



THE COLLEGE OF TEACHERS INAUGURAL PROFESSORIAL LECTURE

ENGAGING TEACHERS, ENGAGING PUPILS, ENGAGING SCIENCE: are we learning our lessons?

Derek Bell

Professor of Education, The College of Teachers
Chief Executive, The Association for Science Education

23 June 2008

at

The Royal Society, London

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Introduction

Education is never out of the news for very long and science education seems to get more than its fair share of space and time in the media and in government debates. It might be an exaggeration to state that everyone has an opinion on what is wrong with science education but there are certainly days when that is how it appears and we see headlines such as "Science elite rejects new GCSE as 'fit for the pub'"¹ or "Make science easier, examiners are told"².

There is, of course, a danger that this state of affairs is treated as being unique to the present time, yet criticism of the education system, schools, teachers and pupils in general, as well as science education in particular, is certainly not new. For example, a report of 1875 stated that "the present state of scientific instruction in our schools is extremely unsatisfactory"³ and, more recently, the House of Commons Science and Technology Committee concluded, "We have found that there are major problems in science education in schools, notably at GCSE"⁴.

I do not propose to dwell on what, in many cases, is misinformed criticism but to reflect more positively on teaching and learning in science. I make no apologies for drawing heavily on examples from primary science because I firmly believe that there is much to learn from the practices that are so well exemplified in that phase of our education system. I do, however, make a disclaimer to say that the ideas and opinions presented in this talk are (as far as any ideas belong to one individual) my own and, unless explicitly stated as such, the views expressed are not the policy of the Association for Science Education (ASE), the College of Teachers or the Royal Society who have kindly supported this lecture.

Origins of the title of this lecture.

The title of my talk arises out of a piece of work that ASE undertook in 2004-05 with National Science Learning Centre (NSLC), instigated by Sir Mike Tomlinson, when he was President of ASE, and supported by the Gatsby Foundation, to explore with teachers what was needed to address the concerns that were, and still are, being expressed regarding teaching and learning in science. The findings formed a small but significant evidence-base of issues and possible solutions that has informed ASE's responses to consultations and, I like to think, influenced some of the policy making which led to the STEM Programme Report⁵ and the outcomes of the House of Lords Enquiry into Science and Teaching in Schools⁶.

The use of the word 'engaging' is very deliberate because of the slight ambiguity as to its meaning in this context. On the one hand it is used as an 'adjective' in that it is describing teachers, pupils, and science as people / things that are interesting, easy to relate to and trigger some kind of curiosity / enthusiasm. While on the other hand it is used as a 'verb' in that it refers to the process of teachers interacting with pupils in order that they in turn will interact, either individually or together, with the subject matter which is science.

Plowden and all that

Whenever I take part in an event about education I have a little bet with myself as to how long it is before someone mentions "young people" or "children" – our students and pupils– and then how long it is before "teachers" are referred to in some way. Sometimes it can be a very long time and, I am afraid, on some occasions never. However on this occasion I am putting the marker down at this early stage to make the point that ultimately it is the interaction between teachers and learners and their engagement with shared subject matter that is the basis for the development of the knowledge, skills, conceptual understanding and attitudes that contribute to learning in all its guises. Furthermore I would make the point that all of us, whatever our role, have a responsibility to help create an environment in which high quality teaching and learning can flourish.

We all probably have our own milestones / critical events which have influenced our own thinking and learning or that we feel have been particularly influential in the way in which we approach things. For me one such event was being introduced to the phrase, "at the heart of the educational process lies the child"⁷. I have to say, however, that it later become one that I got bored of seeing written (and often misquoted) in student essays!

Originally published in 1967 (when I, hasten to add I was still at school!) it is perhaps the most quoted phrase from the Plowden Report into primary education. In many respects this was a real landmark report and one which showed, with the benefit of hindsight, amazing vision. Among many other things, it proposed:

- the setting up of educational priorities areas;
- the use of 'teacher aides';
- the need for greater communication between parents and teachers;
- the importance of getting transition from primary to secondary school 'right'.

