
**Towards a more authentic science curriculum:
the contribution of out-of-school learning**

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Abstract

In many developed countries of the world, pupil attitudes to school science decline progressively across the age range of secondary schooling while fewer students are choosing to study science at higher levels and as a career. Responses to these developments have included proposals to reform the curriculum, pedagogy and the nature of pupil discussion in science lessons. We support such changes but argue that far greater use needs to be made of out-of-school sites in the teaching of science. Such usage will result in a school science education that is more valid and more motivating. We present an ‘evolutionary model’ of science teaching that looks at where learning and teaching take place, and draws together thinking about the history of science and developments in the nature of learning over the last hundred years or so. Our contention is that laboratory-based school science teaching needs to be complemented by out-of-school science learning that draws on the actual world (e.g. through fieldtrips), the presented world (e.g. in science centres, botanic gardens, zoos and science museums) and the virtual worlds that are increasingly available through information technologies.

Background and introduction

In many developed countries of the world, science education is seen to be in crisis. Pupils' attitudes to school science decline progressively across the age range of secondary schooling and declining numbers of students are choosing to study science at higher levels and as a career (Goodrum *et al.*, 2001; Osborne and Collins, 2001; Haste, 2004; Sjøberg *et al.*, 2004). For some time science educators in many countries have expressed concerns that current provision in schools (especially at age 14-16 years) is all too often boring, irrelevant and outdated; designed only to educate a minority of future scientists, rather than equipping the majority with the scientific understanding, reasoning and literacy they require to engage as citizens in the 21st Century (Sjøberg, 1997; Millar and Osborne, 1998; Goodrum *et al.*, 2001).

In contrast to this, the science and the ways in which it is communicated, in places outside of schools (science museums, hands-on centres, zoos, botanical gardens, etc.) is often seen as exciting, challenging and uplifting. In these places new technologies and advances in our understanding of learning in informal settings have been put to good use (Popli, 1999; Godin and Gingras, 2000). In the UK, educational provision in the informal sector has been stimulated by government policy shifts and by large-scale investments (Anderson, 1997). In pupils' homes, the growth in use of multi-channel television and the internet have spawned sources of high-quality and attractively packaged information about science and issues of relevance to young people. A recent survey in the UK showed that time spent on ICT in the home (excluding gaming) now greatly exceeds that spent at school (DfES, 2002). Newspapers and magazines offer additional rich sources of science and debates about recent, relevant and often

controversial issues, though a recent study reveals that they are not so obvious (as science centres and museums are) to learners as a source of scientific learning (Jarman and McClune, 2004).

The educational experience for learners at home and in the informal sector in science is often in stark contrast to what is on offer in schools. A conundrum for science educators is that pupils of school age are being turned off science in their schools yet the same pupils may be entertained and engaged by science outside them. Ross, Lakin and Callaghan contrast school and out-of-school learning of science in a rather revealing way, using a horticultural analogy (see Figure 1).

>Insert Figure 1 about here<

In the first of the images on the left of Figure 1, school science is juxtaposed with experiences in the pupil's other or out-of-school world. A fence divides the highly structured world of school science, organised as seemingly disconnected topics, from the more diverse, rich, often less structured but more integrated world of experience outside school. In the second image on the right of Figure 1 the examination system (GCSEs are taken by 16 year-olds in England and Wales) harvests the school knowledge of science but leaves little to last in the memory, whilst the other, unassessed world outside school remains a rich source of experience and knowledge to be savoured. In Ross, Lakin and Callaghan's words:

At best they (pupils) have a scientific system that is good enough to pass examinations. But after the crops have been harvested the land is bare, the ideas are lost and everyday life is unaffected. (Ross *et al.*, 2004, p. 56)

Pupils of school age spend about two-thirds of their waking lives outside formal schooling yet educators tend to ignore, or at least play down, the crucial influences that experiences outside school have on pupils' knowledge and understandings, and on their beliefs, attitudes and motivation to learn. The value that pupils themselves place on these experiences, over some of those provided by schools, in helping them learn science was revealed in a survey of pupils' views about learning science carried out recently in the UK. Out of eleven alternative strategies for learning science, 'going on a science trip or excursion', was rated the most enjoyable way of learning and the fifth most useful and effective (Cerini *et al.*, 2003).

In recent years there has been a huge investment to provide opportunities to communicate science in museums, science centres, botanic gardens, zoos, field centres and at industrial and commercial sites. In the UK this development was accelerated by grants totalling over £1 billion awarded by the Millennium Commission so that by 2004 it was estimated that every major centre of population in the UK was now served by at least one such provider (Ecsite-uk, 2005).

