Second Edition

Primary Science

A Guide to Teaching Practice

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CHAPTER 1

THE CURRENT CONTEXT OF PRIMARY SCIENCE TEACHING

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Chapter Overview

This first chapter, setting the context for those that follow, is important and necessary because as the authors, we need to set out our stance on how we will try to support your learning to teach science effectively. It will therefore address the what, why and how of teaching science to younger children.

Science teaching policy and directives have been in a constant state of change now for over 25 years, and you have to take account of this, of course. But equally important is your own school and classroom context, and the importance of debate and discussion between colleagues about what works best. So one key plank of our strategy is to involve you in making your own beliefs clear and developing a way of working which suits your children. To do this, you will need a 'long view' – a developmental perspective – on how science itself has developed, the where and when of innovation, and an understanding of how science as a process is unique. The chapter reminds us of how, surprise surprise, it was not us who first developed science ideas; this happened in China and in Islam, long before Europeans woke up to it during the Enlightenment. And ideas are still changing, one aspect of this being the importance of linking science with other disciplines in the social, economic and political fields.

One important aspect discussed in this first chapter is the notion of uncertainty: that science is not simply about 'right answers' but about being able to accept the tentative nature of many of our ideas. Living with this, as a science teacher, is very important,

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especially as you and your pupils explore the world around you and attempt to form ideas and conclusions. Are sea levels on your local beach really rising? Are song birds disappearing from our gardens? How much evidence do we need to be confident? You are all children of the National Curriculum (NC), which with its emphasis on testable knowledge has in many ways made it more difficult to be tentative. But before the emergence of the NC in 1988, primary science was supported by some excellent materials which are discussed here, such as the SPACE research reports and the *Science 5–13* materials. A further challenge arises from the impact of the National Literacy and Numeracy Strategies, which in subtle ways served to interpret Science as a 'vehicle' for learning of literacy and numeracy, rather than the other way round.

Recent reviews by major research bodies, including the Royal Society and the Wellcome Trust, have however re-emphasised what is key to good science learning, and the chapter summarises these, as well as ideas emanating from Europe, USA and African states about what makes for effective teaching and learning, the constant factor being the importance of sustaining children's enthusiasm and excitement about discovery. Recent years have seen a gradual divergence of approaches across the four parts of the UK, and this has helped all of us to question our approaches, reduce over-prescription and increase subject integration. And for you, probably taking on science teaching for the first time, sharing your successes and concerns with others is possibly the key aspect of your professional development.

Introduction

If you are a trainee, or an inexperienced primary teacher confronting science for the first time, you are probably opening this book expecting to find answers to some big questions, like *'What is science?'*; *'Why should we teach it?'* ; *'What is good science education?'*; *'How do children learn best in science?'* and *'How should I teach it?'* Consequently, you may wonder why the focus of this first chapter is relevant. As you will already know, what has to be taught is laid down in the National Curriculum; so how will probing back through history help?

You may feel like this because your previous experience has conditioned you to expect answers in the form of definitions, for example the kind that start off *'Science is ...'*, or *'As a teacher of science in primary schools, you should ...',* clear-cut statements that tell you what to do to conform with official expectations. But the authors of this book, all of whom are and have been closely involved in training and developing teachers of science for primary schools, do not believe in that approach. And we have gone to great lengths to consult with focus groups of trainees and teachers in different parts of the country, on what exactly ought to go into 'your' book on primary science.

The reason for this is that the two dimensions of science education, science the subject and science pedagogy, have been in a constant state of flux for a very long time, and still are, as this first chapter tries to show. Of course, there are reasons why things constantly change. So the way in which you teach science will need to be adapted to the situation you find yourself in – which means adjusted to the children you teach, the environment of your school, the current concerns of society, government policy and technological change, to name only a few factors. To be effective as a teacher of science, therefore, you cannot just trot out the tried-and-tested ideas of the past; you need to be a thinking, reflective teacher who weighs up alternatives and makes up their mind on the basis of the best evidence, sound advice, and what suits your own personality.

The following chapters will therefore provoke discussion and debate rather than tell you what to think. Such discussion will inevitably draw on many of the key qualities of effective scientific enquiry and will show how these concerns relate to classroom practice. This will start by exploring how the characteristics of science, and science enquiry, have evolved, leading in recent years to their application in a primary classroom context. We aim to balance historical perspectives with a clear focus on the present climate for primary science education. Most importantly, we will always be helping you find an appropriate balance between the characteristics of scientific activity and science as a body of knowledge.

Where did science start?

It is likely that science began when our ancestors first made stone tools, used fire and water to cook, or utilised skins and wood for clothing and shelter; but they certainly did not think of themselves as scientists. In fact, the term 'scientist' was only coined in 1833 by William Whewell at the request of the poet and philosopher Samuel Taylor Coleridge, who needed a word to describe the group of active experimenters who were making such huge advances in 'natural philosophy', as it was called then, at the end of the eighteenth century. Thousands of years ago, the people of the Nile valley made observations of when the river flooded, so they could predict when best to plant their crops. The Mayans of South America were remarkable astronomers who made such accurate observations of the sun, moon and planets that their calendars were virtually as accurate as ours are today. One way in which they did this was by digging deep, well-like pits in the earth and lying at the bottom, because by doing so they could observe a tiny portion of sky from which all extraneous daylight was excluded. They recorded, without any instruments, observations of stars, some of which are now no longer visible to the naked eye!