All of which have, more recently, become part of education policy in some form or other. However, Plowden also championed the use of:

- 'child-centred' approaches to teaching';
- topic-based curriculum;
- 'Discovery learning'.

Unfortunately many of what were described as the short-comings of the education system in the 70s and 80s were often referred back to these proposals from the Plowden Report. Critics (e.g. Black Papers⁸) argued that such approaches led to undirected learning or, at the extreme, no learning at all, and that teaching through

topics was superficial, unplanned and lacked direction. This criticism greatly maligns what the report said because it also argued that:

- teaching methods should be subjected to “astringent intellectual scrutiny” and that
- there is a need for “the practice of skills and the consolidation of knowledge”.

To my mind, core to Plowden were principles and values which require that:

- children’s views and learning should be are highly valued;
- the curriculum should be something with which they can engage – it has to have a relevance to them and their lives;
- the contributions of subject disciplines – the skills, knowledge and values they bring - make key contributions to learning;
- teachers, as the professionals, should be trusted to do their job with appropriate levels of support.

Some of this certainly sounds familiar as part of the debates we are experiencing today. So what progress have we made and have we learnt our lessons? In the context of science I would like to try to address these four aspects of teaching and learning which in many respects underpin, for example, the revised secondary curriculum which was introduced from September 2007⁹ with its stated aim that,

The curriculum should enable all young people to become:

- *successful learners who enjoy learning, make progress and achieve;*
- *confident individuals who are able to live safe, healthy and fulfilling lives;*
- *responsible citizens who make a positive contribution to society.*

I would emphasise at this point that these issues are not just relevant to England and the UK. They are world-wide concerns and are the focus of discussions across the globe at every level of education from school staffrooms to the highest tiers of government.

Children’s views and ideas

Of the many things that have happened since the publication of Plowden - the subsequent upheavals that led to the Great Debate (started with a speech made by the then Prime Minister James Callaghan at Ruskin College in 1976) and ultimately to the National Curriculum in England, Wales and Northern Ireland – perhaps one of the most significant to influence teaching and learning has been the recognition of the importance of children’s ideas and latterly their views on the curriculum and the subjects they are taught.

The late Ros Driver summed it up succinctly in her superb little book *The Pupil as Scientist*¹⁰ when she said,

It is, after all, the coherence as perceived by the pupil that matters in learning.

Ros was one of the outstanding figures in science education whose influence remains strong today. It was the work of her team in Leeds on the Children's Learning in Science Project (CLISP)¹¹ that brought to prominence in the UK and elsewhere the idea that,

..it is as important in teaching and curriculum development to consider and understand children's own ideas as it is to give a clear presentation of the conventional scientific theories.¹²

In the early 1990's I had the opportunity and privilege to be part of these developments, not with CLISP but with the SPACE – Science Processes and Concept Exploration – Project¹³ which was directed by two other outstanding figures in science education, Wynne Harlen and Paul Black. The SPACE Project set out not only to explore young children's ideas in relation to scientific concepts but to then develop approaches and activities that would help children develop their ideas towards a better understanding of the science involved. Teachers used a range of techniques to find out children's ideas of which getting them to draw pictures was particularly effective. Not only did drawings, such as that shown in Figure 1, give an insight to the child's thinking but it also provided the basis for non-threatening conversations as the children explained their drawings to their teacher and their friends.

Figure 1. A child's response to the question, "What do you think happens to the food inside your body?"



Having gained such insights into children's ideas the project then looked to devise teaching approaches and activities that would build on and, where necessary, challenge their ideas in order to get the children to think about the concepts and improve their understanding of the phenomena under investigation. In overall terms we were developing activities that:

- enable children to test their own ideas through practical hands-on activities and investigations;
- encourage generalization from one context to another by experiencing and considering other instances of phenomena e.g. evaporation of liquids other than water everyday situations such as paint drying;
- discuss the words children use to describe and explain events by exploring with them their use and understanding of both 'scientific and 'non-scientific' language;
- extend the range of evidence available to test their ideas often trying to find ways of making the invisible visible, through the use, for example, of models and simulations;
- help children to communicate their ideas, allowing them to explain and challenge each others ideas.