In this article we examine the contribution that out-of-school contexts can make to pupils' learning in science. Our view is that these contexts should be seen as complementary to formal schooling rather than as in competition with it. We argue that school science is currently modelled on an outdated and restricted representation of

science, so that virtually all school science teaching is undertaken in laboratories, and that drawing on the wider community of science and ways in which science is undertaken and from the range of contexts in which it is communicated outside schools will result in a more authentic science curriculum.

The notion of authenticity in the context of science education has been raised by a number of authors (Roth, 1997; Hodson, 1998; Woolnough 1998; Bencze and Hodson, 1999). Bencze and Hodson (1999), however, warn that it is an elusive and problematic notion with diverse meanings and implications for curricula. There seems, though, to be some consensus, at least in terms of practical work in school science, that authentic school science should provide experiences that are more in line with the sorts of activities that scientists and technologists do in the real world of science and that such experiences should include student-directed tasks and more open-ended enquiries. In other words, authenticity applies both with regard to the subject matter of science as practised out of school ('experiences that are more in line with the sorts of activities that scientists and technologists do in the real world of science') and with regard to school students themselves ('such experiences should include student-directed tasks and more open-ended enquiries').

In a critique of school practical work, Hodson (1998) refers to a number of 'myths' about science and science education that are transmitted consciously or unconsciously by teachers and in curriculum materials:

1. Observation provides direct and reliable access to secure knowledge.
2. Science starts with observation.

3. Science proceeds via induction.
4. Experiments are decisive.
5. Science comprises discrete, generic processes.
6. Scientific inquiry is a simple, algorithmic procedure.
7. Science is a value-free activity.
8. The so-called ‘scientific attitudes’ are essential to the effective practice of science.
9. All scientists possess these attitudes.

(Hodson, 1998, p. 95)

We accept that these myths might exist and could result in a sterile and less valid school science but our view of an authentic science curriculum is one that goes beyond the critique of practical work. It draws on the ways in which our understandings and attitudes to science, school science and the nature of learning have changed over the last hundred years or so. Later we present an ‘evolutionary model’ that draws together this thinking and relates it to more philosophical issues on the nature of science and science learning but first, it is necessary to highlight some of the contributions that out-of-classroom learning can make to science education.

The contribution of out-of-school contexts to learning science

In this section we present what we believe are key contributions that out-of-school contexts can make to the learning of science for school-aged pupils. First, it is necessary to establish where this learning takes place and how it can arise. Learning can be

initiated by the home or by the school. For example, a school visit to a museum, an industrial site, planetarium or zoo might be planned and led by the teacher as part of the science curriculum or as an extra-curricular activity. Home-initiated learning might be home-situated, such as using the internet, watching TV or reading printed media, or it can take place out-of-home in the case of such things as bird-watching, walking, playing sport or visiting museums.

Five ways in which out-of-classroom contexts can add to and improve the learning of science are described:

- i) Improved development and integration of concepts.
- ii) Extended and authentic practical work.
- iii) Access to rare material and to 'big' science.
- iv) Attitudes to school science: stimulating further learning.
- v) Social outcomes: collaborative work and responsibility for learning.

The first three address what might seem conventional attributes of school science as often discussed by curriculum developers and policy makers and that have direct implications for pedagogy and learning in science. The last two are more concerned with wider dimensions of learning and attitudinal and social factors and as such are not unique to science education, though we maintain that they have a major impact on it.

Improved development and integration of concepts

One of the first things teachers often want to know if thinking of investing time, effort and finance in out-of-school learning is “What is the pay-off in terms of my pupils’ knowledge and understanding of science?”. To a certain extent we think this may be a case of asking the wrong question and we return to this point later. Nevertheless, it is a reasonable and natural thing to ask and although the research evidence of learning gains for pupils from out-of-school science learning is still rather scant, there are notable exceptions. For example, Dierking and Falk (1994, 2000) review studies that have detected improved understanding of such classic school science concepts as force and motion as measured using pre- and post-tests of knowledge following museum visits; the influence of home-initiated activities in the environment (such as bird-watching and wildlife walks with parents) has been found to have an impact on pupils’ performance on animal classification tasks (Author 1, 1991); visits to industrial sites have been found to improve pupils’ (and teachers’) knowledge of industrial processes and this learning is long-term (Parvin, 1999; Stephenson and Parvin, 2004).

