Science and mathematics education, 5–14

A 'state of the nation' report

CELEBRATE
350 YEARS

THE ROYAL SOCIETY

Cover image: Microscopic observation of a bean sprouting by Marcello Malpighi, 17th century. From the Royal Society Archive.

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'State of the nation' report on 5–14 science and mathematics education

Contents

Foreword

This report considers primary and early secondary science and mathematics education across the United Kingdom. Venturing into this complex area represents something of a first for the Royal Society. Why have we done it?

Clearly future advances in science and technology will be essential to combating the greatest social and environmental challenges we face, and suitably qualified experts are required to tackle these. Evidently, the success of Government policies concerning science and innovation depends on the quality of young people's education.

Our work in education policy, like that of many others, has been mostly concerned with the products of the education 'system', focusing on the numbers taking public examinations in science, mathematics and related subjects and pursuing careers in them. On the face of it, this makes good sense given that the subject choices young people make narrow as they progress through the education system, and the extent to which they continue to pursue science and mathematics will increasingly determine the numbers of professional scientists and the overall level of scientific literacy in the population.

However, recent evidence has highlighted how children's initial experiences of education can have profound implications for their future success and well-being. Children are innately curious about the natural world. But, year after year, large proportions are 'turned off' science and mathematics by the time they reach secondary school, with little prospect of that interest being rekindled. Inevitably, those who are most likely to suffer are the under-privileged.

We have sought to understand why this is happening, by sifting through a quantity of the vast array of information available from independent research and national educational records.

It is clear that there are profound issues that will only be solved long term. This will demand a precise understanding of what subject specialism is and should be in relation to primary and secondary education. Finally, as responsibility for education increasingly shifts to local communities, there is a need for private enterprise, educational charities and the learned and professional bodies to give far greater consideration to supporting primary science and mathematics inside and outside the classroom. It is only by concerted action that we will be able to move closer towards achieving equality of opportunity for all children.

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President of the Royal Society

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Summary guide to the report and recommendations

This report has a triple purpose: (i) to provide a summary of the quantitative information that is available on attainment and the workforce in respect of 5–14 science and mathematics education across the UK; (ii) to explain the factors considered to have been influential in producing any observed trends; and (iii) to make recommendations to policy makers on specific actions to improve 5–14 science and mathematics education in the UK. A summary of the key issues in 5–11 science and mathematics education, *Primary science and mathematics education: getting the basics right*, is based upon and published alongside this report (Royal Society 2010*a*).

The background to historical and more recent changes in 5–14 science and mathematics education is described in chapter 2.

Core data on pupil attainment are presented in chapter 3, concerning performance Levels and trends from 1998 onwards. Both test and teacher assessment data are reported where available. However, the most complete pictures of attainment across the last 12 years are derived from teachers' assessments, which have continued to be available, whilst test data ceased to be either collected or reported at various times in Northern Ireland, Scotland, Wales and, most recently, with respect to Key Stage 3, in England.[2] Interpretation of these attainment data needs some caution because of the changes in curricula and assessment arrangements during this time, including the move from end-of Key Stage national testing to greater teacher assessment, and because the individual circumstances of each nation differ.

Data relating to the science and mathematics teaching workforce and the extent of participation in professional development are reported in chapters 4 and 5, respectively. In both cases firm conclusions are hampered by absence of relevant records. For example, it is known that a teacher's own background in these subjects is a key factor in good teaching, but information is lacking about the proportion of currently practising teachers with up-to-date specialist knowledge in these subjects. This means that data do not seem to be available to inform debates surrounding the use of specialist teaching in the upper years of primary school.[3] Similarly there is a lack of centralised records of teachers' participation in continuing professional development (CPD) other than for the courses provided in science by the network of Science Learning Centres and the opportunities in mathematics coordinated by the National Centre for Excellence in the Teaching of Mathematics (NCETM).

Chapter 6 brings together information from research about factors that influence pupils' performance. It refers to classroom factors such as the use of language, experience of working in groups and ensuring that the general sequence of development is reflected in the teaching methods and activities. It looks at the impact of a range of background factors inside and outside of the classroom that may affect children's perceptions of science and mathematics and their attainment. Also discussed here is the decline in pupils' attitudes towards science and mathematics as they progress through primary school and into secondary school. Although there is no evidence of an association between attitudes and attainment, measures need to be taken to improve attitudes and encourage greater participation in these subjects in later secondary education.

Chapter 7 considers the evidence that pupils' learning may be affected by the balance between the stimulation of new experience on transfer and continuity with previous ways of learning. Repetition of material covered in earlier work lowers interest and must be avoided, but without presenting secondary school science as something entirely different from primary science. A key factor in this endeavour is to smooth the transfer from primary to secondary school, where at present there are dips in both attainment and attitudes.

Finally, chapter 8 draws together the key findings and reflections about science and mathematics education in the 5–14 age range, with a view to outlining possible ways forward, including the need for research-informed policy.

Recommendations

The individual recommendations found within this report are listed below.

Chapter 3. Attainment trends in science and mathematics among 5–14 year olds (pp. 14, 27)

Recommendation 1

The Department for Education should carefully review its data publishing protocols with a view to ensuring its releases of Key Stage 1–3 attainment data are clearly and consistently presented, conducive to facilitating comparisons over time. In particular, it should consider dispensing with provisional and revised data, and commit only to publishing final data. Otherwise, it should adopt a consistent approach to publishing, and clearly distinguishing, these different types of data in its publications, and ensure that users can locate them easily. Adopting the second alternative would necessitate the removal of provisional data from open access once they have been superseded, in order to reduce the risk of confusion.

2 Lately, Key Stage 2 tests in science have been abolished in England.
3 See, for example, conclusion 128 of the Cambridge Primary Review (Alexander 2010).

Recommendation 2

The Department for Education should dispense with Key Stage 2 tests in mathematics. It should also conduct a review of the assessment system for pupils aged 5–14, ensuring that assessment is light touch and geared primarily to supporting and encouraging their progress.