Observe, suggest explanations, test them, expand knowledge and apply it – this is what people have done for millennia, a process of 'coming to knowing' about the world and the universe. What those very early ancestors were doing is something still at the heart of much science and technology, namely the search for understanding, answers to big questions, and ways to make work and life easier. Try asking children or your fellow non-science students what science is: they will probably say things like *'How the world works'*, or *'Understanding the world around us'*, but they might also tell you *'Physics, chemistry and biology'* because that has been their main experience – science simply identified as school subjects. It is here that we face the first way in which science has evolved, because even these 'subjects' are quite recent inventions. Geology and geography were new disciplines in the nineteenth century, and now you will find university departments of things like socio-biology, geo-chemistry, paleo-archaeology, neurosciences, and many others. Yet all these new branches of science essentially employ the same underlying approach.

We have to go a long way back to see where science began in earnest, and this happened not in the famous universities of Europe but in China and the Islamic world. In the ninth century, Jabir ibn-Hayyan was preparing strong acids and alkalis using scientific methods well before these techniques became common in the West. Jabir is believed to have written *'The first essential ... is that you should perform practical work and conduct experiments, for he who performs not practical work nor makes experiments will never attain the least degree of master'* – something we are still encouraging learners to do over a thousand years later.

Such 'scientists' were capable of great scientific accomplishments in astronomy, medicine and algebra in a Muslim 'Golden Age' of AD 800–1200, contrary to some current ideas that Islam opposes the scientific method or the advances of scientific understanding and the applications of technology. The Prophet Muhammad urged individuals to be curious and reason about the knowledge to be found in the natural world. This amazing research and development work carried out in the Islamic world is best illustrated on the '1001 Inventions' website (www.1001inventions.com/) which describes the invention of things we take for granted, like soap, shampoo, fabrics, perfumes, fountain pens, toothbrushes, carpets, clocks, coffee, and the camera.

The Chinese were active too, long before Europe, in creating paper, printing, porcelain, the compass, medicines, and gunpowder. In Africa, the people of Benin were creating incredibly detailed and beautiful bronze castings. All of these developments by skilled artisans were based on principles and procedures that resemble what we now call 'the scientific method' of observation and experimentation. These ideas lasted and were refined over many centuries by famous names like Roger Bacon, Copernicus, Galileo, Francis Bacon, Newton, Descartes, Dalton, Darwin, Davy, Faraday, and many others. A quick 'Google' will tell you as much as you wish to know about all of these and many more.

Another more recent shift in thinking about science was Karl Popper's revelation that scientific theories could not be proved, they could only be falsified. In other words, no matter how much evidence you produce to back up an idea, it is still always possible that someone could find evidence to prove you wrong; and once you do find this falsifying evidence, the whole theory collapses and you have to start again. Therefore science proceeds by falsifying and not by proving – even with young children, science should be seen and experienced as testing their ideas against the evidence of their senses.

From a twenty-first century point of view, huge shifts in science-related thinking have taken place: Galileo and Newton changed the way we see our universe and the forces that make it work; Darwin changed our view of ourselves and our origins as a species; and in the past hundred years Einstein, Bohr, Heisenberg, Feynman, Hawking and others have altered the way we think about matter, what it is, and how it can be transformed. But all these came into conflict with other, often religious, beliefs, particularly Galileo and Darwin. Even today, the argument between evolutionary biologists and creationists who promote 'intelligent design' rages on in many countries. Gradually, therefore, our understanding of what science is and how it works is constantly changing.

Food for Thought

A recent international science symposium reported in the press concluded that some fundamental science assumptions might need to be challenged, including the following:

- That there is no clear distinction between mind and matter.
- That there is no clear distinction between being alive and being dead.
- That there is no longer the need for the concept of infinity.

Why might such eminent scientists have come to such conclusions?

Change and uncertainty

During the nineteenth and twentieth centuries it became commonplace to believe that science and technology could control nature, that we were 'harnessing' it to produce energy or grow more food. However, in recent years, tsunamis, earthquakes, volcanoes and even the UK's winter floods of 2014 have reminded us that even with the most sophisticated technology there are things we cannot control. Native peoples in the Americas, Australia and Asia have always known this, and are aware of the need to live with nature and not try to control it. Yet many science professionals still do not regard these people's ideas (on natural remedies, for example) as being 'proper' science. David Peat, in his (1995) book *Blackfoot Physics*, explores these ideas at great length, and other eminent scientists such as Fritjof Capra have emphasised the links and similarities between the ideas of physics and ancient belief systems, such as those of eastern mysticism.

Therefore, science also progresses by making links with ideas from other disciplines and thought systems. In his other ground-breaking (2002) book, *The Hidden Connections,* Capra demonstrates how we need a unifying system that helps us understand the network of connections between science and such fields as economics, ecology, the mind, and social realities, especially at a time when there are widespread concerns about tackling global warming. One further big change is the relatively recent realisation that our understanding of everything is beset by uncertainty and inadequate data.

