



Wondering in science: have we lost the balance?

● Alan Goodwin

We aspire to make science education a meaningful, engaging, relevant and satisfying process for pupils, teachers and teacher educators, which, we hope, will lead to a critical, humane and a continuously learning role in society for all. It is also important that enough of the population will be sufficiently committed to science to become the scientists and technologists of tomorrow. This is, of course, an issue for 'education' across the board, not just in science; however, science is our focus.

This aims to be a provocative paper although also a constructive one. The author argues that, although some of the reforms of the past 20 years may have been well grounded – and well intentioned – it seems that motivation for learning by students has become largely focused upon test and examination scores (this has long been an important aspect of work in schools and colleges and its importance must still be recognised) and that 'love of learning' and 'personal enquiry/interest' are in danger of extinction within the system. Another aspect of the new world has been the formal imposition of 'teaching standards' that has de-emphasised the subject being taught, assumed that teachers with appropriate subject qualifications already know enough and has undervalued the professional subject learning that must continue throughout a teaching career.

*Examples and demonstrations of 'student engagement' and 'teachers' learning' will be provided from the author's research and experience. Emphasis will be given to the importance of providing time and giving priority to encouraging students and teachers of science to **wonder** in (and at) science.*

'Wonder' has long been a special word for me since I was struck by its delicious ambiguity shortly after I joined the world of teacher education. Wondering at and wondering *why* appeared to be two hugely important dimensions of learning science – the first providing the motivation and the second describing the purpose. Eventually I wrote a short paper on the subject (Goodwin, 1994), partly in response to the huge changes that had occurred in science education due to the introduction of the National Curriculum (and rapid changes in its presentation), the development of Ofsted and more regular school inspections and the beginnings of the government's interest in processes and 'so-called' standards in teacher training. (Concerned / combative / interfering / supportive / undermining?) Later, I updated this paper (Goodwin, 2001) and extended it to include 'wondering whether'. Key ideas that summarise both these papers include:



Wondering in science: have we lost the balance?

- Science must make sense.
- If we expect students to develop enquiring minds, then teachers need to demonstrate these too.
- Teachers should not be expected to know and understand everything about science – *even that they are teaching* – but they should continuously explore that they know they do not know and/or understand and re-examine that they (think they) know.
- Enthusiasm is caught rather than taught (and early experiences can be vital).
- Students (and their teachers) need to be actively and intellectually engaged with the subject.
- Appropriate *balance* needs to be sought.

The second paper (Goodwin, 2001) was optimistic in that the newly-revised version of the National Curriculum had just come out and contained (for the first time) an explicit overall statement of aims/aspirations for learning in schools (DfEE/QCA, 1999). Some of the key words include:

'... develop enjoyment of, and commitment to, learning ...build upon pupils' strengths, interests and experiences ... have confidence in their capacity to learn and work independently... promote an enquiring mind... appreciate human aspirations and achievements... prompt a personal response... pass on enduring values, develop pupils' integrity and autonomy.'

In a further statement on the environment:

'...value the environment, both natural and shaped by humanity, as the basis of life and a source of wonder and inspiration.'

At about the same time, the final draft of *Beyond 2000* (Millar & Osborne, 1998) had been published and included in the aims of the science curriculum:

'... seek to foster a sense of wonder, enthusiasm, interest in science.' (p. 2012)



Wondering in science: have we lost the balance?

Unfortunately, these statements seem to have received little emphasis or priority over the past decade and we are still deeply mired within a culture where schools' educational 'quality' and effectiveness are largely perceived by reference to 'league tables' based upon SAT and examination results. This severely distorts the curriculum experience for many pupils and, I believe, has contributed to pupils' perceptions that science is 'boring' (Osborne & Collins, 2001), as well as reduced levels of satisfaction and engagement for their teachers (e.g. Donnelly, 2000). It is clearly appropriate to indicate that these are still 'live' issues – through two recent comments from a pupil and a teacher in the science press:

'...after this two year course the enjoyment for chemistry seems to have been sucked from me. I feel like I haven't really learned anything I didn't already know. As a result of this I will not now be taking chemistry to A-level, having chosen to do French instead.' (Clark, 2009)

'The inspection culture, coupled with current teacher training courses, enforce the view that there is a correct format for any lesson... This is nonsense.' and *'If the system would relax and stop measuring everything, and promote creativity and the less quantifiable human aspects of education, teachers could work even more effectively.'* (Barker, 2009, p.96)

It seems to me that one unintended consequence of the implementation of a National Curriculum, inspection processes, professional standards for teaching and the huge amount of guidance available from QCA and the National Strategies has been to remove ownership of the curriculum from many of the 'best' teachers who, in the more distant past, would have been most engaged with creatively developing and improving the curriculum as well as their own understandings of science. These would have been the 'wonderers' and I wonder whether there is any longer the time or the motivation for them to seriously engage as wondering professional teachers or teacher educators. I am hugely in favour of continuing professional development, but it must engage the teacher him/herself. I was, for example, heartened by the article (Holman, 2009) in the July 2009 edition of *Science Teacher Education*, but I would take issue with the 'flavour' of the main conclusion:

'This means getting talented people to become teachers in the first place, and providing them with the right training, both initially and through their careers.'