Chapter 4. Science and mathematics ‘specialists’ within the 5–14 teaching workforce (pp. 36–37, 40)

Recommendation 3

In the light of its intention to abolish the General Teaching Council for England, the Department for Education should commit to maintaining the register of teachers in England and clarify how it intends to do this. Together with the Training and Development Agency for Schools, and the science and mathematics communities, it should collaborate to resolve each of the issues below, and agree a strategy for improving the quality of records on subject specialists within primary and secondary teaching in England.

(i) Clarify the type(s) of qualifications that should be included in recognising subject ‘specialism’;

(ii) Categorise first degree course subjects for the purpose of identifying science or mathematics specialists;

(iii) Specify the requirements for specialism at different educational phases, from Key Stage 2 upwards.

Recommendation 4

The Department for Education should establish, with the support of the science and mathematics communities, a definition of ‘specialist’ (see Recommendation 3) that recognises that the criteria for identifying specialism will change from Key Stage to Key Stage. It should then formulate both a target for increasing the numbers of science ‘specialist’ teachers in English primary schools to ensure that every child has access to a high quality science education, and invest in strategies for achieving this. Given that there are currently more than 17,000 primary schools in England, and based on the identification of a ‘specialist’ used for Figure 4.1, there is potentially a need to triple the numbers of science ‘specialists’ in the primary teaching population. The Department should also develop with the Training and Development Agency for Schools a mechanism that enables specialism, and the development of expertise through teaching experience and subject-based and other CPD, to be tracked and recognised throughout a teacher’s career.

Recommendation 5

The Department for Education and the Training and Development Agency for Schools should scope out a recruitment and retention programme specifically for primary teachers with science and mathematics expertise. Initial teacher training departments should strengthen their connections with science, mathematics and engineering departments in higher education institutions in order to raise awareness of teaching among students taking STEM degrees.

Recommendation 6

Given the Department for Education’s intention to abolish the General Teaching Council for England, it is important that it should work with the General Teaching Councils for Northern Ireland, Wales, and with the General Teaching Council for Scotland, on a coordinated approach to recording and maintaining consistent and accurate records of the specialisms of teachers on their registers.

Chapter 5. Subject-specific continuing professional development for teachers of primary and early secondary science and mathematics (pp. 55–57)

Recommendation 7

The Institute of Physics, the Royal Society of Chemistry and the Society of Biology should explore with the National Science Learning Centre and others in the science community the development of a cross-disciplinary ‘science for non-specialists’ course for Key Stage 2/3 teachers and higher-level teaching assistants.

Recommendation 8

Subject associations and professional bodies should continue to ensure they provide suitable opportunities and incentives for primary schools and/or teachers to become members or affiliates, in order to drive up exposure to science and mathematics CPD opportunities provided by these organisations and others.

Recommendation 9

In considering the impact on progression and attitudes of early educational experiences, subject associations and professional bodies should review the balance of their CPD provision with a view to having an increased focus on primary education.

Recommendation 10

The National Science Learning Centre (NSLC), regional science centres and the National Centre for Excellence in the Teaching of Mathematics must be allowed to continue their important work in supporting the drive to improve professional standards through subject-specific CPD. For this to happen, continued Government investment will be needed when current funding arrangements end in 2011. In addition, the NSLC's remit needs to be modified to enable a greater focus on providing primary teachers and teaching assistants with CPD in science.

Recommendation 11

The Scottish Government should also consider providing funding beyond 2011 in order to allow the Scottish Schools Equipment Research Centre and its partner agencies to deliver high quality CPD to primary and secondary teachers.

Chapter 6. Factors affecting attainment in 5–14 science and mathematics (p. 70)

Recommendation 12

Knowledge of the factors that promote pupils' cognitive development in science and mathematics should be incorporated within high quality training and continuing professional development for teachers and teaching assistants, coordinated by the National Science Learning Centre and the National Centre for Excellence in the Teaching of Mathematics.

Recommendation 13

The Economic and Social Research Council and other education research funders should encourage more investigations into the long-term benefits of informal learning in science and mathematics and parent participation within it, as well as the development of opportunities in mathematics that complement those in science in the use of museums, travelling resources and Web-based resources.

Chapter 7. Primary–secondary transfer in science and mathematics (p. 79)

Recommendation 14

National regulators and developers of curricula and assessment should carefully review the impact of new and revised curricula and assessment arrangements on primary–secondary transfer in science and mathematics.

Recommendation 15

While longitudinal studies of children's developing mathematical abilities across the primary–secondary interface already take place, there is a need for the Economic and Social Research Council and other education research funders to encourage similar, high-quality studies of children's developing scientific knowledge, understanding and skills and how these are applied to the world around them. This should include using a range of methods, research on boys' and girls' attitudes towards science and mathematics and how these change during primary and early secondary education.

Chapter 8. Conclusions (p. 85)

Recommendation 16

A coordinated programme of evidence-based quantitative and qualitative research into primary science and mathematics education in the UK is required to inform future policy decisions. This should be developed from the Economic and Social Research Council's Targeted Initiative on Science and Mathematics Education, which focuses on the secondary and later phases, and should reference the Alexander Review of Primary Education. Other funders of educational research within this area, including the Wellcome Trust, the Gatsby Foundation and the Nuffield Foundation, should be involved in determining a suitable framework.

