1 Science teachers, science teaching

Issues and challenges

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Introduction

Across the country, the best teachers inspire their pupils with the wonder and excitement of science and engineering. They provide the breeding ground for the scientists, entrepreneurs and technicians of tomorrow. They also make sure our citizens and consumers understand the risks and benefits of modern science. But to do this, teachers require consistent support and access to the best methods and practices

(Labour Party, 2001, unnumbered).

This chapter focuses on science teachers and science teaching. In doing so, we will refer to challenges raised by our colleagues in the rest of this book who aim to provide ‘access to the best methods and practices’. However, any consideration of science teaching needs to take into account three inter-related issues. First, the science curriculum has changed and continues to change in the light of developments in science and technology in the wider world (House of Lords Select Committee on Science and Technology, 2001). Second, the roles and responsibilities of science teachers have changed as the value of science to society has developed and broadened (Dillon, 2002). Third, the training available to science teachers has evolved as a result of major changes in education often instigated for predominantly political purposes (Dillon, 2000). Although the focus of the chapter is predominantly on developments in England, many of the issues are faced by science teachers throughout the world.

The Labour Party’s description of what the ‘best teachers’ do, quoted above, begs the question, what is meant by ‘best methods and practices’? There is an implicit assumption in the statement, made by one of the United Kingdom’s major political parties, that ‘national wealth depends on competing successfully in international markets’ (Laugksch, 2000, p. 84). This argument, which Laugksch describes as a ‘macro’ level justification for science education, is based on an idea that:
international competitiveness in turn relies *inter alia* upon a vigorous national research and development program in order, first, to maintain or capture ground in the worldwide race for new high-technology products in the case of developed countries and, second, to exploit smaller niche markets in the case of developing countries. Underpinning such a research and development program is a steady supply of scientists, engineers, and technically trained personnel. Only nations whose citizens possess an appropriate level of scientific literacy will be able to sustain this supply. 

(2000, p. 84)

Such rhetoric is common among policy-makers worldwide (though challenged by some researchers, see, for example, Osborne and Dillon, 2008, and Chapter 11 in this volume). As recently as December 2008, Lord Grayson, then newly-appointed as the UK’s Science Minister, was reported by the BBC as saying: ‘Science is fundamental to this country. As we go into this global downturn the importance of maintaining our investment in science has never been greater’ (BBC News, 5 December). At a European level, the widely promoted ‘Rocard Report’, *Science Now: A Renewed Pedagogy for the Future of Europe*, opens with this assertion:

> In recent years, many studies have highlighted an alarming decline in young people’s interest for key science studies and mathematics. Despite the numerous projects and actions that are being implemented to reverse this trend, the signs of improvement are still modest. Unless more effective action is taken, Europe’s longer term capacity to innovate, and the quality of its research will also decline. 

(High Level Group on Science Education, 2007, p. 2)

So, in introducing this chapter, we note that science teachers are tasked, throughout the world, with a set of almost Herculean challenges: make science lessons interesting; inspire pupils with wonder and excitement; increase the flow of scientists, entrepreneurs and technicians of tomorrow; and ensure that citizens and consumers understand the risks and benefits of modern science. These external demands help to make science teaching what it is today. This chapter, then, looks at the *habitus* (Bourdieu, 1990) of science teachers – the collection of behaviours, techniques and attitudes which define them and which reflect the influence of culture, politics and society – and at how curriculum, assessment and pedagogy issues continue to present challenges that research might help us to understand better.

**Who are science teachers?**

Science teachers occupy a unique position in schools. They usually have their own specialist rooms and laboratories; in some countries they may be
supported by technicians; and they may, on occasion, wear specialized clothing and use safety equipment. The job entails training students in complex practical skills often dealing with health and safety issues far removed from the experience of teachers of other subjects (Teachernet, 2005). For example, in school science, students are encouraged to use strong acids, fire and scalpels, frequently and with limited first-aid equipment or training.

Science teachers are usually part of a department of either their own discipline or a broader ‘Science’ grouping. Our experience of teaching in and working with schools, over the years, has led us to recognize that science teachers’ allegiance to their specific subject background can be a significant contributor to their identities and thus to their attitude towards the curriculum. Many teachers see themselves as, say, biologists first and science teachers second. This distinction can have implications for how they interpret the curriculum and on how they see their professional development needs (see, also, Chapter 13).