The outcomes of the research were published as a series of reports¹⁴ and provided the foundation for a set of curriculum materials under the title of *Nuffield Primary Science*¹⁵.

Subsequently I was able to pursue some similar work, supported by The Nuffield Foundation, but with children with learning difficulties¹⁶ – and if you think teaching good students is difficult then this is even more challenging and moves you into situations where your teaching abilities are really put on the line. It makes you think more carefully about, for example, the language and materials you use in engaging learners. It also makes you think about issues such as what subject knowledge do we need as teachers to bring about learning and why?

For instance, contrary to the normal advice, open questions are not necessarily helpful to these children. Too often open questions produced no response but more focused and closed questions worked by providing the child something to relate to. For example, during work on electricity one child was having difficulty responding to questions about what a battery does when a switch to a more closed question produced an answer.

- T: *What can you tell me about the battery?*
C: [No response]
T: *What would happen if you took the battery out?*
C: *It'd turn off.*

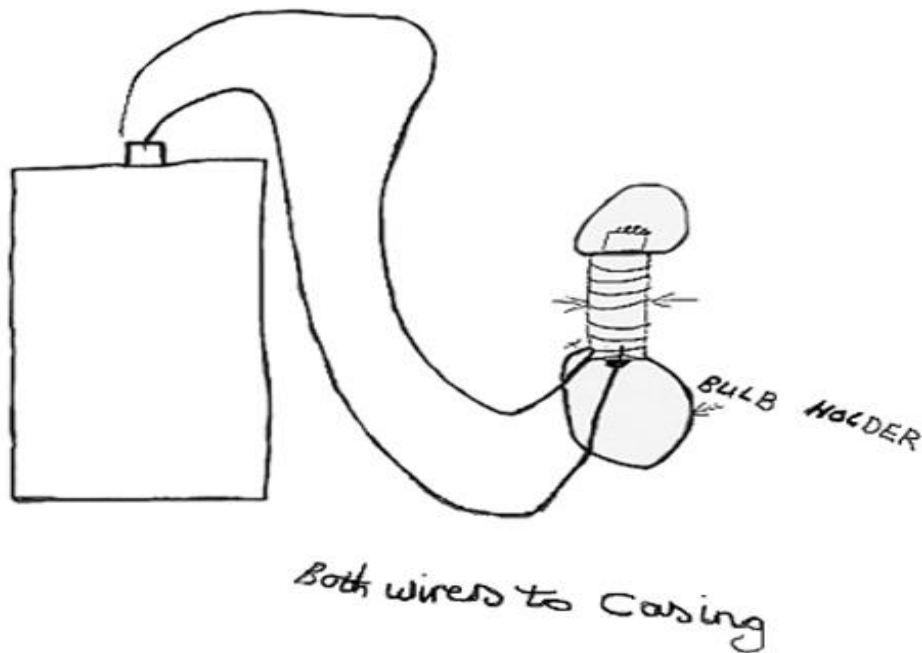
Another child was struggling with questions about how an electrical circuit he had made worked when a skilled intervention by the teacher with a simple piece of 'scaffolding' brought a positive response.

- T: *So the wires and the clips make it light up?*
C: *Yes*
T: *How did the wires and the clips make it light up?*
C: [No response]

- T: *The bulb lit up because*
 C: *.....because the wires connected it to the screws and to the battery.*

Conversely there are times when we inadvertently hinder children's learning as was seen when, working with this same group of children, they were asked to draw a picture of a circuit to make bulb light up. Figure 2 shows a fairly typical effort and at first glance we might consider that it is 'wrong' because the two wires are shown as coming from the top of the battery. However when nearly all the children's drawings showed something similar it seemed strange until the teachers realise that the batteries that had been used with the children did indeed have both terminals on the top!

Figure 2. A child's drawing of a circuit



At another extreme appropriate selection of equipment, perhaps coupled with effective use of ICT, can reveal things that otherwise have to be taken for granted or accepted because they are shown as pictures in a book. The use of a digital microscope with a camera attached is a very good example of helping students see things they would otherwise miss due to the difficulties of using a microscope. My own personal favourite is a short video clip, taken by a colleague¹⁷, I have of the contractile vacuole of a protozoan filling and then bursting. I drew pictures of features such as this when I was at school but had never seen one until I was given this video clip a few years ago.