A well-versed criticism of learning science in less formal contexts such as science centres is that science learning is rarely substantial, that misconceptions are initiated or fostered, and that engagement through enjoyment of the interactions that take place is far more important than educational gains so that claims for any true learning may even be dishonest. In a famous article in the science journal, *Nature*, Michael Shortland put it like this:

At interactive science centres children have fun participating in a series of experiments, but they learn little science and may acquire a good many

misconceptions which at the very least fail to match those offered in the captions. (Shortland, 1987, p214)

For Shortland and others, the problem seems to be one of ‘clashing agendas’. In this sense the intentions of visiting out-of-school contexts to entertain, motivate and interest pupils in science are seen as difficult to reconcile with mastery of scientific ideas, concepts and laws. But is this not the same problem faced by science teachers in almost every lesson in school? Work by Falk *et al.* (1998) shows that a mixture of motivations for education and entertainment produces the most significant learning gains. In a study of 65 individuals visiting a museum in the US they found that the use of vocabulary and ‘mastery of concepts’ associated with the science of gems and minerals had advanced most for those visitors who were found to have high levels of motivation in both educational and entertainment dimensions. Those with high entertainment motivation but very low educational motivation showed gains in some areas, particularly in the application of vocabulary, but scored lowest in terms of mastery of concepts. Studies in a science centre in Finland by Salmi (1993) provide evidence that high levels of intrinsic motivation (a real interest in the topic studied) rather than extrinsic motivation (where the goal may be to pass an examination) are linked with gains on cognitive tests following interactions in hands-on galleries.

Science is indeed generally hard to learn as much of the research over the last 25 years into children’s learning in science has shown. Yet, when pupils visit or are taught in places that explain science in often new and exciting ways, they frequently seem to be more enthused. There is, we believe, something about these contexts and places that

brings about a change through increasing the desire in people to find out and understand more.

Extended and authentic practical work

By extended practical work we mean the opportunity to engage in activity that would not be possible in the normal school laboratory either because of safety considerations or because of new opportunities that arise. These include, for example: launching rockets, ecological surveys, observation of the night sky, large scale experiments of combustion and so on. Practical science in out-of-school contexts is more ‘authentic’ than much of what goes on in school laboratories when it helps demonstrate or replicates the sort of work that scientists frequently undertake in modern science or if it is perceived as having relevance to solving real-life problems. For some authors, reflecting on authentic school science (see for example, Woolnough, 1999), fieldwork provides the ideal example of authentic practical work, mainly because it provides an opportunity to challenge the myths propagated about practical science in a school laboratory referred to by Hodson (1998) and listed above.

It is important to remember, however, that out-of-school learning should not be equated only with ecology. There are many examples from other areas of science that provide good examples of more authentic practical experiences than often occurs in school. For example, pupils have been found to value practical work where it is seen in a different context to that in school, e.g. in the case of visits to industrial or commercial premises (Stephenson and Parvin, 2004). Theme parks are popular with pupils and offer the

chance to engage with advanced physics (e.g. studies of acceleration and pendula) applied in a leisure environment (Swinbank and Lunn, 2004). Additionally, children's museums provide first-hand experiences with authentic objects and are popular with younger learners (Moussouri, 1997). Indeed, museums for visitors of all ages are increasingly providing experiences that actively engage visitors (Black, 2005).

Access to rare material and to 'big' science

A traditional role of places such as museums, botanic gardens and zoos is to act as a repository of typical or rare (even unique) specimens and artefacts forming a reference point for the accumulation and enhancement of scientific knowledge. Collections provide opportunities for pupils to see and sometimes handle specimens and artefacts, raise questions about their origins and significance and place them within histories illustrating the development of technologies and scientific thought. In this way artefacts and collections and the stories associated with them help teach about the ways in which scientific and technological knowledge has been generated and the social enterprise in which those who engaged in this work operated.

By 'big science' we mean the sort of science that requires large or sophisticated equipment (e.g. radio telescopes, particle accelerators, electron microscopes, large-scale DNA sequencing equipment) and often collaboration on an international scale (Swinbank and Lunn, 2004). People can find 'big' science inspirational and controversial. On the one hand, there is the excitement of research into big questions such as 'What are we made of?' and 'What will be the ultimate fate of the universe?'

On the other hand, there are questions about whether the financial costs of the enterprise can be justified. A visit to a research telescope, space centre or genome campus is an excellent way to give pupils an appreciation of ‘big’ science.