Many countries face a shortage of science teachers, particularly those with a physical science background. In a large-scale survey of mathematics and science teaching in England, Moor et al. found that 44 per cent of science teachers had a degree in biology; 25 per cent had a degree in chemistry and 19 per cent had a degree in physics (Moor et al. 2006, p. 106). The number of science teachers in the 630 departments that responded ranged from two to 24 with a mean of nine teachers (p. 110). Overall, 8 per cent of science teachers were defined as newly qualified teachers (p. 110).

An historical dimension

Throughout many parts of the world, science education has been through a process of almost continual change since the 1960s (see, for example, http://www.national academies.org/ise/backup3a.htm). The most significant changes include the introduction of new courses, such as the Biological Sciences Curriculum Study in the USA and Nuffield Science in the UK; the move towards ‘balanced science’ (that is, the teaching of biology, chemistry and physics for all students) as opposed to separate sciences or allowing students to opt out of one or more of biology, chemistry or physics; the rise of ‘process science’ (as opposed to focusing on ‘the facts’); the rise of the ‘Science for All’ and scientific literacy movements; the introduction of a national curriculum or national standards and the associated assessment regimes; and, more recently, the introduction of more vocationally oriented science courses aimed at a broad range of students.

Each innovation has, in some way, challenged existing science teacher pedagogy – the new diplomas being introduced into schools in England being a case in point. Over the years, our view of science has changed (see Chapter 2) as has our view of what learning in science involves (see Chapter 4). The complexity of the relationship between pedagogic change, views of learners
and learning, and changes in the representation of science in the curriculum is indicated by this comment by Monk and Dillon:

Shifting pedagogic perspectives have been the major surface feature of the changes in discourse of science education in the metropolitan countries of the old imperial powers. Generally we have moved from transmission views to more constructivist views. Older views of science as an empirical, inductivist enterprise with access to a knowledge base of an independent reality have been gradually eroded and replaced by newer constructivist views. These are not unitary (Solomon 1994), but multiple. However, they all share a concern for the student’s knowledge base as being idiosyncratic and biographical.

(Monk and Dillon, 1995, p. 317)

This gradual erosion of older views of science has come about through curriculum change, the introduction of new courses and through changes to the nature of pre-service and in-service courses. The process of change in science education, since the 1960s, though gradual, has not been one of seamless transition, rather it has involved reconstruction, reversal and high levels of political engagement (Donnelly and Jenkins, 2001). In summary, then, change is not something that is new to science teaching or science teachers, change is ever-present.

Public policy and the science curriculum

Science is still not a hugely popular subject in school, especially in developed countries (Osborne and Collins, 2000; Osborne and Dillon, 2008). Osborne et al. (2003), having reviewed research into pupils’ attitudes to science, concluded that school science left a significant number of pupils with negative attitudes towards the subject (see also Chapter 11 in this volume). The UK House of Lords Select Committee on Science and Technology concluded that:

The science curriculum at 14 to 16 aims to engage all students with science as a preparation for life. At the same time it aims to inspire and prepare some pupils to continue with science post-16. In practice it does neither of these well.

(2001, p. 9)

Although dissatisfaction with school science education was evident in the USA and in the UK even before the launch of the Sputnik satellite in 1957 (Klainin, 1988), the Nuffield Science projects mentioned above, which played a major role in defining science education in the UK in the second half of the twentieth century, owe at least some of their success to what is sometimes termed the post-Sputnik angst (Waring, 1979). However, despite the innovations of the Nuffield era in science education, successive government
reports and political commentary have continued to focus on the inadequacy of science education in both primary (elementary) (for example, DES, 1978) and secondary (high) schools (for example, DES, 1979). The criticisms, which, in part, continue today, were partially responsible for the changes in the science curriculum in the 1980s and 1990s. These criticisms have been mirrored in countries such as Australia, Canada and the USA (see, for example, http://www.acer.edu.au/enews/0705AER51.html).