To my mind it is small interactions such as these between teachers and learners and between learners themselves that bring about the incremental shifts in understanding that are at the heart of teaching and learning. If such constructive interactions and relationships become stifled or constrained, perhaps because teachers feel they do not have the time, then we take out much of what is valuable and consequently the desire of children to continue learning in any subject becomes diminished.

I cannot overemphasise how much we need to value and respect children's ideas – not ask for them and then dismiss them – because they are based on the evidence and experience the children have to hand. In that sense it can be argued that they are not 'wrong'. Unfortunately, all too often they are told 'that's wrong' so it is no wonder that they start to get 'turned off' by science. Using approaches which actively explore children's ideas, however, may need more time initially but there are benefits in the longer term. In essence such approaches encompass the process of formative assessment the value of which was best summarised by Paul Black and Dylan Wiliam¹⁸ when they wrote,

There is a body of firm evidence that formative assessment is an essential feature of classroom work and that development of it can raise standards. We know of no other way of raising standards for which such a strong prima facie case can be made on the basis of evidence of such large learning gains.

I would argue therefore that we must ensure that there is sufficient flexibility and space in the curriculum to allow for such approaches to be adopted and, importantly, for the professional development of teachers to manage and implement them effectively.

Giving the curriculum relevance

Not only do we have a better understanding of children's ideas in relation to scientific concepts but we are becoming better informed about their views on the curriculum and science itself. Many young people see science as important and of interest (usually outside of school) but it is not for them¹⁹. We need to better understand what it is that 'turns students' off science²⁰.

Studies of student views of the curriculum give clear messages about what they would like to see in the curriculum, as a student led review of the science curriculum²¹ concluded,

..there is great potential but school science fails to convey the extent to which science is related to everyday life and affects all of us. Space needs to be made to allow controversial issues to be included and to allow topics to be studied in more depth.

Taking young people's views into account can vastly improve the curriculum but we need to remember of course that they are only one of the stakeholders in this game. It was with the challenge of developing a more appropriate curriculum and with 'a desire to provide a new vision of an education in science for our young people' that led to the Beyond 2000 Report²² which argued, among other things that,

The current curriculum [in the late 1990s] retains its past mid-twentieth century emphasis, presenting science as a body of knowledge which is value-free, objective and detached – a succession of 'facts' to be learnt, with insufficient indication of any overarching coherence.

and there is

...a growing tension between school science and contemporary science as portrayed in the media, between the needs of future specialists and the needs of young people in the work place and as informed citizens.

Beyond 2000 articulated very clearly what has become referred to as the dual mandate for science education which is required to,

- develop a scientifically, mathematically and technologically literate population and
- meet the need for scientists, technologists, engineers, medics, technicians and mathematicians of the future.

Subsequent work and development, with widespread involvement and support of science educators, teachers, scientists, and industrialists, led to the revision of the science curriculum at KS4 and specifications for GCSEs of which *Twenty first Century Science*²³ probably has had the highest profile. The science curriculum for other age ranges and in other parts of the world has also been influenced by the thinking behind these developments, although it has to be said the developments are not without their critics²⁴.

The introduction of 'how science works' as a key strand into the curriculum has, for me, been a real move forward but it has highlighted one of the things which, as a community and profession, we often get badly wrong. A concept such as 'how science works' is only developed after a great deal of thought but the phrase used to capture the idea often gets hi-jacked and its meaning becomes narrowed and / or devalued. In this case my understanding is that 'how science works' involves all those things that scientists do, individually and collectively, to further understanding of phenomena – practical investigations, reading the work of others, discussion and argument about evidence, its interpretation and alternative explanations as well as (the bit that had not, up to this point in time, been included in school curricula in any formal sense) the consideration of the implications of scientific developments and technologies in moral and ethical terms. Unfortunately it is this last bit that seems to have been picked up leading to the accusations of 'dumbing down' and headlines such as 'science fit for the pub'. Yet, as reported by Ofsted²⁵,

Schools that focus clearly on how science works – the practical and investigational aspects rather than only the theoretical elements – are the most successful at teaching the subject.

