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Wonder and Science Teaching and Learning: An Update

Maravillas en la enseñanza y aprendizaje de ciencias: una actualización

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Abstract: This paper briefly explores the reasons why we learn science. The word 'WONDER' encompasses three important dimensions, all of which apply to the learning of science: wondering ABOUT, wondering AT and wondering WHETHER. This is based on the author's experience as a science teacher and teacher trainer in UK for over forty years. It is suggested that the system has become too prescriptive and fails to trust students to learn and expects teachers to 'know it all' before beginning to teach. This leaves little opportunity for either pupils or teachers to ENJOY learning science.

Keywords: wonder, teaching and learning of science

Resumen: Este papel brevemente explora las razones por qué nosotros aprendemos

la ciencia. La palabra “Maravilla” contiene tres dimensiones importantes,

que se aplican al aprendizaje de las ciencias: maravillarse acerca de algo al ver con curiosidad y deseando saber más sobre el tema y conocerlo mejor, al verlo con sorpresa y desconcierto y verlos como un potencial que abre múltiples posibilidades.

Se base en las experiencias del autor como profesor de ciencias y como formador de profesores en el reino Unido durante más de 40 años. El sistema tradicional se ha vuelto demasiado prescriptivo y no confía en que los estudiantes puedan aprender y espera que los profesores lo sepan todo antes de

comenzar a enseñar. Por consiguiente, tanto alumnos como profesores tienen pocas oportunidades de disfrutar el aprendizaje de las ciencias.

la ciencia.

Palabras clave: sorpresa, enseñanza y aprendizaje de ciencias

Introduction

It is now seven years since I approached this topic in a presentation to the ASE Conference in January 1994 in Birmingham. This was developed as my Presidential Address to the N.W. Region of ASE in April 1994 and a short paper published (Goodwin,1994). I have been surprised and delighted by the number of times I have been asked to make presentations on this theme. Moreover, in a number of University Departments of Education, the paper became required reading for students beginning a course of initial (primary) teacher training. This present paper has been developed from the presentation made at the Centenary Annual Meeting of the ASE in Guildford in January 2001.

In the first paper I celebrated two 'beautifully ambiguous' aspects of wonder:

- Wondering ABOUT (which reflects the activity of scientists).
- Wondering AT (which reflects the human response to discoveries and understandings and indeed, to our capability of 'wondering').

At that time there were no overarching aims or general rationale for our National Curriculum. Thus, I was really pleased to find the following statement appearing in the final draft of 'Beyond 2000' (Millar and Osborne, 1998)

> "Aims of the science curriculum ……..
>
> Sustain and develop the curiosity of young people about the natural world around them, and build up their confidence in their ability to inquire into its behaviour. It should seek to foster *a sense of wonder, enthusiasm and interest in science* so that young people feel confident and competent to engage with scientific and technical matters ……"
>
> p.2012 Section 5.1

These words were not in the consultation draft, and although I am not claiming credit or responsibility for

the change, I hope I contributed!

It is also very encouraging to find very similar sentiments in the 'official' statement of curriculum aims in the 2000 version of our National Curriculum. (DfEE, 1999). This is the first time that any statement of overarching values and aims has been included. Unfortunately it is not a change which seems to have been significantly emphasised or celebrated. If you have not noticed the words, some of the key ones include:

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

Also, in the statement of values regarding the environment

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

It could be argued that these aims are implicit in the requirement of the 1988 Educational Reform Act that " The curriculum of a maintained school must promote the spiritual, cultural, moral, mental and physical development of pupils . . . . ." However, it seems that making them explicit has been long overdue.

There is no intention to re-present my earlier paper (Goodwin 1994) here, but it is appropriate to list the main sections into which the discussion fell:

1. Science must make sense
2. If we expect pupils to develop enquiring minds, then teachers need to demonstrate these, too
3. Teachers should not know or understand everything about science (but they should continuously explore what they don't know, and re-examine what they (think they) know).
4. Enthusiasm tends to be caught rather than taught (and early experiences can be vital).
5. Pupils need to be actively and intellectually involved.
6. Balance.

It is the third of these, relating to teachers' knowledge of science, which has turned out to be the most controversial although at one presentation I recall an outburst by an exasperated secondary science

teacher when I opened with ‘science must make sense to the pupils’.

> “*We don’t have time for that sort of thing now we have the National Curriculum”.*

With regard to ‘teachers’ knowledge of science’ there is clearly an ongoing debate. There is no doubt that as far as possible teachers ‘should know’ – and should have carefully prepared to teach science subject matter and skills with their classes. However, I would contend that it is *quite inappropriate* for teachers to expect (or be expected) to know all the answers to students’ questions and never to make ‘scientific errors’. What *does* seem to be important is for teachers to listen to students’ questions and *have the confidence* to work with them to find an answer which is mutually satisfactory within the context of their (pupils’ *and* teacher’s) current scientific understandings and purposes. The excellent list of science subject matter published by the DfEE for primary teachers (DfEE 1998) is, in my view, totally devalued and undermined by the statement that it is “the scientific knowledge and understanding which all trainees are required to demonstrate by the end of their course” (p.77). As guidance it is exemplary, as a standard it seems absurd. (Goodwin 2000) The standard is not rigorously achievable by science graduates or by those of us who have been teaching science for 40 years. The meaning and significance of all of the non-trivial statements are problematic and are properly subject to continuing debate. The unfortunate outcome of a simplistic view of learning and of ‘knowing’ is that it trivialises the process and undermines confidence and motivation. It also tends to push *science* off a science teacher’s personal professional development agenda, most particularly since he/she has already been certified as ‘knowing all that is deemed necessary to teach science’.