1 Introduction

1.1 The importance of early education in science and mathematics

Primary and early secondary education serve more than the purpose of providing a foundation for later secondary and then tertiary education. During these periods, young people are developing knowledge, capabilities and other attributes that affect their daily lives as well as their further learning. This is a crucial period of their education during which changes in their ways of thinking, particularly the ability to deal with abstract concepts, enable them to see connections within their rapidly expanding experience of the world around them. Generally it is a time when children enjoy new experiences and want to be challenged, to learn things of relevance to their lives and to understand how everything fits together.[4] So the first nine years of schooling are not merely a time of preparation for the next two to four years; they should meet the needs of pupils as they live through these formative years. This is the message in the aims of the curriculum in England for Key Stages 3 and 4 and which are proposed also as aims for Key Stages 1 and 2: that young people should become 'successful learners', 'confident individuals' and 'responsible citizens' (QCA 2007). Similar aims are stated for the Scottish Curriculum for Excellence, with the addition of 'effective contributors'.[5] A more recent review of primary education identified a wider set of aims or purposes (Alexander 2010).

Clearly these aims go beyond developing 'the basics', which has traditionally been seen as the key aim of primary education. While mathematics—or at least development of numerical skills—has long been regarded as fundamental in the education of young children,[6] the position of science historically has been less secure. So, while it is not necessary to argue the case for the position of mathematics in the primary curriculum, it is still pertinent to set out the case for science in the primary school.

Claims for the importance of learning science from the start of schooling are based on three kinds of evidence: (i) what is known about how children develop ideas about how things behave in the natural world; (ii) about how their reasoning develops; and (iii) about how attitudes develop and change. In relation to the first, extensive research shows beyond doubt that children arrive at their own ideas about the natural world in their early years, whether or not there is science in the curriculum. These intuitive or naive ideas are often in conflict with scientific ones and, if taken into secondary school, may inhibit effective learning. On the second point there is widespread international recognition that understanding in science develops through the use of enquiry skills.[7] These skills, relating to the collection of data and their interpretation, determine the ideas that children develop in their exploration of the natural world. Early experience of developing and using scientific enquiry skills contributes to understanding 'how science works', a key component of early secondary science curricula. On the third point, it is well established that attitudes towards science form early and have already become less positive when children reach the end of primary school. Some of this decline may be due to a general pattern for pupils' attitudes towards most school subjects to become less positive with age, but there is evidence that the decline is less pronounced when pupils are engaged in scientific activity.

1.2 Aims and procedures of this report

Given the importance of primary and early secondary education, those developing policy and practice ought to be aware of the extent to which educational provision optimises the opportunities for all pupils to learn science and mathematics. There are multiple factors affecting pupils' cognitive and affective outcomes, both within and outside school. These include the curriculum and assessment, the management of schools, the relationship between schools and other agencies, teachers and their training, children's development, the role of parents and home background, the transfer from pre-school to primary school and from primary to secondary school. This report does not attempt to cover this range in the same way, eg as the Cambridge Review of Primary Education in England has done, nor does it focus attention on the influential role of the media in bringing about educational reform. Rather it sets out to identify trends in Levels of performance of pupils aged 5–14 in science and mathematics across the UK and to identify factors that may have an impact on pupils' attainment. The intention is not only to report the available quantitative and qualitative evidence, but to comment on its adequacy as a basis for informing policy and then make actionable recommendations to key policy makers.

The achievement of these aims presents a considerable challenge. Not only are there two subjects to consider but also two very different school contexts—primary and secondary schools—in which pupils in the age range being considered are taught, and different ages of transfer from one to the other in Scotland compared to other parts of the UK. Further, the governance of education is now a matter for each of the four nations of the UK to decide and, since 2007, curricula and assessment procedures have diverged as a result. Curriculum and assessment reforms, already

4 QCDA consultations with pupils on the new primary curriculum (QCDA 2009).
5 Scottish Government 2008 *Curriculum for Excellence*, see http://www.ltscotland.org.uk/curriculumforexcellence/
6 There are no universally agreed and understood definitions of 'mathematics' and 'numeracy' (ACME 2009).
7 For example, the IAP Science Education Programme, see http://www.interacademies.net/CMS/Programmes/3123.aspx

being implemented in Northern Ireland and Wales and in progress in Scotland, include changes that affect the position of science in the primary years. Although it is rather too early to report the impact of these particular reforms on pupil attainment, this report can comment on the evidence base that is available and which is needed for responsible policy decisions.

As a result, the areas of concern addressed in this report include:

- the levels of, and trends in performance of, 5–14 year old pupils across the UK in science and mathematics;
- the number and qualifications of those teaching science and mathematics to pupils in primary schools and the lower years of secondary schools;
- the opportunities teachers have for specific continuing professional development in these subjects;
- factors within and beyond the school that may affect pupil attainment in science and mathematics;
- the conclusions that may be drawn from the available data regarding how to improve performance in and attitudes towards science and mathematics;
- the policy recommendations that follow.

The methods used in addressing these areas of concern were: (i) the collation and analysis of assessment and test data from Key Stages 1, 2 and 3 in England and the equivalent data, where available, from Northern Ireland, Scotland and Wales; (ii) the collation and analysis of information about the workforce for science and mathematics education for 5–14 year old pupils across the UK; and (iii) the review of relevant research findings relating to pupil attitudes, the transfer from primary to secondary school, and the impact of personal, home and other within and without school factors.

A note on recommendations and additional data

The recommendations made in this report are intended to highlight actions that need to be taken by those with responsibility for improving the effectiveness, and the measurement of the effectiveness, of primary and early secondary science and mathematics education. An electronic appendix contains supplementary tables and figures, referenced in the main report by the prefix 'A' (eg Table A3.2; Figure A5.5).

A note on the Government department responsible for education in England

On 12 May 2010, following the General Election, the Department for Children, Schools and Families (DCSF) became the Department for Education. In recognition of this, where necessary, recommendations in the report have been modified to take account of this change. However, in order to maintain a correct historical perspective, the data on attainment trends were sourced from the DCSF, and are credited as such.

2 The context of 5–14 science and mathematics education in the UK

This chapter reviews the changes to policy and practice in science and mathematics education in primary and early secondary schools in the nations of the UK, beginning with a brief account of conditions leading to the introduction of national curricula and guidelines in the later 1980s. The influence of political devolution brought divergence in curricula and particularly in national assessment arrangements, leaving England in 2010 as the only UK nation with national testing at age 11, including mathematics but no longer science. Tables 2.1 and 2.2 indicate 5–14 education ages, year groups and stages in use in the UK prior to and after 2007, when changes were implemented in all four nations.