By now you may well be thinking *'Hmm, maybe this book isn't for me, after all …'*, but stay with it! Because uncertainty is everywhere, and as teachers we have to recognise this. No-one was certain where the volcanic ash cloud was going in April 2010, despite the incredible technology available to the Meteorological Office who have some of the most powerful computers in the world. New species are being discovered all the time (441 new species in Amazonia in 2013, and many more in the deep oceans), while others like the Tiger and Snow Leopard have a desperately uncertain future. We are unclear about how fast the climate is actually changing, uncertain about how fast the Greenland icecap will melt, uncertain as to whether the 2014 winter floods will be an annual event, because it is impossible to have enough data to know for sure and science is anything but certain.

Critical Thinking Task

Seven years ago, a national daily broadsheet ran an item about rising sea levels, which included the following:

> The Carteret Islands are part of Papua New Guinea, the anarchic nation of mountains, jungles and islands … The last tide could come in at any time. Then these islands at the end of the earth will simply vanish … the low lying atoll seems doomed … Every year, the tidal surges are becoming stronger and more frequent; the Carterets are a portent of catastrophe to come.

The article went on to claim that rising sea levels were the main likely cause of this.

Using research available on line, assess the validity of these claims, and with the best evidence you can accumulate, identify what you would include in a short article setting out what you think is the actual and current situation in this part of the Pacific, including an evaluation of the reliability of the evidence available. Having researched this area could you use this as a context in which to explore a more relevant or local environmental issue with primary-aged children? How would you do this – hot seating, role play, children as researchers ...?

You may find the following websites useful as a starting point:

- Australian Government Bureau of Meteorology (BoM): www.bom.gov.au/oceanography/projects
- Australian National University research: www.rses.anu.edu.au/geodynamics/gps/papers/png_jgr.ps
- Pacific tectonic plates: en.wikipedia.org/wiki/Pacific_plate
- Satellite images: www.oceandots.com/pacific/png/kilinailau.htm

So developing young minds to think scientifically means first of all not preparing them to expect certainties – not wanting to know what the 'right answer' is, because despite the years of testing you have probably endured in school, so often there are no right answers. Of course, if you jump off a building there is a high probability that you will fall and hit the ground; some probabilities are quite high! Ironically, of course, we have better 'gear' for enquiry and investigation than ever before. In school I used a Bunsen burner, test tubes, balances and, rarely, a microscope; now there is a huge range of digital technology at your disposal (digital microscopes and digital magnifiers to name but two) to help you do and see things that were impossible twenty years ago. There are still a myriad things in your environment to enquire into, things probably unique to the surroundings of your school.

Take the humble dandelion, a plant probably found around every school in the country, and consider how many investigations into its growth, size, distribution (have you seen how well they grow on the compacted soil of a footpath?), seed dispersal, and place in the food chain that you could carry out. Simply investigating how the seeds move in the air could fascinate children for hours (what happens if ... you cut the parachute shorter, for instance?). Then take a bowl of fruit, and think of the observations, predictions and theories you could come up with by just considering the link between their size, colour, skin, and the seeds inside each fruit. We will suggest more simple examples of original research that children can undertake in subsequent chapters.

The emergence of resources for science teaching

This kind of thinking about 'science as enquiry' (discussed in more detail in Chapters 2 and 3) only penetrated primary schools fairly recently. Until the mid-1960s, the closest that younger children got to science activity was through nature walks and a nature table in the classroom: this might involve collecting frogspawn in spring, bringing it to the classroom and watching the eggs develop; or gathering wild fruits and seeds in autumn and planting them in soil; or making systematic observations of the weather on a class chart. Of course, much of this would have depended on whether your class teacher had the knowledge and understanding and even an interest in this sort of work. You may not be surprised to learn that the physical sciences were rarely tackled either.

There was at that time still no national curriculum in the UK, so it was entirely up to individual schools, and even individual teachers, to decide if and how to deal with science learning. At this time an organisation called the Schools Council, an independent body that drove much curriculum change, was well established. Each of its project teams, predominantly composed of teachers, moved to develop a programme for science explicitly and predominantly based on what teachers identified. Out of this emerged *Science 5–13* (Schools Council, 1972) a project based at the University of Bristol, which had a much clearer basis in the understanding of children's learning, introducing the idea that 'science skills' were central to effective learning, as well as new ways of looking at a wide range of science content. Its publications included the ground-breaking introductory book *With Objectives in Mind*, setting out the essential skills and concepts needed for an understanding of science. It was organised in three developmental stages, using Jean Piaget's ideas about intellectual development. Crucially, it also tackled the physical sciences with units on topics such as *Structures and Forces*, *Working with Wood*, *Science from Toys*, *Metals*. The scheme also coined the now-familiar concept of *Minibeasts*. Happily, these excellent resources (developed, in the main, by teachers) are now becoming available again online.

Science 5–13 was highly influential amongst teachers and especially teacher trainers at the time. This illustrated how, as our understanding of science changes, so do ideas about the way it is taught. Its impact was in some ways a precursor to the government's publication in the mid-1980s of *Science for All* – a first attempt not only to create a basis for good practice, but also to insist that all primary school teachers should be teachers of science, something that had existed systematically in few classrooms up to then.

