In this paper we argue for a more authentic school science. We see the current school curriculum of the developed nations as having been modelled on a now outdated and restricted version of science – one heavily reliant on laboratory-based work. The informal sector now often communicates more relevant science in better ways than happens in schools. We show what the informal sector can contribute to school science and provide evidence for how interactions between pupils and adults can be improved. We close by suggesting some of the things that can be done to make school science more authentic and relevant to young people today.

Introduction

In many developed countries of the world science education is in crisis. Pupils’ attitudes to school science decline progressively across the age range of secondary schooling and fewer and fewer students are choosing to study science at higher levels and as a career (Sjøberg et al., 2004). Science educators in many countries are concerned that current provision in schools (especially at 14-16) is boring, irrelevant and outdated; designed to educate a minority of future scientists, rather than equipping the majority with the scientific understanding, reasoning and literacy they require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 (Millar and Osborne, 1998). In contrast to this, the science and the ways in which it is communicated, in the informal sector (science museums, hands-on centres, zoos, botanical gardens etc) is often exciting, challenging and uplifting. At home, the advent of multi-channel television and the Internet have spawned a series of quality sources of information about science and issues of relevance to young people’s lives. The educational experience for learners at home and in the informal sector in science is therefore often in stark contrast to what is on offer in schools.

In this paper 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 discuss the contributions that out-of-school contexts make to science in schools and use a model that encapsulates what goes on in these more informal contexts to illuminate the complexities of adult-learner interactions. We use findings from a number of studies to suggest how teachers can improve these interactions to make learning more fruitful. We close by arguing that school science is currently modelled on an outdated and restricted representation of science, namely that science is undertaken mainly in laboratories, and that drawing on the wider community of science and approaches in informal learning has much to offer.

**What can out-of-classroom learning offer school science?**

Here we summarise what we believe are key contributions that out-of-classroom 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 bird-watching, walking, playing sport or visiting museums.

We see six ways in which out-of-classroom contexts can add to and improve learning of science. We list them below and then go on to discuss, very briefly, how we see each area contributing to science learning. The first three ways address what might be seen as conventional attributes of school science as often framed by curriculum developers and policy makers. The last three are concerned more 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.

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) Personal development and responsibility
vi) Socialisation

**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-classroom learning is; “What is the pay-off in terms of my pupils’ knowledge and understanding of science?” We think this may be a case of asking the wrong question and we return to this issue later. Nevertheless, it is a reasonable and natural thing to ask and although the research evidence is scant on this, there are notable exceptions. For example, Dierking and Falk (1994) quote studies that have detected improved understanding of concepts as measured on pre- and post-tests in physics 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 (Braund, 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 & Parvin, 2004).

**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 might 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-classroom contexts is more ‘authentic’ than much of what goes on in school 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. 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 & 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 & Lunn, 2004). Additionally, children’s museums provide first-hand
experiences with authentic objects and are popular with children (Moussouri, 1997). Young learners seem to gain much from opportunities for collaborative role-play with family members and explainers and through chances for free exploration and socialisation that informal contexts often provide.

Access to rare material and to ‘big’ science

A traditional role of 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.

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 & 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 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.

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 (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 advised re-focussing our concerns about outcomes:
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 & McClafferty, 1996, p.83).

Our point here is about future engagement. If the pay-off is more engaged and positively oriented science students then school learning must benefit. We return to this point later.

**Personal development and responsibility**

Schools are necessarily places where learning is structured and confined by timetables. In out-of-school contexts new opportunities arise where activity is unconstrained 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, for working in teams and for active consideration of the environment.

**Socialisation**

In the next section we briefly outline a model that illuminates the complex interactions that affect learning in out-of–school contexts. A key component of the model deals with the social interactions that take place. This has been a major part of recent research and we believe the benefits of effective social interaction are great. For teachers, these were illustrated in the quote from Rennie and McClafferty provided above. For pupils, the benefits that accrue from collaborative work and socialisation are strong particularly when a residential experience is included (see, Bebbington, 2004).

**Understanding the complexities of interactions in out-of-classroom learning of science**

We have found a model, originally proposed by Falk and Dierking (2000) to help understand the complexities of learning in informal contexts such as museums, useful in highlighting actions that teachers might take to make learning in out-of-school contexts more beneficial.
The model (shown below as Figure 1) consists of three overlapping contexts, each of which impacts of the learner’s experience and hence influences outcomes. The personal context is concerned with the degree of intrinsic and/or extrinsic motivation shown by learners, and outcomes are often reflected in the affective domain of learning. The physical context describes the sets of cues from the setting that help learners make sense of phenomena, artefacts and events, and that are often more difficult to appreciate in formal education. The socio-cultural context is arguably the most important, yet one that has not been well researched. It deals with the interactions between learners/visitors and with the expectations set by culture and schooling. In the following section we describe research that suggests actions teachers might take to facilitate learning and make science more authentic.