2.1 Before the introduction of national curricula

2.1.1 England and Wales

When, under the 1944 Education Act, primary and secondary education was made free and available to all children, what was taught was left to schools to decide: apart from religious education, nothing was centrally

Table 2.1. Ages, year groups and stages in the UK to 2007 for 5–14 year olds.

Age	England		Wales		Northern Ireland		Scotland
4/5	Reception		Reception		Y1	KS1	Pre-school
5/6	Y1	KS1	Y1	KS1	Y2	KS1	P1
6/7	Y2	KS1	Y2	KS1	Y3	KS1	P2
7/8	Y3	KS2	Y3	KS2	Y4	KS1	P3
8/9	Y4	KS2	Y4	KS2	Y5	KS2	P4
9/10	Y5	KS2	Y5	KS2	Y6	KS2	P5
10/11	Y6	KS2	Y6	KS2	Y7	KS2	P6
11/12	Y7	KS3	Y7	KS3	Y8	KS3	P7
12/13	Y8	KS3	Y8	KS3	Y9	KS3	S1
13/14	Y9	KS3	Y9	KS3	Y10	KS3	S2

Notes: Y, year group; KS, Key Stage; P, primary; S, secondary.

Table 2.2. Ages and stages in the UK from 2007 onwards for 5–14 year olds (changes in bold).

Age	England		Wales		Northern Ireland		Scotland	
4/5	Reception	**FS**	Reception	**FPh**	**Y1**	**Foundation**	Pre-school	**Early stage**
5/6	Y1	KS1	Y1	**FPh**	**Y2**	**Foundation**	P1	**Early Stage**
6/7	Y2	KS1	Y2	**FPh**	Y3	KS1	P2	**First Stage**
7/8	Y3	KS2	Y3	KS2	Y4	KS1	P3	**First Stage**
8/9	Y4	KS2	Y3	KS2	Y5	KS2	P4	**First Stage**
9/10	Y5	KS2	Y4	KS2	Y6	KS2	P5	**Second stage**
10/11	Y6	KS2	Y5	KS2	Y7	KS2	P6	**Second stage**
11/12	Y7	KS3	Y6	KS3	Y8	KS3	P7	**Second stage**
12/13	Y8	KS3	Y7	KS3	Y9	KS3	S1	**Third stage**
13/14	Y9	KS3	Y8	KS3	Y10	KS3	S2	**Third Stage**

Notes: FS, foundation stage (England); FPh, foundation phase (Wales).

prescribed. In relation to science there was little in the primary school, other than nature study and some 'object lessons'. In the case of both science and mathematics, what was taught at the secondary level had not kept pace with scientific and technological development during and after the War. Attention to badly needed change started with the post-16 stage of the secondary school in the 1960s and gradually worked downwards in the form of curriculum development projects in science and mathematics funded by the Nuffield Foundation, the Schools Council and private industry. When it reached the primary school it became clear that existing practices were highly unsatisfactory either in helping children to begin to understand the scientific and broader mathematical aspects of their world or as a preparation for the new secondary curriculum.

The first primary science and mathematics curriculum projects promoted the child-centred approach to primary education strongly endorsed in the Plowden Report (CACE 1967a) in England and the Gittins Report in Wales (CACE 1967b). This approach allowed children to make connections in what they were taught and develop their understanding at their own pace. Children regularly worked in pairs or groups rather than, in the teacher-centred approach, always as a whole class, all undertaking the activities at the same time. The considerable change in classroom practice that these projects required was their weakness as well as their strength. The HMI report on primary education in England (DES 1978a) noted disappointing progress in science teaching in primary schools, with the ideas and materials produced by curriculum development projects having had little impact in the majority of schools. A survey associated with this report (DES 1978b) showed that only about half of primary classes had any science at all and in only about one in ten was the work developed seriously. Changes in mathematics were also difficult to implement on a large scale, and many schools turned to new textbooks, which were very limited in their vision. It became common practice for children to work through these on their own rather than engaging in group work or whole class discussion.

The first round of successful secondary curriculum projects in both science and mathematics was developed for the independent and grammar schools. However, with the growth of comprehensive schools in the 1960s and 1970s, new projects were launched to ensure that the whole attainment range was covered, and many had a large take-up.

The result of all these initiatives was a wide range of different practices right across the 5–14 age range. Not only was there no central control of what was taught and no information about the pre-16 achievements of pupils, there was also decreasing local control following the demise in most areas of the 11+ examination. The Government therefore announced the establishment, in 1974, of the Assessment of Performance Unit (APU) to provide information about the relative achievement of different student groups and changes over time.

APU surveys were conducted at age 11 (in mathematics, English language and science), at age 13 (science and foreign languages) and at age 15 (in mathematics, English language, science and design and technology) in England, Wales and Northern Ireland. The extensive range of items included meant that what was tested in the surveys covered a far better sample of the curriculum than could be covered by a single test taken by all pupils. Further, including a number of items, assessing the same skill of concept but set in different contexts, enabled the effect of particular contexts to be minimised. In the science surveys large banks of items were created for each age group for each of six main categories of science performance, of which three involved direct manipulation of objects and equipment. In mathematics the main components were traditional pencil-and-paper testing of concepts and skills in different topics, but small-scale tests of problem-solving and skills were later added for the two age groups.

Although the APU results for mathematics showed a slight but steady improvement with, as for science, interesting differences between aspects of the subject, nevertheless the national concern with mathematical standards continued, stoked by a Prime Ministerial speech in 1976, and culminated in the report of the Cockcroft Inquiry into the *Teaching of mathematics in schools* (DES 1982). This report recommended an emphasis on the uses of mathematics in everyday contexts, a broad description of a common core curriculum to fit students for employment, a recognition of the need for curriculum differentiation, and a variety of teaching methods to include problem-solving, investigation, discussion and practical work, as well as exposition and practice. It had a considerable effect on mathematics teaching and assessment at all levels.