The arrival of the National Curriculum

Sadly, however, ideas about science teaching have sometimes been steered and influenced by considerations that remained quite remote from evidence-based views of ‘good science practice’. In particular when the government of the day centralised control of school education in the early 1980s, removing it from being the responsibility of local authorities, political interference in teaching led in the late 1980s to the emergence of the first National Curriculum for Science and the standard testing of children’s science knowledge, which became increasingly controversial. This was never the intention of the experts who devised the curriculum; their intention was to develop a system that balanced the testing of knowledge with the examining of enquiry skills through practical investigations. However, cost and logistics, alongside the government’s wish to simplify, gradually led to the abolition of practical tests and a reversion to paper and pencil exams. This, unsurprisingly, also led too many teachers away from science as a process to a narrower view of science education, which was a pity as great strides had been made by schemes such as those mentioned above to develop science learning based on enquiry skills.

Additionally at this time international surveys of attainment in basic subjects were being carried out with increasing frequency, and the UK’s continued failure to do well in these prompted yet more government intervention. Consequently, teachers and other educators had to manage the introduction of a completely new raft of jargon into the way we talk about the curriculum, including Programmes of Study (PoS), Attainment Targets (ATs), and Standard Attainment Tests (SATs). These arose out of the government’s wish to adopt approaches that had seemed to prove successful elsewhere, and especially in the USA and Japan. Worryingly, after the UK’s poor results in the PISA tests in 2014, the same soul-searching amongst ministers is going on again.

Running parallel to this was some seminal research undertaken by the universities of Leeds, Liverpool and King’s College, London, on children’s science misconceptions. Until this time it was commonly thought that children’s minds, as far as science was concerned, were empty vessels into which ‘correct’ science ideas could be poured. This research showed powerfully that this was not so, and that children on entering school already had their own ideas about science phenomena, even if many of these were at odds with the ideas of scientists. The *Science Process and Concept Exploration Project* (SPACE) (Russell and Watt, 1992), thus systematically explored young children’s understanding of science concepts and their development in 12 areas, including topics such as Electricity, Materials, Evaporation, and Growth. The results led to the publication of eight major research reports and then to the development of a set of curriculum materials, *Nuffield Primary Science* (Nuffield Foundation, 1995), which quickly developed a national and international reputation. This new scheme aimed to establish and communicate the ideas which primary school children have in particular science concept areas, and set out to show ways in which teachers could help children to modify their ideas as the result of relevant experiences, bringing such views more in line with those of the science community.

Teachers' professional development

In the early 1990s, therefore, following these bursts of developmental activity, primary science suddenly took centre stage where curriculum and teacher education were concerned. The amount of time devoted to science in primary teacher education, and the numbers of trainers involved, increased rapidly. Science now deemed a 'core subject' of the primary curriculum inevitably gained greater status in schools. Government schemes of work, such as that from the Qualifications and Curriculum Authority (QCA), flooded into schools and universities, and continuing professional development (CPD) programmes proliferated, sponsored by local authorities, universities and private operators. A bandwagon was in motion. Scotland followed its own path, deliberately avoiding the standard testing route, but otherwise all the home countries put science in the forefront of their thinking. For example, many primary schools were using science-based topics as ways of thematically linking subjects together; however, as we shall see later in this book this was also not without its problems.

It has probably not escaped your attention that this has changed yet again. The first major factor in reducing the emphasis on science was the introduction of the National Literacy Strategy (NLS) in 1998, closely followed by the National Numeracy Strategy (NNS). Literacy has always held pride of place in the concerns of many primary teachers, and whilst it became increasingly difficult to attract teachers into science CPD programmes, those relating to the NLS were usually oversubscribed. Literacy has continued to be the central and probably most controversial aspect of primary teaching ever since. It has been difficult at times to combat the tendency of some advocates to see science as a 'vehicle for literacy teaching' rather than the reverse! Nevertheless, Ofsted (2013) recognise that 'Teachers who coupled good literacy teaching with interesting and imaginative science contexts helped pupils make good progress in both subjects'. The emphasis on literacy education in primary schools is unlikely to go away; it is too high on the political agenda for that to happen. Adept teachers of primary science will always ensure high quality science provision in spite of other pressures placed on the curriculum.

The second major influence on primary science teaching was the change to a New Labour government in 1997, along with Tony Blair's claim that the priorities for that government were 'Education, Education, Education'. The strategy adopted to achieve this took the form of increased testing of primary age children in particular – tests which served to reverse, in many schools, the move to effective, inquiry-based science (now usually referred to internationally as Inquiry-Based Science Education or IBSE). Testing, and thus teaching, continued to emphasise the learning of factual knowledge rather than the acquisition of science enquiry skills that were much harder and more time-consuming to test. Under pressure from Ofsted inspections to improve the (arbitrary) standards, schools and teachers rapidly refined their strategies for 'teaching to the test' in order to improve their school's standing in the now mandatory league tables of attainment.

Student Perspectives

Students we have spoken to tend to be more concerned with the professional and teaching lessons to be learned from other countries, and less concerned with what other curricula might have to offer them. We believe this is likely to be a consequence of their feeling that curriculum content is, in some ways, out of their hands and more context-dependent than teaching methods – and in some respects, they would be right.

