Engagement, communication and uncertainty in science education
Compromiso, comunicación e incertidumbre en la educación en ciencias

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Abstract

In this short paper the author explores his belief that science curricula need to engage both teachers and students in the learning of science. National Curricula and guidelines can be helpful but teachers need to develop and deliver a curriculum for/with their students. Students must remain critical —there is always uncertainty, things change, teachers do not know all the answers— and in any case communication between teachers and pupils is always imperfect.

Key words*: science education, engagement, communication uncertainty.*

Resumen

En este artículo, el autor explora su opinión en lo que los currículos en ciencias, necesitan compromiso tanto de los profesores como de los estudiantes en el aprendizaje de las ciencias. Currículos nacionales y pautas pueden ser útiles, pero los profesores necesitan desarrollar y dar a conocer un currículo a sus estudiantes, quienes deben mantenerse críticos —siempre hay incertidumbre, cosas que cambian, los profesores no saben todas las respuestas— y en cualquier caso, la comunicación entre profesores y pupilos siempre es imperfecta.

Palabras clave: *educación en ciencias, compromiso, incertidumbre en la comunicación.*

INTRODUCTION

This paper develops further ideas about the *engagement* of students and teachers in the process of 'wondering' about and at science. (GOODWIN, 1994; 2001) and prioritising 'learning' over 'knowing' (GOODWIN, 2002) for teachers as well as students.

A major motivation for this paper is concern for the apparent disengagement of many science teachers from taking personal responsibility for their students' science curriculum in the wake of the dramatic government interventions in education since the late 1980s in the United Kingdom. In outline these were:

- The introduction of the national curriculum.
- The consequent (over) emphasis on test and examination results as measures of 'quality' and progress both in formal school inspections and for published school league tables.
- The introduction of, so called, 'standards' for teacher education introduced via the Teacher Training Agency. (Circular 4/98 - DfEE (1998)).

The unfortunate way in which the National Curriculum was introduced in England and Wales is documented by Black (1995) and its affects on science teachers, researched at the University of Leeds, is reported by JENKINS and DONNELLY (1999) also (DONNELLY; 2000). A recent paper (KINCHIN; 2004) speculates on a severe reduction of the engagement of science teachers with the curriculum, as measured by publications in the School Science Review under the title "Is teacher innovation on the verge of extinction?" However, perhaps the most disturbing issue is the disengagement of pupils from science. In the UK the proportion of students at 16+ who choose to continue with studies of physical science continues to fall. This concern is amplified by research findings e.g. OSBORNE & COLLINS (2001) in a recent study looking at the curriculum from the pupils' perspective noted that:

> *'...the subject that attracted the most vehement expression for its lack of relevance and appeal is chemistry'.* P. 448-9.

This paper takes a general view of the place of engagement and communication in the aspirations for science education. Communication – discussion, argumentation, presentation - are central to what science ***is*** – and should be central to how science is learned. Unless learners and teachers are both critically engaged in the subject it is unlikely that any deep or meaningful communication can occur. Detailed ideas as to how group discussions are effectively organised and co-operative learning fostered are important but unless participants are committed to learning such strategies may even be unhelpful.

Engagement:

This represents an essential requirement for both learners and teachers (teachers are learners too). It is too simplistic to consider teaching as a straightforward process of transmitting things that the teacher already knows to her/his students. It requires motivation of all concerned for the process to be meaningful, significant and satisfying.

From the teachers' perspective it is important that the curriculum is meaningful, personally significant and 'owned'. This is not to imply that there should be no externally imposed structure and content, but that teachers should feel party to it; should feel empowered to improve and adapt it for the needs of themselves and their students; enabled to go beyond the expectations to meet their own and their students' enthusiasms. KINCHIN (2004) makes a telling point that I quote in full since it seems to encapsulate the concerns I share:

> *"…….. Even now colleagues tell me that they feel constrained by the National Curriculum rather than empowered by it. Other initiatives (notably the QCA scheme of work) may also have had a narrowing effect on the curriculum, making some colleagues feel that their role has been reduced to ……..delivering something that someone else has put together. What of current ' impositions'? I personally regard the Key Stage 3 National Strategy materials as some of the best materials to come out of the DfES at anytime in my career. However, an unreflective and formulaic approach to this initiative that involves mechanically writing lesson objectives on the board and ensuring that every lesson includes a starter, main activity and plenary whatever the context, will continue the trend of de-professionalising teaching".* (p. 17).