Figure 1: A contextual model of learning in informal, out-of-school contexts (adapted from Falk and Dierking, 2000); in: Braund and Reiss (2004).
Improving interaction in the socio-cultural context

Interactions in what Falk and Dierking call the socio-cultural context of informal learning can be between learner and learner or between learner and accompanying or attending adults. Though the former type of interaction is important, in this section we discuss how adults can affect the quality of conversations in out-of-school contexts. Our explanations derive mainly from studies carried out in zoos and at the Natural History Museum in London. At the end of this section we discuss how adults, including teachers and chaperones, might be better prepared to facilitate interaction that may result in a higher level of outcomes.

Teachers, parents, explainers and other adults, such as ‘chaperones’ (these are those – often parents, school governors or school employees such as teaching assistants – who supervise groups on visits), working with pupils in informal contexts can make a vital contribution to
learning. Their presence affects the content of the conversations that pupils have. Likewise, if pupils look at exhibits without an adult, the focus of conversations is different. For example, groups of pupils in natural history museums and zoos allowed to look at exhibits without an accompanying adult, talk less about the parts of animals’ bodies, though they may mention other aspects of exhibits to the same extent as groups accompanied by chaperones (Tunnicliffe, 1995).

When pupils talk at exhibits without an adult, there is a distinct lack of reference to ‘management’ or ‘social’ aspects of a visit. Not unexpectedly, pupil-only groups provide significantly fewer exchanges that contain at least one reference to a source of knowledge gained before the visit. The content of conversations of these groups is predominantly a commentary about observations but one that lacks focus relevant to the educational objectives as set by their school. Tunnicliffe (1997) found that the presence of an adult in groups of pupils helps focus conversations on knowledge, both declarative knowledge related to the experience of the visit itself and to embedded or tacit knowledge gained, for example, from previous experiences, including those at school.

The presence of adults, however, can also suppress behaviours affecting pupils’ overall enjoyment of the out-of-classroom experience (Tunnicliffe, 1997). Analysis of group dialogue at zoos shows that adults sometimes seek to exact an element of control over learning. The example below illustrates this point:

Boy    Teacher, look!
Teacher You’re right, there are some gibbons in here.
Girl 1 You have to be careful or they will bite off your hand.
Teacher Look!
Girl 1 There’s a baby one!
Teacher How many are there?
Girl 2 Three.
Girl 1 Three! There’s a baby one, a mummy one and a daddy one.
Teacher Does anyone know what noise the gibbon makes?
Boy   Oh, oh! [gibbon noise]
Teacher All right! Now we are going to look at the rhinos.
Data from analysis of the conversational content of groups of children from different year groups visiting zoos shows that the age of pupils had little effect on the content of conversations. This finding gives rise to some concern. The data indicate that teachers are not developing observations made by the pupils in ways appropriate for their stage of development (Tunnicliffe, 1996).

The findings of these and other studies leads us to question the amount and quality of briefing and preparation that takes place before visits to out-of-school contexts. We see this as a key issue underpinning Falk and Dierking’s socio-cultural context. We think that accompanying adults (especially chaperones) must be informed of the educational aims and objectives of visits and the key knowledge that it is hoped pupils will acquire before a visit takes place. Chaperones require background information about the topic that is the focus of the visit and need to know what the focus of observations should be so that they can draw pupils’ attention to features relevant to the learning that is central to the visit. Adults accompanying groups should be told by the organising teacher the names and other terms that they would like the children to use but must bear in mind that pupils often use names and explain behaviours using language and concepts derived from everyday experiences (Braund, 1991). One suggestion is that dialogue between adults and pupils should begin with familiar terms and everyday observations to make exhibits relevant and then progress learning by developing the use of scientific language and structured observation. We are not suggesting, however, that pupils should travel around these places carrying worksheets of instructions and questions. To us this would be an anathema, killing the experience by recreating school–type learning. Recent research on peoples’ personal agendas when visiting informal places for learning suggests that there is most cognitive gain when enjoyment and education are both evident and provided for (Falk, Coulson and Moussouri, 2001). This challenges some of the criticisms made of hands-on science centres, that they can provide entertainment but that their claims to educate in science are at best spurious (Shortland, 1985).