Artefacts, collections and the histories that surround them as well as examples of big science have much to offer in terms of helping students appreciate the nature of science and the scientific enterprise, an area that few pupils of school age seem to be aware of (Driver *et al.*, 1996).

Attitudes to school science: stimulating further learning

Currently in the UK, as in many other parts of the developed world, pupils’ attitudes to science, and in particular school science, are far from positive and decline markedly as pupils progress through secondary school (reviewed by Bennett, 2003, Chapter 8). For us, the fundamental issue is the ways in which out-of-classroom contexts provide new connections with science and stimulate people to dig deeper and think more about science and its relationships with society. When reviewing research in science centres, Rennie and McClafferty (1996) advise re-focussing concerns about outcomes of learning in these more informal settings away from the understandable concerns of most teachers to see cognitive gains in their pupils towards a deeper relationship with learning:

The key question is not: do people learn science from a visit to a science centre? But, do science centres help people to develop a more positive relationship with science? (Rennie and McClafferty, 1996, p.83)

We see this as crucial in pointing out the level of peoples' future engagement with science and therefore in helping raise levels of scientific literacy. If the pay-off from out-of-school learning of science that is integrated within a more authentic science curriculum is more engaged and positively oriented science students then school learning must surely benefit.

Social outcomes: collaborative work and responsibility for learning

Schools are places where learning is structured into topics, dictated by the requirements of examinations and confined by timetables (as shown in Figure 1). In out-of-school contexts (e.g. a field trip) new opportunities arise where activity, although of course subject to new constraints, is less constrained by school bells and lesson times. Work can be more extensive and thorough and provides more autonomy for learners. There are opportunities for pupils to take responsibility for themselves and others, by working in teams and for active consideration of the environment (Amos and Author 2, in press). For pupils, the benefits that accrue from collaborative work and socialisation are particularly strong when a residential experience is included (Bebbington, 2004). For example, the opportunity to study interrelationships in habitats over longer timescales is possible (Bebbington describes studies that can take place over 24 hours). Some experiences are serendipitous; the observation of a sunset, seeing badgers emerging

from their sett, overcoming a fear of the dark. According to Bebbington and to Nundy (2001) the important feature here is that pupils begin to draw on a range of experiences that they would not normally see as learning opportunities and to appreciate that learning has wider boundaries than schooling.

In some ways this can be seen as a reference back to writings of the early pedagogues. For example, Comenius and Rousseau both wrote about education as encompassing all experience whether from home, in the environment or through formal instruction (Author 1 and Author 2, 2004). They valued the contribution that each could make to the development of the individual. In more recent times we have come, albeit often implicitly, to equate education only with schooling. We shall now go on to argue that a wider conceptualisation of the locations within which worthwhile school science can take place (i.e. including out-of-school contexts) to a certain extent parallels developments in conceptualisations about the workings of science itself.

An evolutionary model for more authentic school science

In a book that brought together much of his life's work, John Ziman began by acknowledging that science is under attack (Ziman, 2000). He went on to characterise the view that science has an all-conquering intellectual method as 'the Legend'. As he put it:

The moral basis for the defence of science must be a clear understanding of its nature and of its powers. One might have thought that this understanding

was already widely shared, especially among working scientists. Unfortunately, this is not the case. Most people who have thought about this at all are aware that the notion of an all-conquering intellectual method *is* just a legend. This legend has been shot full of holes, but they do not know how it can be repaired or replaced. They are full of doubts about past certainties, but full of uncertainties about what they ought now to believe.

(Ziman, 2000, p. 2)

Ziman went on to argue that there are, nowadays, new modes of knowledge production in science. He talks about the heyday of science between, say, 1850 and 1950, whereas today we live in an era of ‘post-academic science’ characterised by a great emphasis on work that is transdisciplinary, collective, more utilitarian, more political, industrialised and more bureaucratic. For the purposes of this paper, we wish to emphasise in particular the way in which contemporary science draws on a wide range of inputs, experiences and technologies in a variety of places. Of course, laboratories are important but for almost every scientific phenomenon, the laboratory is not *the* site but only one site of knowledge production. Once again we emphasise our intention is not to denigrate or get rid of school laboratories; rather it is to see them as just one locus within which school scientific learning takes place.