What student teachers emphasised in discussions was the importance of ideas about professionalism, approaches to professional development, and alternative ways to foster science learning, such as play-based learning. Hence, the sections below provide examples of how these have been developed elsewhere, particularly within continental Europe and the developing world, and specifically within IBSE.

Recent changes

Research, however, stubbornly continued to indicate that early improvements soon levelled off (Royal Society, 2010) and that primary teachers, 97% of whom still did not have a post-school science qualification, continued to lack confidence when it came to teaching science. At the same time, the emphasis on digital technology and children's need for ICT skills was gaining ground. Having commissioned a new review of the primary curriculum in 2008, the Brown government in 2009 made the decision to adopt these proposed changes to the curriculum which would give increased emphasis on ICT, withdraw core status from science, and make it part of an 'area of learning' characterised as 'scientific and technological understanding' (Rose, 2008). The consultation process, however, had suggested that many in primary science education were not happy with the findings, particularly as another large review had come simultaneously to quite different and (to primary science people) much more preferable conclusions that took account of teachers' concerns (Cambridge Primary Review, 2008).

Thus only a matter of months before the Rose Review was due to be implemented, New Labour was replaced in May 2010 by the present coalition government, and plans for revision along the lines of Rose were shelved. Partly as a result of this, differences between the primary science curricula and approaches in Scotland, Wales and Northern Ireland widened and the content of the four curricula now have considerable differences in emphasis, especially where IBSE and curriculum integration are concerned. The profession back then therefore needed some authoritative pronouncement based on evidence. Fortunately, it was provided by the Royal Society's *State of the Nation* report on Science and Maths Education (Royal Society, 2010), which suggested that we should:

- provide every school with access to a science specialist;
- increase funding for teachers' continuing professional development in science;
- focus assessment on promoting progress rather than measuring it;
- ensure that national policy for science education is based on evidence from research and effective practice;
- encourage more research into children's development of science knowledge, understanding and skills.

While this provides valuable, logical and balanced guidance, schools generally remain reluctant to make major changes until the air clears around the current curriculum changes. But for you, as a trainee or novice teacher, or as one of the many non-science specialists wishing to engage more productively with science, it raises several important questions that you might wish to discuss before moving on to the rest of this book.

Food for Thought

If asked to initiate a discussion about policy for science in your school, what would be on your agenda and what would be your priorities in order to bring about improvement?

Taking account of the Royal Society's recommendations, identify and explain which of these you think are most likely to be implemented given the current proposed curriculum changes?

What can you learn from the development of primary science as set out above that could help you arrive at good practice in your own classroom?

Useful lessons from elsewhere

The 1960s saw a rapid development in new technology in the fields of nuclear power, electronics, radio astronomy, and new materials, all fostered by the 'Cold

War' between the USA and the Soviet Union. This brought about a proliferation of new and more powerful nuclear weapons and the space race, culminating in the first manned moon landing in 1969. The powerful industrial nations, which included Britain, realised that greater technological developments meant having more scientists. The change was not primarily about curriculum content, however. One of the key innovations in the USA had been the way in which technologists and technicians (largely within the military) were now being trained, involving the notion of 'behavioural objectives', characterised by a very high degree of specificity, to make it easier for trainers to know if learners had been successful. This has ultimately led to our current emphasis on 'learning objectives' that are SMART in nature (specific, measurable, achievable, realistic and time-bound). A number of alternatives to learning objectives have emerged that include learning outcomes, learning intentions, and learning purposes.

One of the outcomes of this in the UK was the *Science 5–13* programme already mentioned, initiated by the Schools Council in 1973 and subtitled *With Objectives in Mind*. You will recognise the stated objectives of the scheme as being similar to those emphasised here, as they focused on the following:

- Developing interests, attitudes, and aesthetic awareness.
- Observing, exploring, and ordering observations.
- Developing basic concepts and logical thinking.
- Posing questions and devising investigations to answer them.
- Acquiring knowledge and learning skills.
- Communicating.
- Appreciating patterns and relationships.
- Interpreting findings critically.

The scheme proved popular with trainers and some teachers, partly because much of the development work came from teachers themselves – yet it is important to remember that we were still fifteen years away from having a national curriculum. Hence there was no pressure on schools (or the local education authorities which still controlled them) to teach science at all, never mind in any specific way. Consequently, in 1978 a report by Her Majesty's Inspectorate (HMI) concluded that few primary schools had effective programmes for teaching science and that in even fewer classes were science skills taught, and that the most severe obstacle was teachers' lack of knowledge of elementary science (DES, 1978).

Meanwhile big changes were taking place elsewhere, in perhaps rather more unlikely localities. As the 'winds of change' blew through the British Empire in the early 1960s, one country after another sought independence from Britain and this happened rapidly in Africa in particular. Hence, in the mid-1970s, UNESCO initiated and supported the Science Education Programme for Africa (SEPA) to bring together science educators from these countries to develop new curricula, materials and teaching methods, with its primary focus being on 'the learner and his immediate environment' (SEPA, 1976).