Conclusions such as this underline the importance of engaging students and ensuring that the curriculum has relevance for them. It is, however, worth just pausing for a moment to reflect on what is meant by 'relevant' in this context because once again we have a term, the meaning of which has become narrowed. Too often I hear 'relevant' being used as a synonym for 'applied'.

For some students relevant does indeed mean the work should be 'applied' e.g. the need to understand the chemistry of polymers as a basis for making new materials. For others, however, it is the need for some 'personal link' such as knowing someone with a heart defect as a stimulus to find out more about the structure and function of the heart. Discussion of 'ethical issues', hearing about a recent scientific discovery or of a person in science are other things that give science relevance for students. We must also remember that for some students some things are relevant simply because they are found to be fascinating – there is a 'wow' factor. The key message here is that if we are to meet student needs we must build flexibility in to the curriculum otherwise risk ending up with another 'one-size fits all' model and many of the problems we face today will simply return at some point in the future.

One way of helping us avoid falling into the “one-size fits all” trap is through the increased emphasis on enrichment and enhancement of what goes on in the classroom. Learning outside the classroom, developments in the ‘informal education sector’ and the outreach activities of universities and industry are major ways of widening and improving the understanding of science for both young and old alike.

However in all of this debate, as an education community in general and science education in particular, we still have to work hard to make sure that the message is clear. The rigour of the science processes and the thinking that takes place to bring about learning should be no less than it ever was, indeed, in the hands of good teachers it will be even better. The importance of informal and out of school learning in this process should not be under-estimated.

Contribution of subject disciplines

One of the challenges in the curriculum generally, but particularly for science, is the contribution of subject disciplines. Science may be considered a single subject in some ways but we know that in reality it brings together a range of disciplines each with its own distinctive contribution to make to learning.

The return to ‘cross-curricular topics’ is a little bit of a concern because it runs the risk of falling into the traps of the immediate post-Plowden era. It seems to me therefore better to talk in terms of inter-disciplinary projects in which the different areas of science, and other subjects for that matter, come together in order to solve a problem or to explore a particular phenomenon. The rise of STEM²⁶ highlights this issue even further – if in the ‘outside world’ STEM subjects are seen to link together then we have to attempt to give all students the opportunity to explore some of those linkages while they are still in school/formal education.

In order to do this and to teach effectively we need to be comfortable with what we are teaching. This raises the question of subject knowledge required by teachers. Whilst we must remember that effective teaching requires more than just knowledge of the subject content, we are more likely to be comfortable if we have a sound understanding of our subject matter. This is not because we can ‘tell pupils the answers’ but because we are able to better identify good starting-points, know when children are getting close to a scientific view, recognise when they are going into blind alleys and ensuring that they encounter experiences that will help them re-think their ideas. Confidence in our subject knowledge should also enable us to help children reflect on and test their own ideas in a more systematic and rigorous manner.

In the context of teaching and learning at least as important as our own subject knowledge is the way in which we visualise the models we use to help develop children’s conceptual understanding of scientific phenomena. Much of science depends on models but we do not often share with our students the idea that models are limited and that they differ in their level of sophistication. So, how do we help our students grasp the idea of models becoming more sophisticated and that, by using them as part of our teaching, we are not telling our students that what they learnt previously is completely “wrong”?

One approach I use is to ask students if they had a toy train when they were very young and then get them to describe it. Invariably the description refers to something made of wood or plastic that was pulled along and did not run on tracks. Yet it was clearly a train! Asking students to describe other toy trains they have had usually moves to something which ran on tracks with markings of a railway company and then to the increasingly detailed, precisely constructed versions that make up the most expensive electric train layouts, often the one their father keeps in the attic! The descriptions do not stop there and move on to miniature railways in parks etc.

At each stage the model of the train gets nearer and nearer to the real thing. Eventually in this example we can get to a real train – but at no point is the fundamental idea of a train rejected. Rather as each model is considered it adds to the understanding of what a train is and to how it works. In other words each of the different models is another step in the learning process introducing new aspects of the phenomena yet retaining and reinforcing the fundamental characteristics of the concept.