>Insert Figure 2 about here<

In Figure 2 we suggest an evolutionary model for more authentic school science. Figure 2 is intended to be read heuristically: as an historical analysis it obviously oversimplifies. However, we believe it makes three valid points:

1. There is a correspondence between how science has changed (the boxes headed ‘Classical 19th/20thCentury science’ and ‘Contemporary collaborative, trans-disciplinary science’) and how school science needs to change.
2. Our arguments for the greater importance that needs to be accorded in science education to out-of-school learning sit alongside the emphasis that is increasingly given in school science courses to a shift from ‘Transmission learning’ to ‘Constructivist learning’ (the boxes at the bottom of Figure 2).
3. Our vision is one in which school science draws on more sites of valid data gathering and knowledge production.

For the sake of clarity, we want to erect a ‘straw man’ view that emphasises the adequacy of the school laboratory as a site for learning in school science. This straw man view proceeds along the following lines:

The job of science is to uncover the laws of nature. However, nature is far too complex for students to be able to do this. The best way forward is therefore to ensure that students learn science in school laboratories. In such laboratories, variables can be controlled so that students can see that in the absence of friction, objects do continue to move at constant velocity; that crystals of sodium chloride can be dissolved in water and reconstituted once the water evaporates; that silt sediments more slowly than sand; and that respiring organisms produce carbon dioxide and water vapour.

Both of us were reared in science classes that operated along these lines and we do not want to lose such activities from school science. However, our point is that there is

more to science and that students know there is. In the 1960s such activities may have been enough to enthuse students, to attract them into further study in science and to give them a good idea of how science proceeds. Nowadays, though, such activities, when they make up the entire diet of school science, fail to satisfy. No wonder intelligent students decide science is not for them. It is not science that they are rejecting but the pale imitation of it that is all too often served up in school science laboratories.

Whilst the above may seem overstated, empirical work both on teachers' views and on historical changes in the curriculum (Donnelly, 1998) show that this 'straw man' is not too much of a caricature. Donnelly showed how science teachers in England divided their lessons into 'theory' and 'practical work' and concluded that "pupil laboratory activity appeared to be central to science lessons in the view of most of the teachers interviewed" (pp. 588-9). One teacher indicated the centrality of practical work by saying:

The two lessons you have seen today, to my mind they are relatively standard. There is an introduction about what we are going to do, how it fits into the scheme of things. There is then a description of maybe a practical exercise. ... We then go ahead and do it. We look at the results ... we summarise them and draw some conclusions, we send them home to write it up as homework. I would regard that as fairly standard fare for science education. (Donnelly, 1998, p. 588).

Donnelly goes on briefly to examine the extent to which the laboratory structures the practices of science teachers, a structuring indicated famously by the title of Delamont

et al's (1988) paper 'In the beginning was the Bunsen: the foundations of secondary school science'. We believe that one way of looking at the laboratory as a structuring device is to see it as an attempt to strip away the context within which science takes place. The model, then, becomes one in which 'real' science is that which is an abstraction; the 'real' world is then seen as that somewhat imperfect envelope within which science is wrapped. To give an illustration: it can then be accepted that glaciers are retreating, that spring comes earlier, that sea levels are rising but the debate as to whether or not global warming is taking place goes on, since whatever evidence is adduced in support of that hypothesis – e.g. that thermometers indicate that the atmosphere is getting warmer – can either be refuted (the thermometers are in towns and therefore merely reflect urban, not global, warming) or re-interpreted (the warming is caused by sunspots, or is cyclical, or whatever).

To continue the analogy: it is worth stripping a car engine provided it can be re-assembled. One of us has been involved in the development of a context-based course for advanced level biology students (Author 2, in press). School science courses have traditionally been constructed from a scientist's viewpoint with the concepts being developed in a way that is seen to be sensible by a scientist. Typically this means that pre-eminence is given to scientific concepts (Hart, 2002). But many students see things differently and want teachers to show them *why* the concepts are important. One possibility is to make the context the driving force. There are many ways of understanding the term 'context' but for the purposes of this paper we wish to emphasise the potential for out-of-school learning to enhance valid school science and show how learning is consequently made more authentic.