The inclusion of science as one of the three subjects assessed in the APU surveys at age 11 established its position as part of the 'core' of the primary curriculum, a position confirmed when the National Curriculum was created in 1989. For both science and mathematics the decisions about content and skills to be assessed were later influential in the formulation of the National Curriculum and in assessment. The APU was terminated in 1990 when the Government decided to use aggregated national test results to monitor national trends in performance.

2.1.2 Northern Ireland

In 1947 the Northern Ireland Education Act, paralleling the 1944 Education Act in England, legislated for the transfer of all pupils, at about the age of 11, from 'primary' to a grammar, secondary intermediate or technical intermediate school (the latter being phased out by 1974). While mathematics was taught throughout compulsory schooling, a survey of primary education carried out by the Department of Education Northern Ireland Inspectorate from 1978 to 1980 estimated that only about one primary school in ten was actively engaged in teaching science (DENI 1981). In response to the Inspectorate's survey, a significant programme of curriculum review and development was inaugurated. A series of subject guidelines, including one for science (NICED 1986), together with a more general guideline on primary school aims and objectives, was developed. Although schools were not required to participate in this initiative, nor were they required to address science if they did so, nevertheless it could be reported by the end of the Eighties that science was 'evident in the majority of schools' (DENI 1990, p. 10).

The results of the APU surveys show evidence of this late blossoming of primary science. It was reported that, by the end of the study, about 90% of those in Northern Ireland included science activities in the work of their 10/11 year olds (Russell *et al*. 1988). In respect of pupils' performance, children in Northern Ireland achieved scores broadly similar and in some cases exceeding those in England and Wales both at ages 11 and 13.

One of the factors contributing to the slower progress in establishing primary science in Northern Ireland than was the case in England was the impact of the procedures used to select pupils for grammar school places. Unlike England, Northern Ireland retained a selective system of secondary education for the majority of pupils. Over the period 1948 to 1988 different means were employed to identify those deemed suitable for grammar school education. Most commonly, though, these comprised tests of verbal reasoning, English and mathematics. The narrowing effects of such high-stakes testing on the primary curriculum at this time have been well documented (eg DENI 1981, 1988; Wallace 1994).

2.1.3 Scotland

In 1946, the Advisory Council on Education in Scotland produced a report on primary education which made no mention of the terms 'science' or 'mathematics' (ACES 1946). Nature study, geography and history were grouped together as 'three subjects with a large common element' and arithmetic was the only branch of mathematics that was represented. In primary schools throughout the 1950s and early 1960s, nature study was typically taught as a discrete subject using radio broadcasts that focused on seasonal events and descriptions of wildlife. Arithmetic was also taught as a separate subject with emphasis on oral and written computational skills, and some element of problem solving, usually in a fairly contrived context.

The publication of *Primary education in Scotland* (SED 1965)—often referred to as the Primary Memorandum—brought together mathematics, science, geography and history under the umbrella of environmental studies (ES). The report advocated that these subjects should be taught in an integrated fashion by means of topics or centres of interest. The same report recommended that the scope of mathematics should be broadened to include shape, quantity and measurement in addition to number and that mathematics should be applied where appropriate in ES topics.

Over the next 20 years, a series of science projects aimed at promoting a more child-centred approach to learning was instigated in Scotland as in England. Nevertheless in 1980, the HMI report *Learning and teaching in Primary 4 and Primary 7* noted that 'science fared badly, with 60% of all teachers giving it little, if any, place in the curriculum', and expressed concern at the neglect of science particularly in the final year of the primary school (HM Inspectors of Schools 1980). There were many reasons for this low level of implementation, including a lack of definition about what science should be taught, primary teachers' lack of confidence and understanding of key areas of science and a tendency to provide resources for schools without any associated professional development in how best to use them with pupils.

Because of concerns about educational standards, the Assessment of Achievement Programme (AAP) was established in the mid-1980s, by the Scottish Office Education and Industry Department (SOEID). Based largely on the experience of the APU, the AAP surveyed a representative sample of pupils' attainment in English language, mathematics and science at P4, P7 and S2 every three years over a period of around 15 years. It remained in place when the APU was terminated in the rest of the UK and was developed in 2003 into the Scottish Survey of Achievement, which remains in operation.

2.2 The new national curricula from 1989 onwards

2.2.1 England and Wales

The 1988 Education Act made provision for a National Curriculum that all State schools in England and Wales would be required to follow. Introduced in 1989, it initially comprised ten foundation subjects: English, mathematics, science, technology,[8] history, geography, art, music, physical education and (at the secondary school level) a modern foreign language. The first three of these were designated as core subjects and as such were the first to be specified and in far greater detail than other foundation subjects. The curriculum in Wales was the same as that in England apart from the inclusion of Welsh language as an additional subject in the core and English not being a required part of the curriculum until the age of seven. The ages 5–16 were designated in terms of Years (1–11) and divided into four 'Key Stages'.[9] In both England and Wales, the 'teaching requirements' for each subject were arranged as a 'Programme of study' for each Key Stage and what children were expected to learn was set out in terms of 'Attainment Targets' specified initially at ten progressive 'Levels' to cover the age range 5–16. The expectations for the end of each Key Stage were expressed in relation to these Levels. In addition to the subjects in the National

8 The National Curriculum was revised in 1995, with a Statutory Instrument (no. 56) providing for specification of programmes in 'design and technology' and 'information technology'.

9 Primary, Key Stage 1 (Years 1 and 2), Key Stage 2 (Years 3–6); Secondary, Key Stage 3 (Years 7–9), Key Stage 4 (Years 10 and 11).

Curriculum, schools were required to teach religious education.