What, though, is meant by the ‘science curriculum’? In the late 1950s, Kerr wrote that ‘[t]he teaching of general science as an alternative to biology, chemistry and physics has been a controversial topic among science teachers since the Thompson Report of 1918’ (1958–59, pp. 156–7). ‘General science’ was characterized as being of lower status than the separate subjects (see, for example, Goodson, 1985). Since the 1970s, more determined moves were made towards making science ‘balanced’ across the traditional divisions of biology, chemistry and physics. The rationale was usually expressed in terms of citizenship and living in the modern world (DES, 1985).

In Beyond 2000, a critique of science education at the turn of the twenty-first century, Millar and Osborne (1998) picked out what they considered to be the major developments in education, and particularly in science education in England since 1960. First, they identified ‘the major curriculum innovation, undertaken by the Nuffield Foundation which... gave greater emphasis to the role and use of experimental work’ (1998, pp. 2002–3). Nuffield Science involved a more experimental, investigative approach to science education pedagogy than had previously been the case (Jenkins, 2004). The Nuffield approach to science education involved an emphasis on practical activities, supported by worksheets, teachers’ guides, a network of teachers, examiners, academics and publishers. Nuffield Combined Science, first published in 1970, was probably the most influential course. Indeed, Keohane (1986, p. vi) remarked that ‘by 1979... half the schools in England were using the course wholly or in part’. The 1986 revision of the Nuffield Combined Science materials, published as Nuffield Science 11 to 13, took into account various changes that had taken place since the first version was published in 1970:

in that period, school children, schools, science, technology, and society at large have undergone great change. And that is not to mention the great changes in children’s expectations of schools and science lessons, in teachers’ expectations of children and resources for learning, and in society’s expectations of teachers.

(Nuffield Science 11 to 13, 1986, p. 2)

The editors and authors of the scheme took into account ‘what science lessons in primary schools and for the 13 to 16 age group [would] be like’ (Nuffield Science 11 to 13, 1986, p. 2). The objectives of the Nuffield Science 11 to 13 curriculum reflected a view that science education should be relevant to students and should encourage them to act in a ‘scientific’ manner during lessons (see
also Driver, 1983). Acting in a scientific manner, although not actually being a scientist \textit{per se}, involved students developing a critical understanding of the nature of science (Monk and Dillon, 2000) (see also Chapter 2).

Millar and Osborne (1998) also noted another significant development in science education as the introduction of the comprehensive school system in the mid-1960s which led, \textit{inter alia}, to the development of courses ‘for the less academic pupil’ (p. 2003). This change had enormous implications for science teacher pedagogy. The science curriculum, which traditionally was aimed at preparing future scientists and technicians was inappropriate for the majority of students. The idea of ‘Science for all!’, first mooted in a public lecture given by James Wilkinson in 1847 (Hurd, 1997), gained ground around this time. Under the broad umbrella of Science, Technology and Society (STS), a range of courses were introduced which aimed to address the needs of girls as well as boys and to provide a more relevant and broader science education for students who would never become scientists (Fensham, 2004; Turner, 2008).

Douglas Roberts (2007a) distinguishes between two ‘visions’ of scientific literacy: Vision I and Vision II. Vision I ‘looks inward at science itself – its products such as laws and theories, and its processes such as hypothesizing and experimenting’, whereas Vision II ‘looks outward at situations in which science has a role, such as decision-making about socioscientific issues’ (Roberts, 2007b, p. 9). A Vision I approach might be appropriate for future scientists whereas a Vision II approach might be better suited for the majority of citizens. The tension between the conflicting visions operates at the level of the curriculum design as well as in the classroom.

Some of the more recent changes in the science curriculum owe something to external political and social factors and, more specifically, to research into girls’ under-achievement carried out as long ago as the 1970s and 1980s (see, for example, Head, 1985). At that time, dissatisfaction with the quality of state education in the UK, highlighted by James Callaghan, the Labour Prime Minister in 1976, eventually resulted in the introduction of the National Curriculum by a Conservative government in 1988 (Donnelly and Jenkins, 1999). The National Curriculum was designed, in part, to serve the needs of those who wished to compare schools by ensuring that all schools taught the same content so that their results could be compared more easily than was previously the case. The National Curriculum also addressed the criticisms of those who saw too many girls opting out of the physical sciences at the age of 14 by ensuring that all students studied elements of biology, chemistry and physics (Head, 1985).