Models are not simply mechanisms for describing or explaining things as they are. Models can also be predictive and allow the exploration of 'what might happen if ...'. So, going back to our trains again, there is enormous scope for using models to test designs for new trains or the effects of different gradients on their speed. Of course, today we can also use computer-based models and simulations to explore ideas and test hypotheses, opening up a whole new world of enquiry.

I like to think that by sharing with students these ideas about how models become more complex it is possible to help them get to grips with their own understanding of scientific phenomena. Moreover it helps them come to appreciate the increasing sophistication of the models we use to aid our thinking and explanations of the phenomena we are studying in science.

Teachers are the professionals

The real challenge is bringing all these things and many others together to engage pupils in learning. Watching accomplished teachers interacting with their pupils and sharing their knowledge, interest and enthusiasm for a subject makes teaching and learning look easy. This is probably more widely recognised now and the standing of teachers has generally improved over recent years as Osborne and Collins²⁷ stated,

In essence, school science's most valuable resource is not its equipment or its laboratories but a cadre of well-qualified, enthusiastic teachers who are justly remunerated for their skills.

If this has been accepted then why is there still a sense of frustration among teachers and others referring to the effect of such things as:

- the overall context of targets and league tables;
- the existence of a blame culture with the teacher 'as victim';
- the perceived compulsion of national curriculum, schemes of work and national strategies in England;
- the mechanistic 'delivery' approach to the curriculum;

- the reduced sense of professional autonomy?

Yet, when asked for their wish list the teachers, we talked to during our study²⁸ showed their commitment and aspirations to improving teaching and learning in their schools. Box 1 shows some of their views.

Box 1

Engaging Teachers on:

Pedagogy and resources
I would like...

- *my job to be creative and be involved in developing teaching strategies;*
- *time to get used to new initiatives and to get them working in my classroom (before being presented with the next);*
- *the resources I need to make my lessons exciting (e.g. a working fume cupboard, enough beakers etc...).*

Assessment
I would like...

- *assessment to motivate my pupils and reward their success;*
- *my pupils to know what they are trying to learn;*
- *assessment to encourage learning (and not be a full stop at the end of learning).*

Primary
I would like...

- *to feel as confident with my science knowledge as I do with history and geography;*
- *to be able to continue teaching engaging science in year 6, rather than feel pressured to do endless SATs preparation;*
- *our medium term planning to be more flexible so that I had space to experiment with new ideas.*

CPD
I would like...

- *to have the right to a certain amount of CPD, without needing to ask for it all the time;*
- *CPD to support innovation and not just to encourage the following of a recommended method.*

Professional development features high on the agenda both as a way of releasing some of the frustrations of those making the quotes and allowing them to realise some of their wishes. Professional development is also a means of releasing others from the more mechanistic modes of delivery they have come to adopt.

Few people would disagree with the idea that CPD should be an entitlement for all teachers and should be planned in line with personal and organisational needs in mind. There is certainly a strong commitment to improving CPD for science teachers through the establishment of the network of Science Learning Centres and the proposals for greater co-ordination of the wide range of high quality provision that is available as part of the STEM Programme²⁹.

Hand in hand with the idea of entitlement goes the matter of responsibility for organisations and individuals. Organisations, particularly in this case schools and colleges, have a responsibility to make sure that CPD opportunities are available for individuals and teams so that they are able to develop their own professional expertise and contributions to school improvement. The organisation is also responsible for ensuring that any specific entitlements (e.g. the arrangements for support, guidance, and funding for teachers in their induction year) are provided.

From the individual's point of view there is a responsibility for keeping up to date, developing new skills, and maintaining the highest possible professional standards in everything they do. This includes thinking ahead to possible future developments and preparing for them in appropriate ways.

Another dimension of responsibility for professional development is that which relates to the profession itself. As teachers of science we have a responsibility to ensure that science teaching generally is of the best possible quality and to contribute to raising the status of the profession as a whole. Although it may not be considered a day-to-day priority, the way in which science teaching is perceived in the wider community is an important contribution to the confidence that parents, industry, business and government have in the science education available to our students.