Since its initial implementation, the curriculum has been revised on several occasions. Soon after it began to be phased in, complaints were made about too much content and too much prescription. As a result of a review conducted by Sir Ron Dearing (Dearing 1994), in 1995 a revised National Curriculum was implemented with somewhat reduced curriculum content, and the detailed Level specifications of the Attainment Targets for each subject changed to broader and Level Descriptions with the number of Levels reduced to eight plus 'exceptional performance'. The content was further reduced in a revision carried out in 1999, and in 2002 the curriculum was extended to include the foundation stage. In the case of mathematics, the changes were largely cosmetic; in fact, the 5–14 curriculum has hardly changed since 1988. Comprehensive changes to the curriculum made after 2007 are discussed later.

In the early 1990s the DES made available funds for professional development and the development of guidance for teachers; similar support was offered in Wales. A good deal of written material was also produced in both mathematics and science by the DES and publishers. There was evidence that this attention and support was having some effect and that teachers began to feel more confident.[10] In view of the good science results in national tests at age 11 (see Chapter 3) and favourable international comparative data relating to science achievement, attention and funding were switched to improving numeracy and literacy where there was greater concern about national standards.

The National Literacy and Numeracy Strategies were introduced in 1998 and 1999, respectively, in England only; revisions for both were provided in 2006. These strategies advised the use of particular lesson structures and subject-based teaching approaches. In 2001 these were extended to secondary schools as part of the Secondary National Strategy. Their effect in primary schools was not only to elevate the status of numeracy and literacy and to separate them from other subjects, but to downgrade others, including science.[11] Although further help in science was provided to schools in the form of *A scheme of work for Key Stages 1 and 2*, first published in 1998 and revised in 2000, the much-needed professional development for primary science was only sporadically provided through the National Strategies. However, from 2005 onwards the establishment of a network of Science Learning Centres has been providing around 4,000 days of training in science for primary teachers, mainly in England. At the same time £15 million funding for a National Centre for Excellence in the Teaching of Mathematics was announced. (See Chapter 5 for more on professional development.)

10 Ofsted inspections in the mid-1990s reported that 80% of science lessons were judged to be satisfactory or better.

11 A survey by Galton & MacBeath (2002) found a reduction in time for science in Year 6 from three to two hours per week.

As time for science teaching in primary schools was squeezed by attention to the literacy and numeracy frameworks, teachers found even greater difficulty with the curriculum, which they increasingly saw as overloaded and over-prescribed. This led to greater use of transmission, as opposed to enquiry-based, teaching, a situation exacerbated by the impact of testing (see Chapter 6). Relevance of science to children's everyday experience and environment was sacrificed and, not surprisingly, there were reports of pupils' interest in science and confidence in their ability to learn science being lowered (TIMSS study of 2007; see Sturman *et al*. 2008).

2.2.2 Northern Ireland

A year after the Education Reform Act (1988), the Education Reform (Northern Ireland) Order (1989) established the Northern Ireland Curriculum. Within this, 'Mathematics' and, separately, 'Science and Technology' were designated 'areas of study' and 'compulsory contributory subjects' throughout its four Key Stages. Its introduction was supported by the publication of *Guidance materials* (NICC 1990), the equivalent of the English non-statutory guidance. In addition, there was a programme of in-service training, limited, however, by the coincident reduction in the number of science advisory officers and by their increasing involvement in the support of whole-school issues such as literacy, numeracy and ICT (ETI 2001).

Thereafter, the chronicle of the Northern Ireland Curriculum follows quite closely that of the National Curriculum. In response to complaints about the burden of its content, and particularly the burden of its assessment and reporting, the Curriculum was reviewed and revised on a number of occasions. Towards the end of 1999, following advice from the Northern Ireland Council for the Curriculum, Examinations and Assessment (CCEA), the Department of Education gave the go-ahead for a major review and revision of the Northern Ireland Curriculum, resulting in the new arrangements for primary and post-primary schools being phased in from 2007.

2.2.3 Scotland

In the late Eighties, the 5–14 Development Programme was established under the management of the Scottish Consultative Council on the Curriculum (SCCC) to review the curriculum in the seven years of primary education and the first two years of secondary education. National Guidelines on Mathematics 5–14 were produced in 1991 and these defined Attainment Targets in mathematics at five Levels (A–E) in terms of information handling, number, money and measurement and shape, position and movement. Problem solving and enquiry was also included but without any description of levels of progression. National Guidelines on Environmental Studies 5–14 (expanded to include technology, health education and information technology as well as social subjects and science) were produced in 1993. Attainment Targets in three areas of science were defined at five Levels (A–E) in terms of knowledge, understanding, skills and attitudes. Later a Level F was added for all subjects. Unlike the national curricula in other parts of the UK, National Guidelines were not mandatory, although most schools in Scotland followed the advice offered in them. However, across the nation, these National Guidelines were found to be too complex and cumbersome to teach.

An HMI report on *Improving science education 5–14* (HMI 1999), based on evidence from research, made a number of major recommendations to national bodies, including signalling the need for a review of the Environmental Studies guidelines. Revised and separate guidelines in science (and other ES curriculum areas) were produced in 2000 that simplified the structure of what was taught and assessed and which included more advice for teachers about possible learning activities and approaches. Over the next few years, the Scottish Executive established the Improving Science Education 5–14 Project in collaboration with Learning and Teaching Scotland (LTS), the Scottish Schools Equipment Research Centre (SSERC) and the Scottish Science Advisory Group (SSAG) representing local authorities, to address the recommendations in the HMI report. Despite some signs of improvement (HMIE 2005), there continued to be weaknesses in many schools' science programmes, one of several factors in the decision to conduct a comprehensive review of school education.