With the introduction of the National Curriculum and the concomitant national system of assessment, league tables and parental choice, schools in the 1990s became more competitive (Sinclair et al., 1996) (see also Chapter 10 in this volume). As a result of the general shift in education away from more collegial models of working (such as inter-school collaborations), teachers began to focus more on school improvement in isolation rather than through developing as a ‘community of practice’ (Lave and Wenger, 1991). The engine
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for change shifted from an internal personal desire for excellence to an external locus of control within a climate of accountability (such as described by Gewirtz, 2002). Recent initiatives in England, which reflect a desire to put school reform back in the hands of schools, such as the Leading Edge Partnership Programme (see www.ledge.org.uk) and the introduction of Specialist Schools (see http://www.standards.dfes.gov.uk/specialistschools/) may encourage more collaboration to solve shared problems.

Courses developed during the 1980s aimed to increase the emphasis placed on the processes of science (that is, the skills necessary to undertake science experiments) (Jenkins, 2004). Millar and Osborne also noted the influence of the Department of Education and Science policy statement, Science 5–16 (DES, 1985) which argued that all young people should have a ‘broad and balanced’ science education (that is, a curriculum containing biology, chemistry and physics throughout the school system) and occupying (for most pupils) 20 per cent of curriculum time from age 14 to 16 (Jenkins, 2004). The introduction, in 1986, of the General Certificate of Secondary Education (GCSE) resulted in a variety of science courses that included all three main sciences intended for all students. This move was not, in our view, universally popular.

Whether science in schools should be separated into biology, chemistry, physics or other science subjects, or whether it should be taught in an integrated, co-ordinated or ‘balanced’ way, is another issue that has been debated and has implications for the professional development of science teachers. In the UK, there is evidence that more students are being taught separate sciences than has been the case in recent years (Fairbrother and Dillon, 2009) and that the balanced science/separate science debate refuses to go away.

The move towards a model of science education that incorporated studies of the nature of science and of its applications was taken up by the major professional organization for science teachers, the Association for Science Education (ASE). However, their original proposals (ASE, 1979) which promoted more ‘attention to the nature of science and studies in environmental science, applied science and the interaction of science and society’ (Jennings, 1992, pp. 3–4) proved unpopular with teachers, some of whom did not regard themselves as able to teach socio-scientific issues. Both the ASE and the Royal Society issued policy statements advocating reform in science education (ASE, 1981; Royal Society, 1982).

Since science became one of the three core subjects of the National Curriculum, the nature of science education changed and ‘there has been a general acceptance that learning science involves more than simply knowing some facts and ideas about the natural world’ (Millar and Osborne, 1998, p. 2003) (for a counter-view, see Hodson, 1990, 1992).

Other key developments not identified explicitly by Millar and Osborne (1998) in their Beyond 2000 report include moves to make science more multicultural (Reiss, 1993) and attempts to develop a global dimension to science education (Brownlie et al. 2003). The opportunities for the development of a more beneficial relationship between science education and environmental
education have also been identified (Dillon and Scott, 2002) (see also Chapter 12 in this volume). Many of these influences and trends in science education need to be understood by science teachers if they are to keep abreast of their subject’s place in the curriculum.

Assessment issues

Assessment is the topic of Chapters 9 (formative) and 10 (summative) so we will keep this section rather shorter than the section on the science curriculum. The link between curriculum and assessment is exemplified by the train of events that was set in motion by the introduction of the National Curriculum in England and Wales in 1988/9. In response to some of the criticisms of early versions, the National Curriculum was revised several times. The curriculum was originally divided into more than 20 Attainment Targets. It was progressively reduced to four. The assessment system has also been changed substantially with a return to grades as opposed to levels for examinations at age 16.

