsistent with the models of the world that we use in physics. Unfortunately, these preconceptions bias students' thinking considerably. The physics teacher has to work hard to try to overcome students' prejudices and to persuade them of the value of the scientific way of looking at things.

'The history of scientific and technical discovery teaches us that the human race is poor in independent thinking and creative imagination. Even when the external and scientific requirements for the birth of an idea have long been there, it generally needs an external stimulus to make it actually happen; man has, so to speak, to stumble right up against the thing before the right idea comes.'

Because of the common-sense notions that students bring to classes, so-called *discovery learning approaches* are seldom likely to be effective in helping students acquire accepted scientific models of the world. Simply providing students with access to the phenomena that sparked critical insights in Archimedes, Newton and Meitner is unlikely to lead to many learners reproducing the discoveries of the great scientists of the past. Instead the teacher has to carefully 'scaffold' learning so that students 'stumble' to just the right conclusions!

'The human mind has first to construct forms independently before we can find them in things.'

Einstein offers his support for what is known as constructivism in science education. Einstein acknowledges that our knowledge is something that is constructed in human minds. As an individual learns,

there is a process of building up a framework of knowledge about a subject, bit by bit. Each new understanding has to be carefully built on the foundations of existing conceptual frameworks.

'The only justification for our concepts is that they serve to represent the complex of our experiences; beyond this they have no legitimacy.'
However, Einstein does point out that he is not a radical constructivist who would consider *any* mooted conceptions as worthy of being taken equally seriously in physics. In common with most physics educators, Einstein believes the adequacy of our conceptual frameworks should be judged in terms of their value in explaining, predicting and controlling the physical world.

'Marvellous, what ideas the young people have these days. But I don't believe a word of it.'
Einstein acknowledges that research in physics education has revealed an amazing variety of ways that different students may conceptualize forces, light, electrical circuits and the like. However, many of these ideas are at odds with the empirical evidence underpinning the scientific models of the world represented in the school physics curriculum.

'Imagination is more important than knowledge'
Being compassionate, and wanting to encourage the study of physics, Einstein would not wish to appear over-critical of students coming to physics classes with their alternative conceptions. Einstein values imagination highly in physics. Children demonstrating a rich range of ideas about scientific topics are ultimately likely to be more successful in learning the curriculum models of science than their less imaginative peers. (Einstein appears to be familiar with the findings of Ault *et al* [1].)

'Elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined...the above-mentioned elements are, in my case, of visual and some muscular type. Conventional words or other signs have to be sought for laboriously.'
Einstein claims that his productive thinking is rarely verbal in nature. He comments elsewhere [3] that 'I very rarely think in words at all'. He seems keen to remind physics teachers that learners are individuals, with their own preferred learning and thinking styles. It is unhelpful for a teacher to assume that her students will necessarily think in the way that she does. Any teacher believing that so-called kinaesthetic learners are less intellectually able than verbal and visual learners should note Einstein's acknowledgment of his own use of kinaesthetic learning in developing his ideas.

'God does not care about our mathematical difficulties. He integrates empirically.'
Although accepting the potentially productive nature of different thinking styles, Einstein points out that often physics is modelled most effectively in mathematic terms. He warns those students thinking of taking physics courses in further and higher education that they should be aware that success is likely to be dependent on competence in mathematics.

'The Temple of Science is a multifacetted building.'
Einstein, not above being mischievous, reminds us that although physics is part of the wider natural sciences, it has qualities that set it apart from other science disciplines. Perhaps he is concerned that since physics has ceased to be a discrete part of the English national curriculum, many learners may be presented with an undifferentiated science curriculum. Einstein hints that learners' experiences of science should crystallize out to reveal the different faces of science, rather than just set into an amorphous lump. Perhaps he is also reminding us that the science educator has an important place in the temple.

Next issue: Bohr on complementarity – was he thinking of the academic/vocation divide in science education?

References

[1] Ault C R, Novak J D and Gowin D B 1984 Constructing Vee maps for clinical interviews on molecule concepts *Sci. Educ.* **68** 441–62
[2] Mackay A L 1991 *A Dictionary of Scientific Quotations* (Bristol: Adam Hilger)
[3] Miller A I 1986 *Imagery in Scientific Thought* (Cambridge, MA: MIT Press)

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