Teachers need to be actively engaged if they are to engage students. However, the engagement of pupils also requires that they too are party to their curriculum – and *not* simply having the curriculum *done to them.* In the context of a compulsory schooling and a statutory curriculum (although we should remember that the curriculum is an entitlement *not* a requirement) it is easy to see how pupils can come to resent activities that they see as meaningless, of little personal worth and with which they fail to engage – and eventually fail.. Since the requirement of 'active engagement for learning' applies equally to all pupils the issue of motivation comes to the fore. Coercion cannot be an answer since 'A pupil can be forced to approach learning, but cannot be made to think!' Self-motivation is eventually the only answer – although teachers can encourage this by example and by offering an engaging and responsive curriculum that pupils can adapt to their current needs and priorities. Pupils, like teachers, need to be party to their curriculum and feel a sense of ownership. Again this can be exemplified from the writing of others e.g. Ovens (2004):

> *" children's authentic curiosity and independent thinking may be killed 'stone-dead' if the teacher sets up the expectation that s/he controls all the right answers on which the children's learning must converge".* (p. 18)

The above was written for an audience of primary school teachers but its wisdom is applicable to all learning in any context - to university undergraduates, to post-doctoral students and to teachers CPD.

The above leaves open some serious questions such as (It is not suggested here that there are simple answers.):

- How flexible should teachers be allowed/encouraged to be in negotiating a curriculum for themselves and their students? (Perhaps a clue to an answer is to require students to access their curriculum entitlement without being forced to swallow it.)
- At what point are students allowed to take responsibility for their learning? When can they opt out *openly* and take responsibility for their action?
- How far should teachers be trusted to teach and students trusted to learn? (In both cases *if* both are fully engaged the results will be im-

mensely more positive than if they are following externally imposed requirements.)

- The place of tests and examinations? These are very useful *formatively* and probably necessary *summatively* (To accredit and give assurance that the student has learned to the appropriate standard?) However, assessment must be 'in tune' with the aims and aspirations of the curriculum or these aspirations will become distorted.

Communication: discussion, argumentation, questioning and presentation

A major aspiration for science education is considered to be preparing *all* students to reach an appropriate level of scientific literacy and for a substantial number to aspire to become scientists, engineers, technologists themselves. (This is a paraphrase of 'Science: beyond 2000'.) Key to this is to encourage students and require —and allow— teachers to *engage* in education and in the *learning* of science. Thus, although language both written and spoken is central to learning and teaching the attitudes and motivations of those concerned in the enterprise will determine how language is used and developed.

> *The first key to wisdom is constant questioning.... By doubting we are led to enquiry, and by enquiry we discern the truth.* (Peter Abelard 1079-1142; Quoted in Byers (2001)).

However, the current system of expectations with a focus on accountability, efficiency and *correct answers* seems to militate against the more critical and creative activities of asking questions, investigating, wondering, mustering evidence and making (and defending) tentative decisions. Hopefully, in this way, becoming aware of the human nature of scientific facts and ideas and where their own knowledge and understanding is partial and the evidence is not watertight. Certainly a set of *correct* (fairly certain) science information and *useful* science skills is an essential component of an *ideal* science education but an appropriate balance with a *critical engagement* with science and its applications/ implications must also be sought. A key issue is that no part of the learning should be justified *only* on the grounds that 'it is on the syllabus' neither should *answers* be justified *only* by the fact that they will 'gain marks' in tests. If the students are engaged in the study then communication is both natural and necessary and need not be forced.