2.3 Curriculum developments from 2007

2.3.1 England (Key Stage 3)

Dissatisfaction with the form of the National Curriculum and particularly the impact of testing, added to the frustration at the lack of improvement in end-of Key Stage test results from 2001 onwards (see Chapter 3), led to a re-examination of the Key Stage 3 curriculum, aimed at reducing prescription and giving teachers more freedom to meet the requirements of the 'personalised learning' agenda. The review was carried out by the Qualifications and Curriculum Authority (QCA) between 2005 and 2007 and the new Key Stage 3 curriculum was implemented starting in 2008. For science, the statutory Programme of Study comprises key concepts, processes, the 'range and content' that pupils should study and the 'curriculum opportunities' that should be provided. The content is economically set out in 14 Statements of Ideas and Propositions with some expansion in non-statutory notes. In addition there are non-statutory themes to be considered through all subjects. The four Attainment Targets, for 'How science works', 'Organisms, their behaviour and the environment', 'Materials, their properties and the Earth' and 'Energy, forces and Space' are specified as Level Descriptions from Levels 4 to 8 plus 'exceptional performance' beyond Level 8.

In mathematics, too, the intention was to reduce prescription and to reincorporate some of the recommendations of the Cockcroft Report (DES 1982) that had become lost owing to the focus on numeracy skills and written tests. There is a renewed emphasis on problem-solving process both in functional real-world mathematics and in pure mathematical investigation. There is also, for the first time, inclusion of some work on mathematics in relation to its history and place in the wider culture. However, the Secondary National Strategy framework still exercises great power at Key Stage 3 and does not reflect the emphases of the new curriculum.

2.3.2 England: the primary curriculum

There were two reviews of the whole primary school curriculum in England, both reporting in 2009. One was a fundamental review of primary education, funded by a private foundation and therefore independent of Government. Known as the Cambridge Primary Review, it considered, in addition to the curriculum and assessment, a wide range of matters relevant to children's primary education. This extensive exercise began in 2006 and the final report was published in 2010 (Alexander 2010).

Meanwhile, in January 2008, the previous Government launched a separate review of the primary curriculum in England. Its terms of reference, set by the Secretary of State of the Department for Children, Schools and Families, made clear that the focus was solely on the curriculum and excluded assessment, testing and all other aspects of primary education included in the Cambridge Primary Review. Given the inherent link between the curriculum and assessment, this inevitably meant that the Rose Review was unable to address many of the causes of dissatisfaction with the National Curriculum in England.

In November 2009 the Department for Children, Schools and Families announced the new National Curriculum, based on the Rose Review recommendations, organised around 'Understanding English, Communication and Languages'; 'Mathematical understanding'; 'Scientific and technological understanding'; 'Human, geographical and social understanding'; 'Understanding the arts'; and 'Understanding physical development'. The proposals (Balls 2009) set out what children should be taught in each of these areas at 'early', 'middle' and 'later' stages. The new curriculum also set out 'Essentials for learning and life' (literacy, numeracy, ICT capability, learning and thinking skills, personal and emotional skills and social skills). The Programmes of Study at Key Stages 1 and 2 in science and technology and mathematics, as at Key Stage 3, incorporated, in comparison with the curriculum being replaced, less prescription and more process-rich work, both interdisciplinary and within the subjects. Although implementation was planned for 2011, the legislation required to bring this into effect was not passed before the 6 May 2010 General Election, and the new Conservative–Liberal coalition Government has dismissed the proposals.[12]

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12 The Government formally announced its decision to abandon the Rose Review proposals on 7 June 2010. For more information, see http://www.education.gov.uk/news/news/nationalcurriculum, accessed on 9 June 2010.

2.3.3 Northern Ireland

The revised Northern Ireland Curriculum has been designed to address a number of problems and limitations associated with its earlier formulation. Its statutory, subject-based, structure was considered inappropriate by primary teachers and inflexible by secondary teachers and the prescribed programmes of study were overburdened with content. Consequently, the revised Northern Ireland Curriculum, as it applies at Key Stages 2 and 3, aspires to flexibility, relevance and connectedness. It emphasises the explicit development of 'cross-curricular' skills ('Communication', 'Using mathematics' and 'Using ICT'), thinking skills and personal capabilities.

The primary curriculum is set out as six 'Areas of Learning', among which are 'Mathematics and Numeracy' and 'The World Around Us' (TWAU), the latter focusing on the development of knowledge and skills in relation to Geography, History and Science and Technology. The statutory requirements of TWAU prescribe that teachers should enable children to develop knowledge, understanding and skills in relation to 'four inter-related strands', namely 'interdependence, place, movement and energy and change over time'. Therefore, science is no longer identified as a separate subject and its content is only minimally specified.

Within the revised Northern Ireland Curriculum there is strong encouragement for teachers to integrate 'Assessment for Learning' (AfL) into their practice. Schools are required to assess pupils' progress, with reference to Levels of Progression, in Communication, Using Mathematics and Using ICT. There are no formal 'end of Key Stage' tests for mathematics or science. Furthermore, with effect from 2010, it is not currently the policy of the Department of Education to include academic criteria in its recommended admissions criteria for transfer from primary to post-primary schools nor is it providing 'transfer' tests and procedures to support their inclusion. Nonetheless, a selective system is still in place and the selection process has a dominating role in Key Stage 2 assessment. Grammar schools have formed consortia to devise and administer entrance tests. While these include an assessment of mathematical ability, unlike those they replace, they do not include an assessment of science.

The secondary curriculum at Key Stage 3 is set out as seven Areas of Learning, among which are 'Science and Technology' and 'Mathematics'. The statutory requirements for science prescribe that teachers should enable pupils to develop knowledge, understanding and skills in relation to scientific methods of enquiry and to the themes of 'Organisms and health', 'Chemical and material behaviour', 'Forces and energy' and 'Earth and Universe'. In addition, learning in science is expected to make a contribution to the development of 'cross-curricular' and 'thinking' skills, to personal capabilities and to a number of 'key elements' of the curriculum such as personal health and ethical awareness. The substantial reduction in prescribed content and the discontinuation of the formal Key Stage 3 tests afford teachers freedom to focus on topics and issues they consider of specific interest and relevance to their pupils.