**Towards more authentic school science**
If school science is in so much trouble, as we said at the start of this paper, then it strikes us that there may be something fundamentally wrong with the way in which it has been conceived and modelled. We can see school science as a modelled version of scientific reality. Science in the early 20th century was mainly seen, in the industrialised nations, as a body of knowledge accumulated from discoveries made, tested and validated through experimentation. At this time the latest discoveries and inventions drew huge crowds to public meetings and science was a dominant part of public life. In schools this science came to be represented often as recreations of classic experiments carried out, wherever possible, in laboratories (Jenkins, 1993). Practical work in school science, in most of the developed nations, has since become almost a mantra and characterises science teaching to such an extent that teachers may now feel guilty if they do not use it in every lesson.

Yet the science of today is not the same as that a century ago. In the 21st century scientists are more likely to spend the majority of their time thinking, talking, reading and using computers rather than at laboratory benches. Science today is a multi-disciplinary affair involving collaboration between many branches of science to solve the, often complex, problems in today’s societies. For example, at the University of York, a zoologist recently observed the absorbent properties of lobster and crab shells. A microbiologist studied their structure, a molecular chemist extracted absorbent compounds from them before involving a chemical engineer in providing the product as small pellets. Process engineers finished the job by providing a method that used pelleted shell product to filter polluted water. Finally, environmental scientists helped apply and market the new technology throughout the world.

We think that one of the main reasons that school science is not meeting the needs of the current generation of young people is that it is still being modelled on an outdated and reductionist version of science that fails to match the current realities and needs of science and technology in the 21st century.

In the informal sector science is often very different to the outdated version found in schools. One of the key advantages they (museums, zoos, botanic gardens etc) have over schools is that the science does not have to be presented as disembodied packets of knowledge (topics or themes) often struggling to appear relevant to young people and packaged as an examination syllabus with certification its main goal. In out-of-school contexts science can be presented through its applications, its stories and its histories with the intention of broadening people’s
horizons and engaging them in thinking more critically about science and society. It can, therefore, be set more naturally in the cultural and social milieu of adolescents tackling up-to-the minute advances and reflecting more authentically what scientists do. In a way this is what museums and other places, in the industrialised nations, have always done well at – telling the latest stories from science and engaging the public in debates about science. This is perhaps where schools have most to learn from the informal sector. One way forward is to see the informal sector as a powerhouse of information, expertise, creative thinking and ideas that can help the formal sector make its science more relevant to its pupils.

It should be possible to help pupils connect science learned in school with science presented elsewhere. In this way practical science done in school or on a field trip could be compared with or supplemented by data gathered from a visit to an informal setting or gathered from the Internet or through watching television programmes at home. A more explicit way to link the formal and informal sectors is to provide opportunities in science courses for pupils to spend time gathering data and visiting places as part of assignments. This is now being done in courses in post-16 science in England (e.g. Salters-Nuffield ‘A’-level Biology – SNAB1) and we are working on closer links with the informal sector in a new course being developed for 14-16 year olds in England (21st Century Science2).

Pupils today spend far more time exposed to science outside school than in it. An education that only values the contribution made by school in a person’s overall interest in and engagement with science now seems less valid. The contribution that the informal sector makes is immense. Science educators ignore it at their peril. Places such as museums are often judged by the extent to which they attract learners to revisit them. We wonder what would happen if schools, in the developed world, were judged in the same way. How many would be able to claim that large proportions of their clients (pupils) volunteered to return to study more science?

In an African context our conclusions are that science education should not try to recreate the anachronistic and failed model of science that currently exists in many schools in the more developed nations. Practical work has been a dominant part of school science for more than a hundred years and an aspiration of many developing nations is (quite naturally) to provide the laboratory facilities associated with the well-endowed schools they see elsewhere. We do not
say this is wrong. There is a place for effective laboratory work (we do not have space here to enter into all the ways in which practical science in schools is currently ineffective but the work of Hodson (1990) is worth reading) but there must also be opportunities to value the many other ways and places in which science knowledge is produced and used. African nations have, of course, a rich natural heritage but there is also a growing informal sector, e.g. in museums, hands-on centres, botanical gardens, field centres and so-on that will proliferate as nations develop. The key in providing a better and more authentic science curriculum is to make whatever science goes on in schools relevant and useful to young people’s lives. In doing this we have much that can be learned from the informal sector.

Notes

(1) *Salters-Nuffield Advanced Level Biology* is a new examination course at advanced (‘A’) level (for ages 16-19) and has been piloted in 50 schools and colleges in the UK since 2002. The course includes an element in which students are encouraged to relate biological principles learned in the classroom and laboratory with actual examples found in research, industry or in the public communication of science.

(2) *Twenty-first Century science* is a new examination course at GCSE (age 14-16) level in England. The course is currently being piloted in 80 schools. It is innovative in that it requires pupils to engage in debates and discussions about current issues and discoveries in science and technology. Much of the learned science content is related to these issues and debates. In this course pupils can carry out course work related to science that is communicated in a science centre, zoo, botanical garden or other such site.

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References