Science in the National Curriculum for England and Wales (DoE, 1995) recognized the importance of the inclusion of some education in the epistemological and methodological basis of science by making one of the four Attainment Targets, Scientific Investigation, which was itself divided into three strands:

1. Asking questions, predicting and hypothesizing.
2. Observing, measuring and manipulating variables.
3. Interpreting results and evaluating evidence.

Sc1, as it has become known, was assessed by teachers as part of the overall national system of assessment. The implementation of Sc1 was the cause of more controversy than the content of the curriculum itself. Donnelly et al. (1996, p. 8) point out that:

[T]he evidence… suggests that it was indeed a major change in practice for most science teachers. Despite its origin in a long-established tradition of British science education, Sc1 can be seen as a radical, compulsory form of curriculum development.

The major change was in terms of a shift towards more investigatory practical work than had previously been the case: students were encouraged to undertake experiments in a more exploratory manner (see also Chapter 6). Nevertheless, the evidence from examination boards was that pupils were beginning to achieve standards of work that were not being achieved prior to 1988 (Millar and Osborne, 1998).

Sc1 assessment procedures have also changed as the National Curriculum has been revised with a concomitant necessity for continuing professional development (CPD) for science teachers. The implication is that assessment reform, coupled with curriculum change can drive science teaching in a
particular direction. The situation is made more complicated by a recent emphasis on Assessment for Learning (AfL) (QCA, 2007) which incorporates major changes to the way that teachers assess, record and plan lessons (see also Chapter 9 in this volume).

Science teacher pedagogy

Having looked at the influence of the curriculum and the assessment system on science teachers, we turn now to look at science teacher pedagogy itself – the dependent variable. By pedagogy we mean more than teaching. Pedagogy implies the whole philosophy and value system that leads teachers to make the choices they do in what and how to teach. Shymansky et al. writing about their research in Australia describe a ‘typical’ classroom and science teacher:

The classroom was a self-contained lecture-laboratory room. The teacher, a middle-aged man with a strong academic background in physical science, was an active graduate student pursuing a masters degree in science education at a local university. He expressed commitment to many constructivist ideas. He was enthusiastic about implementing ideas that he had researched at the university, and valued hands-on/minds-on activities, collaborative problem solving, and communities of learning. However, to some extent he was restricted in his teaching values and intentions by the need to complete the requisite subject matter of the unit of study within an allotted period of time. Nevertheless, within the traditional structure of the science department in his school, his lessons included strategies and activities that promoted knowledge construction and discourse opportunities. He used whole-class discussion for organization of the day’s activities, and students frequently worked in small groups to complete experiments, reports, and study guides.

(1997, p. 576)

Although nowadays the ‘typical’ science teacher might (a) be female and (b) not be studying for a conventional masters degree, and, therefore, would be less aware of the discourse of ‘constructivism’, there are many characteristics of the description above that would typify a secondary school science lesson in England and many other countries. The crux of the debate about science teachers’ pedagogical development relates to the perceived need for teachers to challenge the orthodox ‘teaching values and intentions’ which manifest themselves in what many would describe as ‘traditional science teaching’.

For many teachers, compulsory investigatory work ‘by Order’ (Donnelly et al., 1996) created the greatest need for a shift in science teacher pedagogy. Teachers had to organize and assess a minimum of investigations (around one or two each term). Although Nuffield Science and later curriculum material
attempted to challenge the existing orthodoxy of practical work, the majority of experimental work carried out in schools tended to be confirmatory rather than investigational (Donnelly et al., 1996). However, despite the approach inherent in the National Curriculum documents, commentators (for example, Jenkins, 1992) have argued that little real progress has been made in that school science is not radically different from what went on before the changes. Millar and Osborne, for example, described the science curriculum as being ‘a diluted [that is, similar topics but easier] form of the GCE curriculum’ (1998, p. 2004). They argued that that the curriculum content was very similar to the O-level courses that preceded the GCSE, which were generally very traditional in their approach and which encouraged traditional science teaching.

Dillon and Osborne (1999, p. 1) argued that there were ‘a number of widespread concerns about the capabilities of the extant [science] teaching force to deliver an exciting and engaging experience [to pupils]’. These concerns focused on problems with the recruitment and retention of science teachers (see also Chapter 13). Other issues have also been of concern, for example, the Council for Science and Technology (CST) noted in 2000 that ‘a significant number of pupils are negative about the intrinsic and extrinsic merits of science and/or the science curriculum’ (CST, 2000, p. 10). This negativity is, in part, a reflection of the ways in which science is taught in schools (Osborne and Collins, 2000).