A quotation from the IDEAS project (OSBORNE, ERDURAN & SIMON; 2004) is pertinent here:

> *"……our view is that science has been so successful because its ideas and theories depend on a body of incontrovertible evidence. Yet, as school science rushes from one topic to another, students are too often asked to accept many ideas without the opportunity to consider why they are meant to be true".* (piii).

One might argue how far and in what ways the public's hearts and minds have been won. It is however clear that science has to be active. Science is a verb and at its heart is argumentation based on evidence.

A recent comprehensive survey and reference list entitled 'Argumentation and discussion within the science curriculum' has been published by DUSCHL & OSBORNE (2002). A library search for articles on this topic also threw up references to the 'Towards Evidence Based Practice Project (EPSE) (RATCLIFFE; 2000), Concept Cartoons (NAYLOR and KEOGH; 2000; NAYLOR, DOWNING and KEOGH; 2001) and the 'Ideas, Evidence and Argument in Science (IDEAS) Project (OSBORNE, ERDURAN & SIMON; 2004) together with a number of references to KS3 Strategy.

As reported by Naylor, DOWNING and KEOGH (2001) a number of significant features of argumentation as applied to science are pertinent:

- It is not clearly defined.
- There are two kinds of argumentation (Identified by Kuhn in 1992) (1) Monological argument is concerned with the way in which individuals think through a position in regard to some specific knowledge claim. [This I identify with 'wondering about'.](2) By contrast dialogical argument involves two or more people defending conflicting (or apparently conflicting) views on the basis of reason and evidence.
- There is no clear demarcation between argumentation and discussion.
- The process of argumentation involves a series of connected statements, usually presented as a chain of reasoning.
- There is no necessity for argumentation to involve conflict – all concerned may simply be concerned to reach the best 'truth' accessible.
- Argumentation does not appear to be a common feature of science classrooms in UK.

For an argument to be scientific – there must be a basis in 'observation' or 'experimental results' that, at least in principle, are accessible to all concerned. The processes of argumentation often throw up ideas for further observations or experiments that will help to 'settle the matter'. It is in this spirit that Concept Cartoons are offered – rather than leading to only the 'right answer'. Indeed sometimes there is a correct answer but as learners we need to be convinced of this *ourselves* on the basis of evidence and argument.

An essential requirement for any argument to take place is the presence of some uncertainty. There must be more than one tenable set of conclusions. In schools it is often only the teacher's view that is perceived to be valid; argument from the learners is not encouraged – and the teacher must always be right. (Even if the teacher is right, questioning from the pupils may be essential for *them* to understand the teacher's meaning.)

Uncertainty in science learning:

In an earlier paper (GOODWIN, 2004) I identify seven possible sources of uncertainty in science classrooms that would validate a case for including argumentation in the curriculum. And these do not include uncertainties arising from the developments within science itself. These are:

1. The meaning and understanding of words (and other signs and symbols).
2. The choice and interpretation of models and the distinction from reality.
3. Classifications and categorisation.
4. Application of rules, laws and generalisations.
5. Validity of 'explanations'.
6. Errors and inconsistency.
7. Classroom uncertainties.

For *most* pupils, their image of science is determined by their experience of science learning at school. If science learning turns out to be measured by right answers given to test questions it seems unlikely that they will believe that science is creative, tentative or exciting even if this is what they are told. This situation is aggravated if teachers perceive the science curriculum to be imposed by some higher authority and that quality resides mainly in test/examination results. The gap between school science and real science then becomes unbridgeable.

There is a balance to be sought and an *appropriate* level of uncertainty to be found for the curriculum. (GOODWIN; 2004) Also from a science learners' point of view (and this includes science teachers and scientists too) it is not merely the science found beyond school that is uncertain. Very basic science ideas frequently become much less certain when critically examined in the light of experience or in wider contexts. From a personal perspective it is easy to find examples of 'facts' (or things that I now believe to be true – that at some time in the past I am conscious of having believed and probably 'taught' the converse.) Some of these are listed below, but, of course, it may be that *you* knew the truth all along?