It is for this reason that ASE decided to develop a chartered science teacher (CSciTeach) designation³⁰ which aims to recognise the unique combination of knowledge, skills and qualities demonstrated by good science teachers and who show their commitment to maintaining their high quality expertise through ongoing CPD.

Box 2. *Chartered Science Teacher Requirements*

Individuals should be able to show their professional expertise in relation to:

- **Professional Knowledge and Understanding**
 - underpinning base for practice
- **Professional Practice**
 - development of effective teaching and learning
- **Professional Attributes**
 - overarching principles of professional autonomy

Apart from setting quality standards, a key feature of CSciTeach is the requirement for it to be renewed every five years thus ensuring that claims that individuals are up to date can be substantiated in line with practice in other professions. ASE is in discussions with the College of Teachers and other subject associations to establish mechanisms to make such designations open to all teachers regardless of discipline or phase. Such a development is timely and, in the context of wider developments, provides a major opportunity for all teachers to enjoy recognition for their professional status.

Conclusion

There is no doubt that we have moved on since the publication of the Plowden Report. There is now greater explicit recognition that teaching and learning are complex processes dependent on teachers being able to bring together their skills, knowledge, understanding and experience to best effect in a given situation. Where this is most effective there is an acknowledgement that:

- learning is based on existing ideas and responses to new experiences;
- skills and processes are integral to developing conceptual understanding;
- language and communication of ideas are important in the learning process;
- appropriate contexts are an essential element in engaging students through first-hand experiences, both formal and informal;
- formative assessment including self-assessment is critical to learning and the building of confidence in students;
- reflection on “what” and “how” things are learnt needs to be developed further.

At a wider level there is now recognition that,

- teacher development is essential but, alongside this there needs to be a re-establishment of teaching as a profession in the true sense of the word;
- improving ‘standards’ is not enough and we need to get more students and teachers re-engaged with learning in their subject;
- school science should not be divorced from the real world but that does not mean losing the rigour of scientific understanding;
- increasing pupil engagement also increases public engagement in developing a scientifically literate population and a culture in which science and its related disciplines can flourish;
- developments should be based on evidence but this requires that we have reliable and consistent information available on which to draw³¹.

There only remains the biggest challenge of all in that, having learnt some lessons, they need to be put into practice. Unfortunately, this is probably one of the lessons we still do not understand. Change takes time!

In part this is related to our models of change many of which are linear. I would suggest that we need to think of change as being circular, indeed more like a wheel (although some people might say a treadmill!). Change feels linear because we are on a small part of the circumference of the wheel. If we develop the model a little more then the initiators of change, be they the government or the senior management of an organisation, are at the hub of the wheel moving a comparatively short distance compared with the ‘workers’ who are on the outer rim. Thus there is a delay in the time it takes for the changes to be implemented but it does not end there. Another major delay is built into the system which is the time it takes for the ideas to be communicated from the centre to the outer rim. If we then push the model just a little further and speculate that if the changes instigated at the centre cause the wheel to turn ever faster then some of the ‘workers’ could be spun off the wheel – simple physics – I think!

Given the model I have just outlined, there is no doubt that many of the issues and debates in science education will be revisited in years to come but they will never get

away from the fact that at the heart of education are the interactions between learners, both young and old, and their teachers. It is, therefore, our responsibility to learn our lessons in order to create an environment in which high quality teaching and learning can flourish to the benefit of our all young people and, if we get that right, through them our society and economy.