SEPA produced detailed specifications and many new materials supported by some of the best science educators from around the world. Unlike in Britain, however, most of these countries had decided on creating new national curricula from the outset: individual African states therefore took the SEPA ideas and materials and redeveloped or republished them to fit their own new curriculum. Many of these materials proved to be first-rate innovative examples of good practice. Kenya developed a primary science curriculum around the idea of *Problem-Solving Skills*, and produced a wide range of pupil materials to support this approach. For example, their small book, *Ask the Ant-Lion*, encouraged children to find and observe these small, ubiquitous creatures that lived in sand and to 'ask' them questions (such as, '*Where do you live? What do you eat? How do you catch your prey?*'), which pupils then answered through careful, sustained observation and recording. The curriculum content might be very different so a developing country like Kenya inevitably focused on such topics as soil, water, tools, food, and health, but the pedagogic approach advocated was very similar to that proposed by *Science 5–13*.

How is this relevant to our situation today, you may ask? What can we possibly learn from what happened in Africa thirty-odd years ago? The key point here is the mismatch between 'official' expectations of teachers, as set out by ministries, advisers and inspectors, and the background of the teachers expected to implement innovation, for which it was revolutionary, and therefore hard to implement. Dunne and Maklad (2013) provide a very accessible account of contemporary international primary science. They asked the question 'International primary science: what's in it for us?', and have supplied a useful overview of provision in the USA, Egypt, Chile, Sweden, Austria, and India. In the UK, where innovations have come thick and fast in recent decades, your experiences of science as a primary pupil may have been very different from what is now being expected of you. This may account for the lack of confidence in science experienced by primary school teachers.

Food for Thought

Consider the current expectations placed on you as a teacher of science and your own science background developed in school.

Are the teaching methods expected of you in science any different from those you experienced as a pupil, and if so, in what way?

What are the implications of this for your professional development?

Fostering pupil enthusiasm for science: recent developments across the UK and Europe

You will have noticed there has been no mention of primary science in Europe up until now. This is because, with the exception perhaps of Sweden, science had played little part in the primary education of European countries throughout the 1970s and 1980s. We visited schools and training institutions in Poland, the Czech Republic, Bulgaria, Estonia, Portugal, Germany and France in the 1990s, and found little that we in the UK would recognise as science teaching – it did not exist as a subject, and what science teaching there was had emerged in programmes of local study or the environment. In England, as the 1990s wore on under an increasingly punitive testing and inspection regime led by 'league tables' of school performance, unease developed amongst teachers about children's attitudes to science. Children loved doing science but as they progressed through school the emphasis moved to tests and revision, especially in Years 5 and 6, and pupils were increasingly 'turned off' science by the time they transferred to secondary school.

This phenomenon was not confined to England, however, and in France in 1996 a programme called *La main à la pâte* (which translates as 'hands-on') was instigated, not by government dictat but by the Nobel prize-winning physicist Georges Charpak, the astrophysicist Pierre Léna and others, with the support of the French Academy des Sciences (Belay et al., 2007). This initiative gave rise to a programme of European collaboration to develop IBSE called POLLEN, a network for promoting Inquiry-Based Science Education (see the weblink below). It set out to be a pilot programme that would work with communities to develop a 'hands-on, minds-on' approach to science education in primary schools. The project lasted until February 2013, involving 60 tertiary education institutions throughout Europe.

One key change in recent years, because of events outside England, has been an awareness of the need for more creative approaches to science in order to foster children's enthusiasm. Wales, Northern Ireland and Scotland, as well as the rest of Europe, have already moved in this direction. In Wales, for example, where the 'National Strategies' of England have not been applied, the emphasis is now more on 'thinking and learning skills' and the independence of the teacher. This has been achieved through making science testing no longer compulsory, thereby allowing teachers to counteract a narrowing of the curriculum that has been evident in England as a consequence of 'teaching to the test'. Learning skills for science have been gradually introduced as part of the Welsh curriculum, backed up by a teacher-developed assessment promoted by their Assessment Review Group.

Food for Thought

A large research programme in your area finds that whilst creativity in science teaching has increased, pupil attainment on standard testing has gone down.

How would you respond to this?

What evidence would you wish to see that could help you adapt the way you teach science?

Wales has also looked to Northern Ireland and its earlier moves into curriculum change. Unlike in England, Northern Ireland never separated technology from science, simplifying the curriculum content into just two areas, *Investigating and Making* and *Knowledge and Understanding*, an approach that has proved popular with teachers. Schools are left to organise the elements in inventive ways, incorporating a good deal of practical construction and testing. Although children do take examinations before the transfer to secondary schools, this testing process does not include science – yet again freeing teachers to be more pedagogically creative in their approaches to science teaching.

One aspect of this is the creation of a learning area entitled *The World Around Us*, which aims to foster links between science, history, geography and technology where appropriate, all the while encouraging teachers to make connections. In order to sustain this, the statutory content of Northern Ireland's curriculum has been reduced, allowing for flexibility and a stronger focus on skills and IBSE. A clear outcome of this has been the variety of ideas and real enthusiasm for innovation apparent amongst teachers and trainers in the province (Kerr, 2009).