Keys, reporting on the findings of the Second International Science Study (1982–86), wrote that:

> While the majority of 14 year-olds reported that their teachers normally introduced new material and went over material which had been covered previously at the beginning of each lesson, rather fewer reported that their science teachers summarized what had been taught at the end of each lesson…About half the 14 year-olds reported copying from the blackboard often and half doing so sometimes…Over 90 per cent of the 14 year-olds reported having science tests, about 40 per cent often and 50 per cent sometimes.

(1987, p. 159)

Thus there is little evidence that science teaching, in terms of strategies and tactics, made significant progress during the period from the 1970s to the 1990s when many of today’s science teachers were themselves school students. This state of affairs occurred despite the best endeavours of new curricula and new resources which encouraged aspirations of more creative processes that, in the end, were rarely met.

**Pedagogical training for beginning teachers**

The model that many current pre-service teachers see taught in schools may be little different from what they experienced when they were younger. This
lack of alternative models in pre-service education may prove to be a major factor in limiting the professional development of many teachers. Standards applied across the teaching force may neglect the individual biographical element of professional development. Ironically, when placed in teaching practice schools which have teachers with varying styles, our own pre-service students often report tensions in trying to please all the people all the time and, consequently, failing to please anyone.

An approach taken in England and Wales by the then Teacher Training Agency (TTA) strategy involved, *inter alia*, promulgating a series of national standards for teacher training (see, for example, TTA, 1997). Despite the efforts of the TTA (later renamed the Training and Development Agency for Schools (TDA)) to raise the competence of newly-qualified teachers, the evidence suggests that the expertise required to deliver the science curriculum is not fully acquired in initial courses. For example, in a study involving 49 newly-qualified teachers (NQTs) of varying subjects at the end of their first term of teaching, Capel (1998) identified a number of aspects of teaching that the NQTs felt they had not been well prepared for in their initial training. With respect to the issue of teacher individuality, it is critical to point out that Capel also found that: ‘the results suggested that the combination of aspects of teaching identified by any one NQT were unique to that individual and resulted from a combination of personal and situational factors’ (1998, p. 393). There is substantial evidence from elsewhere in England, Australia and the USA to indicate that pre-service courses only have time to develop sufficient confidence to operate adequately in the classroom and to expose student teachers to a baseline repertoire of essential pedagogic strategies (Luft and Cox, 1998; Mulholland and Wallace, 1999). Teachers entering the profession with this minimum repertoire are in need of continuing teacher development to develop further both in terms of subject knowledge and pedagogic content knowledge (see Chapter 13). In some ways, this has been the case for as long as science has been taught in schools (Kerr, 1963).

As was discussed above, in recent years, science investigations, a particular form of experiment (often involving testing a hypothesis practically) and the legitimate descendant of ‘discovery learning’, have become widespread (Jones et al., 1992) and mandatory (DoE, 1995). In parallel with a shift towards a more process-based approach to science has come an increased awareness of the need to consider the internal structure of science’s epistemology and methodology (Monk et al., 1994). Both of these trends required a change in pedagogy in order to be implemented successfully, in line with the demands of the National Curriculum.

**Science education, practical work and the process/content debate**

As we discussed earlier, one of the key changes in science education has been the role of practical (experimental) work in schools (see also Chapter 6). We
also noted that another related issue is the proportion of time that is spent on acquiring scientific knowledge compared with the time spent on developing skills (the process/content debate). This debate is not new, Jevons, writing at the end of the 1960s, noted that:

Schoolteachers themselves get very keen on new approaches – which in itself is half the battle won – but their enthusiasm is not untinged with scepticism about the value of pupils finding out for themselves in the laboratory ... Demands on time mean fewer facts – that is, a lower syllabus content; and that is a price which, in present circumstances, we can afford to go on paying for some time yet as long as we get the right kind of return in the form of minds which are lively and inquiring and not going under in a morass of information.