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Notes and references

- ¹ The Times 11 October 2006.
- ² The Times 29 August 2007.
- ³ The Devonshire Royal Commission, 1875. quoted in House of Commons Science and Technology Committee, 2002. *Science Education from 14-19*, Third report of session 2001-2002, Volume 1 para 1. London: The Stationery Office Limited
- ⁴ House of Commons Science and Technology Committee, 2002. *Science Education from 14-19*, Third report of session 2001-2002, Volume 1 para 139. London: The Stationery Office Limited.
- ⁵ DFES 2006 The STEM (Science, Technology, Engineering and Maths) Programme Report further details at <http://www.dcsf.gov.uk/stem/>
- ⁶ House of Lords Science and Technology Committee, 2006 *Science and Teaching in Schools*, London, The Stationery Office Limited.
- ⁷ Central Advisory Council for Education, 1967 *The Plowden Report: Children and their primary schools*. This is out of print but can be accessed at <http://www.behaviour4learning.ac.uk>
- ⁸ The Black Papers were written in 1971 by B. Cox and A.E Dyson.
- ⁹ Qualifications and Curriculum Authority (QCA) 2007 The National Curriculum at <http://www.curriculum.qca.org.uk>
- ¹⁰ Driver, R. 1983, *The Pupil as Scientist*, Open University Press, Milton Keynes, UK
- ¹¹ Children's Learning in Science Project (CLISP) was based at the University of Leeds in 1980s and 1990s under the leadership of Professor Ros Driver and explored children's alternative frameworks in their understanding of science concepts.
- ¹² Driver, R. 1983, *The Pupil as Scientist*, Open University Press, Milton Keynes, UK
- ¹³ The SPACE (Science Processes and Concept Exploration) Project details can be found at <http://www.nuffieldcurriculumcentre.org>
- ¹⁴ SPACE (Science Processes and Concept Exploration) Research Reports: *Various titles*, Liverpool University Press, 1991 - 94
- ¹⁵ Nuffield Primary Science, these materials are now out of print but further details can be found at <http://www.nuffieldcurriculumcentre.org>
- ¹⁶ Bell, D (2002) Making science inclusive: providing effective learning opportunities for children with learning difficulties. *Support for Learning*, 17(4):156-161
- ¹⁷ I am grateful to Malcolm Oakes, formerly Director of ASE INSET Services, for the video of the contract vacuole.
- ¹⁸ Black, P. and Wiliam, D. (1998) *Inside the Black Box: raising standards through classroom assessment*. London: King's College London, School of Education.
- ¹⁹ See for example Osborne, J. and Collins, S. (2000) *Pupils' and Parents' views of the school science curriculum*. London: King's College London, School of Education
- ²⁰ Several projects funded under the Targeted Initiative on Science and Maths Education announced by Economic and Social Research Council (ESRC) July 2007 are exploring issues around student choice. More details at <http://www.esrcsocietytoday.ac.uk>
- ²¹ Planet Science, Science Museum and Institute of Education, University of London, 2003. *Student Review of the curriculum: major findings*. Reports of the review available at www.planet-science.com/sciteach/review
- ²² Millar, R. and Osborne, J. 1998 (Eds) *Beyond 2000: Science Education for the future*. London: King's College London, School of Education
- ²³ Information about Twenty First Century Science can be found at <http://twentyfirstcenturyscience.org>
- ²⁴ For example, in 2006 The Institute of Ideas published a series of essays under the title of *What is science for* debating issues around new science curricula. More details can be found at <http://instituteofideas.com>
- ²⁵ Ofsted, 2008 The quote is from the press release announcing *Success in Science* report published June 2008 reference number: 070195.
- ²⁶ The STEM Programme Report led the development of a series of action plans including CPD for teachers in science, practical work in science and enhancement and enrichment activities in science. All commencing in 2008.

²⁷ Osborne, J. and Collins, S. (2000) *Pupils' and Parents' views of the school science curriculum*. London: King's College London, School of Education

²⁸ This study was undertaken by ASE in 2004-05 with National Science Learning Centre (NSLC), instigated by Sir Mike Tomlinson, when he was President of ASE, and supported by the Gatsby Foundation, to explore with teachers what was needed to address the concerns that were, and still are, being expressed regarding teaching and learning in science. It formed the basis for responses to government and select committee enquiries into science teaching.

²⁹ One of the outcomes of the STEM Programme Report is to improve the co-ordination of support for STEM including professional development for science teachers and technicians.

³⁰ Further information on Charter Science Teacher (CSciTeach) arrangements and requirements is available at www.ase.org.uk

³¹ In 2007 The Royal Society commenced the publication of a series of 'state of the nation reports'. The first report, *State of the Nation Report 2007: The UK's science and mathematics teaching workforce*, highlighted the need for improvements in the information that is available on which to make decisions.