In 2009, the Scottish government also introduced a key change to the way education in Scotland would be implemented. Outlined within this new *Curriculum for Excellence* (CfE, see the weblink below) was a desire to de-clutter existing approaches and content and to replace these with a more child-centred approach. The 'Sciences' component was the first to be conceptualised, modified and published, so that work within schools in respect of its content was among the first to be piloted and embedded as part of a move towards more child-centred teaching and an integration of history, geography, mathematics, and science. Science is now a discrete component in its own right and has been given a key role in respect of its ability to act as a catalyst for child-centred, collaborative, active, and interdisciplinary approaches within the primary school. The CfE's approach also highlights the promotion of children's own experience, alongside learning outcomes, and presents these in terms of broad aspirations for their learning, prefixed by '*I can … ;*' and '*I have … ;*'.

Food for Thought

In a small group, brainstorm reasons why it makes sense to be aware of developments in other countries as described above. Then list possible constraints on the effective transfer of ideas and methods from one country or culture to another and consider how these can be overcome.

So can we learn from these external experiences? We in England have given the world Newton, Darwin, Franklin, Faraday, Anning, Rutherford, Whittle, Somerville, Crick, Watson and the rest, and this can often create the impression that we have much to offer other countries but little to learn from them. Yet at present, this seems not to reflect the situation in primary science at all. (We also gave the world football, cricket and rugby, but Spain, Brazil, Australia, Pakistan, India, South Africa, and New Zealand are now teaching us a thing or two about how to play!).

It would seem that before looking at what we can learn from elsewhere, therefore, it is worth summarising the problems we need to tackle. A recent seminar for top scientists organised by the Wellcome Trust concluded that, in recent years, the misinterpretation of what the National Curriculum originally intended has resulted in:

- many teachers feeling disempowered to teach in a manner appropriate to their students and circumstances;
- a strong sense of over-prescription in terms of the content of the curriculum;
- increased pressures to 'teach to the test' at all levels;
- frequent, apparently piecemeal, changes to the curriculum in order to fix shortcomings and meet top-down policy changes;
- tests and examinations dominating not just what was taught but also how it was taught.

(Wellcome Trust, 2010; see the weblink below)

Where does this leave us then? Here are a few tentative indicators of where progress can still be made.

Reducing prescription, testing and inspections

Frequent change is demoralising for hard-working teachers, especially in an area like science where many still do not feel that confident. Countries like France, Finland and Japan make relatively infrequent changes to their curriculum or to their prescriptions for how to teach. In the past three decades here, however, change has been incessant. Many teachers feel they know how to teach science better, but all too often are deterred from doing so by the pressure brought to bear from national science testing and punitive inspections. Finland, for example, which consistently out-performs the UK on international comparisons, has abandoned both, as neither is cost-effective in achieving long-term improvement in teaching and learning.

Subject integration

In many countries, science is not taught as a discrete subject (see Dunne and Maklad, 2013) but is linked instead to other areas of knowledge. An awareness of a need for science to be relevant to learners' lives has meant that teachers are more concerned with topics like climate change, renewable energy, poverty, food and health, clean water and biodiversity, and tackling these involves not only science and technology but also an awareness of factors arising in geography, history, economics, social policy, and religious beliefs. Sub-Saharan African countries, for example, have placed a big emphasis in primary schooling on HIV/AIDS education as a major issue for schools, with many pupils and teachers having been affected by the disease. Freeing up the curriculum for local initiatives in this way gives teachers more opportunity to integrate and give local relevance. In 2014, for example, the floods across southern England are providing perfect material for children to study climate change, land use, drainage, and other major concerns in their communities.

Enabling teachers to share

Across Africa and Europe there has been a positive impact on teachers from being able to meet and share their experiences, ideas, and concerns about science teaching. This may be through face-to-face group meetings taking place locally on a regular basis, with an 'expert' as the catalyst, or increasingly through using email and the internet. Knowing that you are not alone with your problem, and hearing how others have tackled a difficult concept or topic, can lead to a growing repertoire of ways to teach.

Incorporating these ideas into your planning

The new National Curriculum for science (Department for Education, 2013) is less content-heavy and more accessible, something our teacher trainees see as particularly important. There is definitely more latitude, and while there is a defined body of knowledge that must be delivered, the shift to 'Working Scientifically' encourages 'doing' science in a much more varied manner. While little can be done about the latest prescription for the primary science curriculum, it is possible for you to take control of some of the other aspects mentioned above. For example, *collaboration* between teachers from your local cluster of schools, preferably with the support of some outside expertise, can provide a huge boost to confidence and to the repertoire of science teaching skills amongst the group, many of whom are unlikely to be science specialists (see subsequent chapters). The Primary Science Teaching Trust has been actively encouraging the development of self-supporting school clusters or hubs (see the weblink below) for this very purpose. Planning for sessions of mutual coaching, for instance, has also proved to be very effective as a professional development tool for both practising teachers and trainees paired in a classroom (Monach and Bryant, 2009).