One pertinent official statement, which again does not seem well known – or when heard tends to be treated with scepticism, is to be found in the Ofsted report on KS3 science. (Ofsted, 2000).

> “*Many science teachers feel under great pressure to cover the content prescribed by the National Curriculum and alas, in consequence are insecure about going beyond it or leaving material out. Some of the* ***best teachers*** *inspected as part of this survey were less constrained by the Programme of Study; they adjusted the content, teaching approach and pace of lessons to meet the needs of their pupils (see Section 5). More-able pupils were challenged by material and ideas beyond those in the National Curriculum and pupils who were struggling were enabled to consolidate basic ideas.* ***All teachers should have the confidence to respond flexibly*** *to the National Curriculum; they need to be* ***reassured that the responsibility for making decisions about how the National Curriculum is applied in the classroom is still theirs”.***

(The emphasis is mine.)

It may be that I am a gullible idealist to find hope in such statements. However, it does seem to encourage us to view the National Curriculum more as a guiding framework. Nonetheless, it is clear that whilst standards are measured almost entirely by test and examination performance and these are seen as the dominant measures of quality, it is inevitable that most teachers will focus on short term goals which maximise attainment scores. They will play safe, stick to the syllabus, keep pupils ‘on task’ as far as possible and not step far beyond the bounds of the expected assessment tasks. In this context following pupils’ interests and enthusiasms is a risky, as well as time-consuming, business. Moreover, teachers’ *own*

interests in science seem not to be valued or even made legitimate. This is despite the fact that it is *specifically* these aspects of science which will most engage the teacher and in which s/he will have most confidence. It is from here that enthusiasm and motivations for science are most likely to be caught by pupils.

At this point I will briefly explore some of the ‘wonders’ that I so much enjoy, even after many repetitions, whilst sharing them with colleagues and students (KS2 and above.)

I still am amazed by the oscillating reaction. This was included in the first paper (Goodwin 1994) and I have since discovered the wonder of the tornado-titration. (Goodwin 2001a) Essentially this consists of carrying out a titration in a large beaker in which one of the colourless reagents (e.g. dilute HCl with phenolphthalein indicator) is slowly stirred. The other reagent (dilute NaOH) is added slowly into the centre of the vortex. Further the primary school ‘show stoppers’ of the hydrogen balloon* and the ‘eggsperiment’* still provide me with a feeling of anticipation and of wonder.

(* See note at the end of the paper.)

Values and Science

This brings me, via a somewhat circuitous route, to an extension of the ‘wonder theme’ which was certainly not explicit within my earlier paper. That is ‘WONDERING WHETHER’. This dimension encapsulates another range of questions:

- should I do this?
- must I do this:
- would this be better than that?
- is it right?
- why is this significant/important?

These questions take us into the realms of moral and ethical judgements and need to apply at a personal, family, community, national or even at a global level. Such questions impinge upon concepts such as:

- good and evil (less emotively, better and worse)

- rights and wrongs
- reward and punishment
- reconciliation and strife
- forgiveness and continuing resentment
- friendship and enmity

These are not, in conventional terms, susceptible to approach by empirical scientific methodologies or even to a theoretical scientific analysis. In his book, 'The Limits of Science' Peter Medawar (1986) indicates (p.66) "*the existence of questions that science cannot answer and that no conceivable advance of science would empower it to answer. These are the questions that children ask, - the 'ultimate questions' of Karl Popper. I have in mind such questions as:*

- *How did everything begin?*
- *What are we all here for?*
- *What is the point of living?"*

Explicitly, Medawar was not a religious man, but in terms of ethics and values his own position (p.96) is as follows. *"I should like my behaviour – short of overt acts of worship or the avowal of beliefs I do not hold – to be such that people take me for a religious man in respect of helpfulness, considerateness and other evidences of an inclination to make the world work better than it otherwise would be."*

There are value judgements implicit in every decision that we make. A fairly trivial example that comes to mind is whether to buy a cup of coffee, keep the money in my pocket or donate it to charity. There really is no way of getting away from making value judgements – in addition, as is explicit in the 'Prayer Book', things we do *not* do can be as important as the things we do.