Practicalities and potentialities

We acknowledge that the science classroom, the laboratory, has a special place for the great majority of secondary science teachers. We can see two principal reasons for this:

1. Laboratory teaching, as we have argued above, shapes knowledge production. Laboratory-produced knowledge is seen as having higher worth than other sorts of knowledge.
2. While there is some variation among science teachers – so that, for example, a science teacher with a specialism in ecology may feel most at home on a biology field trip – most science teachers were reared within a model in which the well stocked laboratory played a key, possibly the central role. Teaching within a laboratory then becomes a part of our professional identity (reinforced, we suspect, by such markers as lab coats and certain items of apparatus/furniture, such as fume cupboards – even when rarely used). In many countries secondary science teachers enjoy certain ‘perks’ as a result of their laboratories: they have laboratory technicians to assist them; they have a ‘prep’ room which may double-up as a place for relaxation or a cup of coffee; science laboratories are less likely than ‘normal’ classrooms to be commandeered for other activities because they are relatively inflexible and, perhaps, somewhat alienating to non-science teachers.

As a consequence of these perceived traditional benefits there can be resistance to relying less on the laboratory for learning in school science. Such practical difficulties

as the trouble and cost of arranging visits to out-of-school sites are additional factors that might constrain science teachers to the laboratory. To illustrate how out-of-school learning goes beyond what is possible in the school laboratory in providing for a more authentic learning of science, we draw on three examples; the potential of ICT at home, the potential of botanic gardens and the potential of chemistry trails.

That ICT can assist in the learning of science is hardly a novel idea. However, Wellington and Britto (2004) look in particular at the implications of ICT use at home for science teachers in school. One point they make is particular apposite to the notion of authentic science, and that is that control that the home use of ICT gives to the learner (Table 1). Such control can be threatening to teachers since there is a tension between conceptions of classroom learning and out-of-school learning with ICT. If though, such threats can be overcome, learning science through ICT can complement learning through laboratory practice.

>Insert Table 1 about here<

Botanic gardens are perhaps less well known than science museums, science centres and zoos as sites of science learning yet they have a long history in education and great potential in developing scientific, including environmental, literacy (Johnson, 2004). However, it is not a straightforward matter to maximise the educational benefits of a visit to a botanic garden (or any other 'placed' location for out-of-school science education):

Obstacles to an effective teaching and learning situation stem firstly from the cognitive frameworks that the children bring with them. In the classroom they develop a routine for lessons, some of which are derived from formalised teaching strategies. If the themes, sequences, interpretative materials or narratives used in the garden are outside these compartmentalised frameworks, children may not recognise the visit as a lesson. They might also disregard what they come to understand during the experience because it is their own construction of knowledge. (Johnson, 2004, p. 79)

This can be read as a form of learned helplessness. It illustrates the need, if schools have built up effective barriers to knowledge (with valued knowledge being in laboratories or school libraries and perhaps dissociated from ‘fun’ activities, such as a day out) to enable such barriers to be deconstructed.

The chemistry laboratory is seen by secondary pupils as being perhaps definitive of school secondary science. Indeed, it has been argued that:

To most students and their teachers, chemistry is something which happens in test tubes in laboratories or in tangled masses of pipes in factories. They need to be shown that chemistry is not something remote but that it is going on all around us, all the time. (Borrows, 2004, p. 151)

Chemistry trails are a way of connecting school chemistry to the real world. In the mantra of many students: it can make chemistry ‘relevant’. Chemistry trails are not

difficult to create and Borrows (2004 and references therein) provides many suggestions; for example, they can be used to study such topics in applied chemistry as building materials and air pollution. Of course, pupils can create their own trails too.

Conclusions

Attempts to deal with the perceived problems of declining pupil attitudes to school science and the low take up of science in the post-compulsory phase have looked at such issues as the curriculum, pedagogy, pupil practical work and pupil discussion (Millar and Osborne, 1998; Wellington, 1998; Mortimer and Scott, 2003) and proposed changes. We support such developments. Our purpose in this paper is to argue that the site of learning needs re-examination too. Our contention is that school science is too restrictive: for all the advantages of school laboratories, they constrain the activities that take place. This leads to an attenuated presentation of science – one that is less authentic as well as less motivating.

Out-of-school science activities occur in a number of forms. Fieldtrips – whether residential ones (e.g. for ecology) or short ones (e.g. chemistry trails) – allow pupils to engage with science in what can be termed the *actual* world. Outings to museums, botanic gardens, zoos and science centres allow pupils to engage with science in what can be termed the *presented* world (cf. Macdonald, 1998). Richer use of IT allows pupils to engage with science in *virtual* worlds. Of course, the ‘actual’ world encountered on fieldtrips is itself a ‘presented’ world and the ‘virtual’ worlds of IT have their actual components too (for example, when on-line video cameras are used to

monitor the behaviour of animals – the number of these now available for science education is huge. Entering “video camera on-line puffin” into Google on 25 June 2005 gave about 42 100 results).