- Some hydro-electric power stations produce more polluting gases (methane and carbon dioxide) per kilowatt hour of power than some coal fired power stations. I believed HEP to be virtually pollution free in operation.
- It takes millions of years for a photon of light to get from the center of our Sun to the outside edge. Since light takes only eight minutes from leaving the Sun to reaching the Earth I had assumed the time to the edge of the Sun would be much less than a minute.
- When an electric current is passed through a solution of hydrogen chloride in water most of the current is carried by the hydrogen ions. I certainly implied in my teaching, that equal amounts would be carried be the hydrogen and chloride ions, since equal numbers of each ion *are* discharged at the respective electrodes.

CONCLUSIONS

It seems vital that the curriculum *as experienced* should reflect the importance of such a *balance* between (fairly) confident knowing, learning and applying information and skills on the one hand and a critical, sceptical, questioning approach to personal learning and the ideas presented by authorities – teachers, examiners, books, TV and the internet.

Hopefully it is clear that engagement, enthusiasm, commitment and trust *should* be nurtured at every opportunity with the objective of developing self-motivated learners. (This in itself implies that some students will choose to be less interested in science than in other aspects of learning – this we have to accept.) Teachers (schools) should try to ensure that pupils are allowed to make informed decisions (even if this means prioritising other subjects than science) hopefully those that decide not to continue with science can still be nurtured to respect scientific ideas and procedures rather than alienated by forcing them through inappropriate science experiences/ courses or qualifications. (It seems unfortunate that this decision in UK is no longer made during the period of compulsory schooling rather than at the end, although perhaps the multiple academic and vocational options becoming available in 21st Century Science will go someway to alleviating this.)

Some key requirements include the following:

- Those setting national guidelines and priorities must legitimate *the search for* an appropriate balance including both important learning and a continuing creative/ critical stance within the classroom/laboratory environment. Teachers must be at the forefront of interpreting this process that must also be reflected in the criteria for inspecting and evaluating the system.
- Teachers must see that such scientific behaviours are valued both *in them and in their students.*
- Students are encouraged to engage critically in their science learning and given credit for this where possible/ appropriate. Asking *good* questions and/or providing critical insights must become expected behaviours in classrooms. Teachers and students will need to learn to manage this confidently, diplomatically and with humour and humanity (and on occasion with humility.)

Hopeful signs appear, the recent Primary Strategy (DfES; 2003) is entitled *Excellence and Enjoyment - A Strategy for Primary Schools;* in the Tomlinson Report and the subsequent 14-19 White Paper (DfES; 2005) student engagement is a central concern. Recent editorials in the Association for Science Education's journal "Education in Science" have begun the process of attempting to re-engage science teachers in the development of the science curriculum: (Ponchaud; 2004) makes some telling comments from his long experience and his recent role as an HMI with OfSTED with responsibility for science:

- *Perhaps the most encouraging aspect of current curriculum change is that it focuses on the needs of pupils.*
- *However, the curriculum is not the same as examination syllabuses, schemes of work or even statutory frameworks; it is about the classroom experience of pupils* (and teachers?) *in its entirety.*
- *If we are to take advantage of the freeing up of the curriculum, then classroom practice is the key. Huge talent, expertise and enthusiasm are available* (in teachers) *which curriculum change can unlock*
- *The following seem to be essential* (highly edited)*:*
  - *Willingness to take risks*
  - *Collaboration and participation*
  - *Celebration*
  - *Valuation of CPD.* (Teacher's learning)
  - *A positive approach. Let's make sure 'bygones are bygones'* p. 4.

(This last point seems to recognise that teachers did have valid cause for complaint?)

A more recent editorial reminds us (Bell; 2005) of the importance of *"engaging critically with science"* p4. Hopefully it will be possible to fully re-engage the science teachers in delivering a science curriculum appropriate for all. It will not be easy. It will never be completed since change happens. It will never be welcomed by *all* students or appreciated by all in authority. However, engaging teachers is the only way to deliver an 'engaging' curriculum. Trust them (and their students) and they will do their best – and their best will almost certainly be better than anyone dares to hope.

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