On his appointment as the President of the Royal Society, Nobel Laureate Sir Paul Nurse was asked in a TV interview what advice he had for improving science teaching in this country. He mentioned just two factors: making science exciting to young people and treating it as a process rather than as a body of knowledge. Incorporating IBSE from the earliest stages is vital if the habit of enquiry is to be established throughout science in the primary phase. The movement towards play-based learning in the UK is strong, and it is a very small shift from thinking of children's science activity as play to thinking of it as enquiry. The play-based science chapter later in this book specifically discusses the value of this approach in mainstream teaching. When starting a new science topic, even with postgraduate trainees, I will usually put out the materials we are likely to use before they arrive and then watch what they do when they enter. Most of the time this involves playing with the materials to establish their potential; what can we do with these? Such play inevitably raises questions – which represent the beginnings of any science enquiry. Science is about learning to test your ideas against the evidence provided by your senses, and the only science knowledge we have is the science that has been done through this approach. So in order to understand science, the children in your class must do science and think scientifically. Nothing less than this is worth doing.

Summary

Primary education since the late 1980s has witnessed a huge number of initiatives from the 'top down'. One of the characteristics of being a good professional is the capacity to engage with change but not in a passive, unquestioning manner. Such a person does not function cynically, but with a clear sense of being able to identify what is right for the educational context in which they are located. Top-down change has focused, and is likely to continue to focus, primarily on the 'what' and perhaps less so on the 'when' but not the 'how'. Decisions about whether or not to do practical enquiry work in science should not be determined by curriculum guidance, but on the principle of educational fitness for purpose.

Change management will always challenge teachers' professionalism. This book accepts and welcomes the dynamic nature of education in general, and science education in particular. We hope that by engaging with what is being shared, you will see that change can be engineered effectively without a consequent loss of quality in educational provision. The authors place a strong emphasis on not providing you with a 'ready reckoner' for science education but with a resource that encourages you to think, to not be afraid to exercise your judgements but also to know what is high quality science education for our younger learners.

Further reading

Dunne, M. and Maklad, R. (2013) International Primary Science; what's in it for us?, *Primary Science,* 130: 5–7.
(A brief and accessible article that compares primary science provision in England, Egypt, Austria, Sweden, India, Chile, and the USA.)

Harlen, W. (ed.) (2006) *ASE Guide to Primary Science*. Hatfield: ASE Publications.
(Chapter 6 by Peacock, Symonds and Clegg provides a brief but useful overview of international perspectives on science education.)

www.upei.ca/~xliu/multi-culture/home.htm
(This site contains various links to information about scientists throughout history. It looks at specific contributions to the development of knowledge and understanding in biology, physics, chemistry, astronomy, and engineering.)

www.al-bab.com/arab/science.htm
(This site is a very useful source for Arabic science and its contribution to contemporary scientific knowledge and understanding.)

Primary Science Teaching Trust: www.pstt.org.uk/funding-and-projects.aspx
(This website offers a raft of very useful support materials and is well worth a visit if you need ideas, resources, CPD opportunities, possible collaborative projects, and links to other useful websites.)

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(An independent research review with an international perspective.)

Capra, F. (2002) *The Hidden Connections: A Science for Sustainable Living*. London: HarperCollins.
(Integrates our understanding of apparently disparate fields such as biology, psychology, economics, and eco-design.)
Department for Education (2013) *The National Curriculum in England: Framework Document*. Available at www.gov.uk/dfe/nationalcurriculum
Department of Education and Science (DES) (1978) *Primary Education in England: A Survey by Her Majesty's Inspectors of Schools*. London: HMSO.
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(A scheme of work with teachers' guides covering the whole of the NC as it was in the mid-1990s, and based on the findings of the SPACE reports.)
Ofsted (2013) *Maintaining Curiosity: A Survey into Science Education in Schools*. Reference no: 130135. Crown Publications.
Peat, D. (1995) *Blackfoot Physics: A Journey into the Native American Universe*. London: Fourth Estate.
(An eminent physicist and author who spent many years living amongst the native peoples of America, to learn about their ways of thinking about science and their environment. The author explores the similarities between modern understandings of the universe and the advanced understandings of ancient civilisations such as that of the Maya.)
Rose, J. (2008) *Independent Review of the Primary Curriculum: Final Report*. Available at http://publications.education.gov.uk/eOrderingDownload/Primary_curriculum_Report.pdf
(A government-sponsored report that set out to be the basis for reforming the primary curriculum.)
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Schools Council (1972) *Science 5–13*. London: Macdonald Educational. Available at http://openlibrary.org/books/OL16576313M/Guide_to_science_5–13
SEPA (1976) *Handbook for Teachers: Science Education Programme for Africa*. Accra, Ghana: SEPA.

Weblinks

Fibonacci project: http://fibonacci.uni-bayreuth.de/
Nuffield Junior Science: www.nationalstemcentre.org.uk/elibrary/collection/461/nuffieldjunior-science

POLLEN project: www.pollen-europa.net/?page=CLDGDJVwskY%3D
Primary Science Teaching Trust: www.pstt.org.uk/funding-and-projects.aspx
Scottish 5–14 curriculum guidelines: www.scotland.gov.uk/Topics/Education/Schools/curriculum/5to14
Scottish Curriculum for Excellence (CfE): www.ltscotland.org.uk/
Wellcome Trust (2010) *Leading Debate: 21 years of the National Curriculum for Science* www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtx063344.pdf