Museums and other informal sites of learning have had to work hard to attract visitors precisely because attendance at them is not compulsory. In almost all countries school science has both the advantages and disadvantages of being a compulsory subject and one that is greatly valued by those who control the curriculum, albeit not always valued by those who sit in the resulting lessons. What is clear is that in an increasing number of countries the quality of presentations of science in the media (including TV) mean that the days are long gone when pupils of secondary age would be impressed by a demonstration of a collapsing can when attached to a vacuum pump, the growth of copper sulphate crystals or the meanderings of desiccated woodlice or dazzled maggots.

What we need is a great deal more thought about the potential for learning science outside the classroom (Falk, 2001; Author 1 and Author 2, 2004). If we can get it right, there is every chance that the school laboratory and teacher-enabled discussions among pupils in science classes can complement and extend out-of-school learning. If we get it wrong, not only may we continue to lose many of our best students from science but the very worth of school science may increasingly be questioned by those in power who sanction the use of large amounts of money on school science laboratories, technicians and teachers.

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Figure 1: Images of learning science.

(From Ross, Lakin and Callaghan, 2004, p.57)

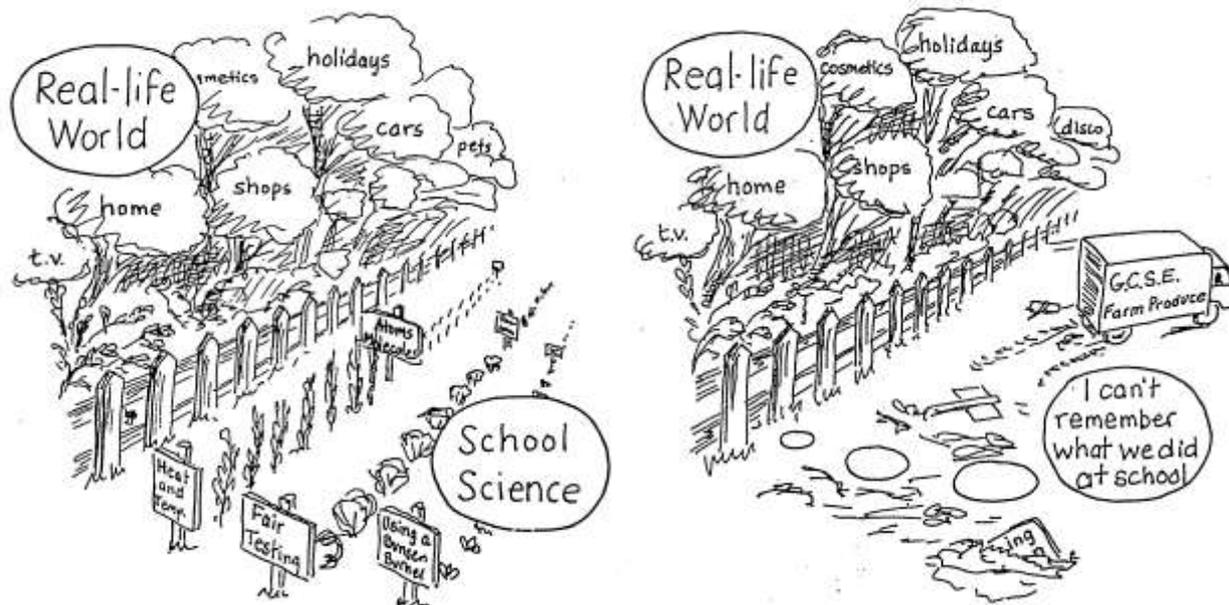
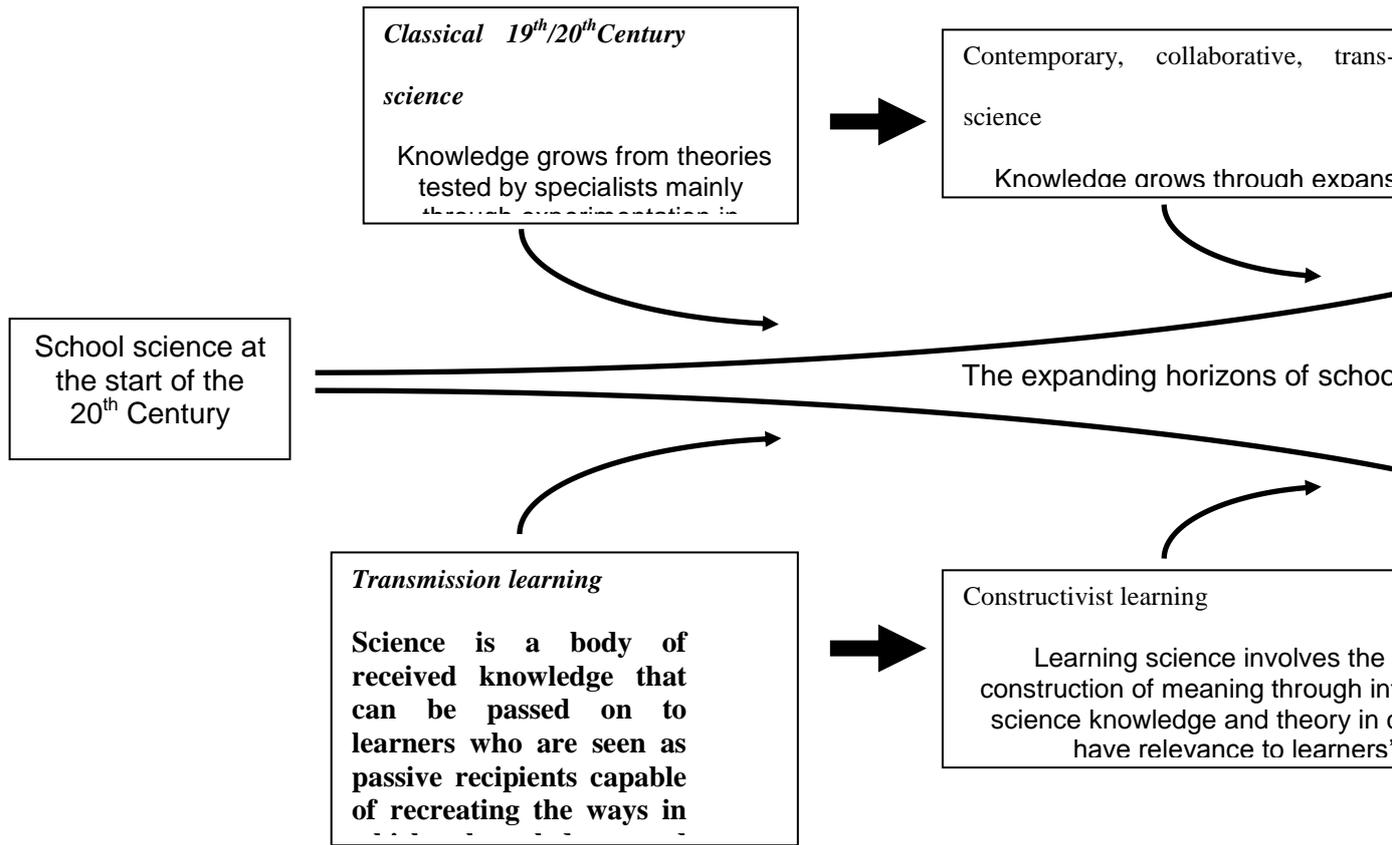