(1969, p. 147)

Commenting on a recent survey of 510 UK science teachers, NESTA, the National Endowment for Science, Technology and the Arts, said that ‘science teachers are resolutely committed to the principle of practical and experiment-based science enquiry learning’ (2005, p. 4). Some 84 per cent of their sample considered practical work to be ‘very’ important with 14 per cent considering it ‘quite’ important. However, if the defining characteristic of school science is ‘the practical’, then the characteristics of the practical have changed substantially within our lifetime and within those of many practising science teachers.

Writing in the late 1950s, Kerr stated that there was ‘some evidence that teachers of science, particularly in grammar schools, still consider the chief value of their work is associated with the claims made for the study of science as a mental discipline’ (1958–59, p. 156). In the 1960s, 1970s and 1980s, experimental work served primarily to demonstrate techniques and to verify theory. In the early 1960s, Kerr, reviewing practical activity in school science, commented that:

There was a lack of consistency between some kinds of experiments which teachers said they did and the stated value of such experiments. Verification experiments were frequently used but teachers thought their educational value was limited. Tradition and convenience perpetuated outmoded methods. On the other hand, finding out or ‘getting-to-know-by-investigation’ experiments were infrequently used, especially by the chemists and physicists, although the teachers ranked their educational value high.

(1963, p. 54)

It may well be the case that tradition and convenience perpetuate outmoded methods. Dissatisfaction with the large number of science facts (the ‘content’) in the curriculum and the emphasis on rote learning have driven debates about science education for many years and prompted new approaches to science
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education in the mid-to-late 1980s (Hodson, 1990; Donnelly and Jenkins, 2001). This shift occurred partly as a result of an increased focus on the processes of science and how they could be taught and assessed.

Osborne (1993), among others, argued for more thought and discussion in school science and less rote-practical work (see also Gunstone (1991) and Solomon (1991)). Hodson (1990; 1992) criticized poorly planned practical work, describing its use as being ‘ill-conceived, muddled and lacking in educational value’ (1992, p. 65). The debate (the process/content debate) was not about practical work, per se, rather it was more about the relative efficacy of different ways of teaching science. The argument was that if pupils were to learn about how science works, then they needed to develop an understanding of the processes of science (that is, the skills used in doing experiments). As Jevons put it:

The case for investigational work in the laboratory rests partly on its supposed resemblance to the ‘real thing’, creativity in research, and the hope that in consequence it will stimulate and foster the right kind of abilities and ways of thought.

(1969, p. 147)

There is some disagreement among science teachers as to whether the amount of science enquiry has changed in recent years: NESTA’s survey of 510 UK science teachers, referred to earlier, found that 42 per cent thought that the amount had increased over the preceding ten years while 32 per cent thought the opposite (NESTA, 2005, p. 7). Our perspective, as people who visit schools regularly, is that schools do vary considerably in the nature and the amount of practical work that they carry out, hence the findings of the NESTA survey.

In the same NESTA survey, 99 per cent of their sample of science teachers believed that enquiry learning had a significant (83 per cent – ‘very’; 16 per cent – ‘a little’) impact on student performance and attainment (NESTA, 2005, p. 5). However, views about the role of processes in science education have been contested: some science educators have argued that practical work might help students to understand how scientists work, while others have argued that a process-based approach (that is, an approach that focused on experimental skills) was likely to lead to better understanding of science concepts (Donnelly et al., 1996) (see also Chapter 6).

Final thoughts

We have tried to show that science teachers are made not born, at least in terms of the influence of society’s views of science and of the influence of politicians on what is taught and how it is taught. The argument could be made that it is the assessment tail that wags the pedagogy dog. That is, what is assessed and how it is assessed do, in the end, dictate how and what people teach. But the
situation is more subtle than that and individual teachers' identities and life histories also influence what they do in the classroom.

We have indicated above how the other chapters in the book provide insight into what is taught, how it is taught, why it is taught, when it is taught and where it is taught. We know a lot about how learners learn and how teachers teach and we hope that in reading the other chapters in this book that you will develop a greater insight into what makes you tick, demonstrate, explain, enthuse and develop.

**Further reading**