But how does this affect science teaching? (For a more detailed exploration of beliefs and values in science education, Michael Poole's (1995) book is a useful starting point.) It seems that the inclusion of some of the ethical and moral issues raised by 'progress' in science and technology is a fairly common way of including the 'wondering whether questions'. A fairly cursory examination of most science lessons generally provides little evidence of an expectation that *students* will make any value judgements at all. In a very real sense the choice for many pupils is limited to whether they should actively engage with the lesson or mentally to go elsewhere. They *are required* to be present and to do as they are told. Most of them do these, but do they expect to actively make meaning of the science for themselves? Sometimes the answer to this question, thankfully, is 'Yes'. Here the focus is *not on the content of the curriculum*, even though it may be valuable to consider controversial topics such as drug usage, economic and environmental issues and sex education. **The focus is on the learning process itself.**

It seems clear, not least from the educational aims, which now grace the front pages of our National Curriculum, that we should expect our pupils to 'develop enjoyment of, and commitment to, learning'

science. (Although, I should stress here that this is not seen as an alternative to hard work or as lessening the need to prepare for and to pass examinations. It is an important question of balance.) There is a serious value judgement implicit here that only pupils can make. Surely by KS3 there should be some considerable progress in this direction since students need to be self-motivated and independent learners by the time they reach 16 or 18? Are we afraid that pupils, given the chance, will avoid learning science? There is a dilemma emphasised here since science became a *compulsory* core subject to age 16 in 1988. However, doubtless under present circumstances, a substantial minority of pupils ascribes so little value to school learning that, given a choice, they would avoid all or most subjects within the curriculum.

I have no easy answers to this and I'm sure I am being idealistic, but it seems to me that *in general* we teachers, under pressure from official inspectors, quality standards and national league tables, take too much responsibility for students' learning. Neither we nor 'the system' *trusts* students to learn, so how do we expect them to develop appropriate values and exercise them? Here seems to be an appropriate place to share the precepts of the 'having' and 'being' modes of learning as summarised by Erich Fromm (1979). These are given in Table 1, but a key aspect of the 'being' mode is:

> "--- they (students) listen, they hear and, most important, they respond in an active, productive way."

What seems crucial is the *joint enterprise in learning science* in which the teacher and students engage in together. Of course there are external constraints like timetables and the syllabus as well as intermediate goals like examinations, but these must not be enabled to dominate to such an extent that they exclude interest, enthusiasm or meaning. This is another example of the need for *balance*.

In my experience it has been on the, relatively rare, occasions that my students have taken control of their own learning that *real* progress was made. This is *also* highly significant for me, because the highest quality examination results were also obtained under these circumstances. More than that, I can confirm that the teachers' learning also moves on apace under these exhilarating conditions. It is this experience, which convinces me of the wrongness of expecting teachers to know all the answers *before* qualifying and the danger of *even suggesting* that they could.

It also brings me full circle to the three WONDERS of teaching and learning sciences. The new wording that introduces the science section of the National Curriculum (DfEE, 1999) to emphasise the importance of science begins: -

"Science stimulates and excites pupils' curiosity about phenomena and events in the world around them …."

Hopefully, **it is legitimate for us to get excited *with* them**?

* * * * * * * * * * *

*** Note:** These two demonstrations are valued ingredients of a presentation to primary school pupils on 'floating and sinking'. The first involves filling a balloon with hydrogen and showing that it floats upwards when released in the air – tied to a thread. With care this can be disposed of 'wonderfully' with a lighted taper.

The 'eggsperiment' is done by putting fresh eggs separately into containers of tap water and saturated salt (Sodium chloride) solution. The eggs sink and float respectively. If a tall container is half-filled with saturated salt solution and then *carefully* almost filled with tap water (so that the two liquids do not mix much), then an egg floats half way down the container. Actually it sinks in water and floats on the salt solution.

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Table 1: The 'having' and 'being' modes of learning. (Fromm, 1979)

Having	Being
Students: - will listen to a lecture, hearing the words, their logical structure and their meaning and, as best they can, will write down every word…. So that later they can memorise their notes and thus pass an examination.	Students: - …do **not** go to a course of lectures, even to the first one of a course, as 'tabulae rasae'.
	…. they have been occupied by the topic and it **interests** them.
- the context does **not** become part of their own individual systems of thought, enriching and widening it.	(NB. Interest = *inter-esse* = *to be in or among*.)
- they transform the words they hear into fixed clusters, or whole theories that they store up.	…. they listen, they hear and, most important, they receive and they respond in an active, productive way.
- the students and the content of the lecture remain strangers except that each student has become the owner of a collection of statements made by somebody else (who has either created them or taken them over from another source).	…. new questions, new ideas, new perspectives arise in their minds. Their listening is an alive process. They listen with interest . . . they do **not** simply require knowledge….
- students must have but one aim, to hold on to what they 'learned' by memorising or by guarding their notes. They do **not** have to produce something new.	…. each student has been affected and has changed.
	Clearly, the lecturer too must 'BE'.

The above is worded to apply within a formal lecture context, but it is relatively simple to envisage modified statements that would apply to other learning modes such as self-study, laboratory work and investigations.

A version of this paper was published in the School Science Review. This is an Official Journal of the Association for Science Education (ASE) in UK. See Goodwin (2001b).