Figure 2

Figure 2: Towards a more authentic school science: an evolutionary model

The nature of science



The nature of learning

Table 1

<i>Classroom learning</i>	<i>Learning through ICT</i>	<i>Home learning</i>
Conformity and order is central; learning is compulsory and collective	Personal empowerment is central; learning is individualised (usually)	Voluntary; personal; individual (often)
Keeping people 'together', 'on track', on course; directed, staged, sequenced, paced learning	Exploring, having a free rein, going their own way; free access to information	Free range, undirected, haphazard, unstructured, unsequenced
Measurable learning outcomes; assessment driven; extrinsically motivated	Free-ranging learning outcomes	Many unintended outcomes (outcomes more difficult to measure); not always assessment driven or extrinsically motivated
Timetabled, 'forced' access; teacher control	Flexible access, when it suits them; learner or teacher control	Free access; learner (or parent) control
Clear boundaries and targets e.g. times, deadlines, subject divisions	Unclear boundaries and targets	Few boundaries and limits; open-ended
Teacher-led, teacher-centred	Learner-led, learner-centred	Learner-centred
Teacher filtered, distilled, vetted	Unfiltered, not always vetted or censored	Often unfiltered or unvetted
Legislated for, e.g. by National Curriculum or other statutes	Not always governed by documents	Not legislated for

Table 1 Comparing classroom learning, learning through ICT and home learning (from Wellington and Britto, 2004, p.211)