Wondering in science: have we lost the balance?

Training is important, but the opportunity to learn and explore what the individual teachers are personally and professionally motivated to engage with (education) can be so much more productive. The quotation above sounds as though somebody else knows what is best for the teachers and *will* do it to them. Following Kibble (2009), it would be good for teachers to experience refractive developmental experiences: *'Reflection allows a teacher to take a look at existing practice within known boundaries. Refraction requires a significant practice-changing experience and results in a changed direction'*, and this is only likely if teachers fully own their experiences. That place between training and education is one of the balances that need to be sought/negotiated.

Generally speaking, I believe that professional teachers and teacher educators hold and achieve much higher standards when given (shared) aspirational targets and are trusted to do things better. Clearly, individuals must be *accountable*, but the default assumption for professionals should be that they are trustworthy and committed – most will personally aspire to higher standards than any system could possibly expect. (A recently published book from the USA (Tobias & Baffert, 2009) provides interesting insights into the concerns about science teacher professionalism within the US systems – and is available for free download from the web).

My prime example of student engagement comes from a sixth-form class I was privileged to take for A-level chemistry around 1966-8. The group was insistent that the chemistry made sense both within the course and within the experience of the group members. Incidentally, this created a number of debates between the science staff who, unwittingly, were giving different explanations of concepts such as 'osmosis', 'the generation of EMF in a galvanic cell', 'evaporation and boiling' and 'hydrogen bonding' (in respect to DNA structure and replication as it was then understood). The students in the group discussed and argued with me and with each other to such an extent that I felt nervous about my lack of control. However, I received a number of calls at the weekends from one member of the group to discuss chemistry issues and, unusually, when the class met, discussion outside the laboratory almost always centred around chemical topics. Despite my concerns about control, the group achieved superb examination results. Unfortunately, I have no recipe for repeating this level of engagement and never quite matched it during the following 32 years in higher education! It was, for me, a very powerful learning experience.



Wondering in science: have we lost the balance?

One of my major interests over the past thirty years has been teachers' and scientists' understandings of science and, although at one time I felt that the huge amount of science learning I experienced in the years after I qualified in science and as a teacher was due to personal inadequacies, I am now convinced that alternative conceptions of science concepts are almost as widely spread among professional scientists and science teachers as they are in the general population, once an individual gets outside his/her (usually fairly narrow) range of specialist expertise.

I would aim to conclude this article by 'demonstrating' continuing learning and sense of wonder by reference to five brief experiences – none of these was available to me before I retired so all represent learning at a post-professional stage. Some details of most of these are available on the SciTutors website and details are given below:

1 Fizzing drinks are examples of boiling solutions

This can be exemplified by shaking a can of carbonated drink and then opening it immediately. It can be compared to what happens if a similar can is left to stand quietly before opening. I would now argue that the bubbles can form when the pressure (of water + carbon dioxide) equals or exceeds the pressure on the surface of the liquid. As the bubbles are richer in carbon dioxide, the concentration of this in the solution gradually falls and the boiling point of this solution rises. This is an example of fractional distillation and leads to the separation of water and the carbon dioxide.

For a full discussion, see the SciTutors article on video-clips and science education research: <http://www.scitutors.org.uk/article.php?id=119> (or go to www.scitutors.org.uk/ and look under the 'course organisation tab' to find the use of video-clips).



Wondering in science: have we lost the balance?

2 The simplest electric motor ever?

This is a version of a Faraday original made possible by the invention and ready availability of 'super-magnets' (not available to Faraday in the 19th Century). This is not my invention, but I introduced it at the ATSE Conference 2008. The details appeared in a Science Note in the September 2009 issue of School Science Review (Goodwin, 2009).

3 The reaction between Hydrogen and Oxygen

Actually, it is the use of disposable syringes for collecting and manipulating micro-scale quantities of gases that was my recent 'learning' experience. Full details of the procedure can be found in the appropriate download from the SciTutors website:

http://www.scitutors.org.uk/files/k3.4_5.0av_syringe_experiments.doc

(or go to www.scitutors.org.uk/ and look under the 'knowledge' tab – go to section 3.3 'Materials and their properties' and then choose 'Doing Demonstrations'.)

4 Iron gains weight when it burns in air

This is a very basic demonstration that I did not learn to use until fairly recently. I have not followed up whether this demonstration is published elsewhere. Full details of my procedure can be found in the appropriate download from SciTutors:

http://www.scitutors.org.uk/files/k3.4_5.0az_iron%20gains%20weight%20when%20it%20burns%20in%20air.doc

or follow the links as described in 3 above.

5 A magnetic particle accelerator

Here is another use of 'super-magnets'. Full details of my procedure can be found in the appropriate download from SciTutors:

http://www.scitutors.org.uk/files/k3.4_5.0ax_magnetic_particle_accelerator.doc

or follow the links as described in 3 above.



Wondering in science: have we lost the balance?

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Wondering in science: have we lost the balance?

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Alan Goodwin is retired. He was previously Head of the Department of Sciences Education at Manchester Metropolitan University. E-mail: alanguodwinuk@yahoo.co.uk