2.3.4 Scotland

In 2003, the Scottish Executive (now the Scottish Government) established a Review Group to identify the purposes of education 3–18 and principles for the design of the curriculum. The initial report, *A Curriculum for Excellence*, was published in 2004 and identified the values, purposes and principles which should underpin the curriculum 3–18. In addition to longer standing principles of curriculum design, such as breadth, coherence and progression, were added challenge and enjoyment, relevance, depth and personalisation and choice. Whereas earlier curriculum developments had focused on specific stages (5–14, 14–16, 16–18, etc), Curriculum for Excellence set out to provide a progressive learning experience for all children and young people from the time they entered pre-school until they left secondary school.

The curriculum in science, mathematics (and numeracy) and other curriculum areas is set out as statements of 'experiences and outcomes' from ages 3–15. The statements, which are more generic and less prescriptive, are expressed in a user-friendly way to reflect what children and young people should have experienced and be able to demonstrate in a variety of ways. The science guidelines take account of recent advances in science and provide increased emphasis on social, moral and ethical issues. The revised guidelines in numeracy and mathematics provide increased emphasis on the relevance of mathematics for life and application of mathematics in practical contexts.

The Scottish Government has indicated that the Scottish Survey of Achievement will be adapted and fully aligned with Curriculum for Excellence in order to continue to monitor standards of performance, but only in literacy and numeracy.

2.3.5 Wales

Responsibility for education was devolved from 1999 to the Welsh Assembly Government (WAG). Almost immediately, reviews were initiated into the content and operation of the National Curriculum and its associated regimes of testing in the core subjects. For pupils in the Foundation Phase (three to seven year olds)—not to be confused with the Foundation Stage in England—the expectations for science and mathematics are specified in 'Knowledge and understanding of the world' and 'Mathematical development', two of seven 'Areas of Learning'.[13]

At both Key Stages 2 and 3, the statutory Programme of Study for science is presented in two categories: Skills

13 See http://wales.gov.uk/dcells/publications/policy_strategy_and_planning/early-wales/whatisfoundation/foundationphase/2274085/frameworkforchildrene.pdf?lang=en

(communication, enquiry, developing and reflecting) and Range (interdependence of organisms, the sustainable Earth and how things work). A similar structure applies to mathematics at Key Stages 2 and 3, with Skills (solving mathematical problems, communicating mathematically, reasoning mathematically) and Range (number, measures and money, shape, position and movement, handling data and the addition of algebra at Key Stage 3).

For both science and mathematics the Welsh Assembly Government, through its Department for Children, Education, Lifelong Learning and Skills (DCELLS), has provided all schools with detailed guidance indicating progression from the Foundation Phase to Key Stage 3.

2.4 National assessment and testing

2.4.1 England

The Education Reform Act of 1988 (legislation which referred to both England and Wales) made provision not only for the National Curriculum but also for statutory 'assessment arrangements' to cover the years of compulsory schooling (ages 5–16) including reporting at ages 7, 11, 14 and 16. A Task Group on Assessment and Testing (TGAT), set up to develop the arrangements, recommended that there should be emphasis on the formative use of assessment[14] and that: 'The national assessment system should be based on a combination of moderated teachers' ratings and standardised assessment tasks' (DES/WO 1988, paragraph 63). It proposed that the national assessment should be reported for individual pupils in terms of Levels achieved for each subject. In practice, although the recommendations were largely accepted by Government, what gradually emerged was a system of externally set end-of Key Stage tests for Key Stages 1, 2 and 3 in the core subjects only (GCSE served the purpose of end of Key Stage 4 assessment). The formative purpose was diminished and teachers' judgements were downgraded by the decision that test data would override teachers' assessment where there was disagreement between the two. Although teachers' assessment was the basis for reporting in years between the ends of Key Stages, optional tests for these years and for other foundation subjects were created by the QCA.

The publication of test results was included in the legislation from the start of national testing, consistent with the view that national testing is 'an important means of driving up standards' (House of Commons 2008, paragraph 17). The mechanism for this impact was a framework of targets and performance tables. During its inquiry into testing and assessment, the Children, Schools and Families Select Committee (House of Commons 2008) received submissions from several key organisations, not least the Association for Science Education (ASE) and the Mathematical Association, disputing the role of tests and targets in raising standards and pointing out the impact on teaching and pupils' enjoyment of learning of enforced compliance to meet targets.

When first introduced, national tests and tasks were externally set but marked by teachers using local moderation, but after a teacher boycott of national assessment in the early 1990s, the Government accepted that all tests at Key Stages 2 and 3 would be externally marked. Tests in science at Key Stage 1 were abandoned after trials and, from 2005, only teachers' assessment results were reported, although teachers were required to use some tests in English and mathematics to inform their judgements. Tests of speaking and listening were dropped from English at Key Stage 2 and the balance between skills-based and knowledge-based questions in the science and mathematics tests was changed in favour of knowledge. In part, this change occurred as a result of the move to pencil and paper only tests with no practical assessments. The importance being given to test results, as the measure of school effectiveness, inevitably influenced the curriculum experienced by pupils (Alexander & Hargreaves 2007). In science in Year 6, and often in earlier years, transmission of factual information replaced practical enquiries (Wellcome Trust 2005). In mathematics investigation and practical problem-solving virtually disappeared and, especially in Year 6, practise for short test questions predominated.

Initially, since the end-of Key Stage 3 results were not considered high stakes, there was less effect of external assessment on the early secondary curriculum. But the Key Stage 3 results came to be used increasingly for evaluative purposes, with optional external tests available each year allowing, as at primary level, tracking procedures for monitoring individual progress by sub-Levels. This meant that teaching in Key Stage 3 was becoming increasingly test oriented. Tests at Key Stage 3 were terminated in 2008 following major problems in the external marking and the decision that they were no long needed.[15]

Until 2009, children at the end of Key Stage 2, in Year 6, took written tests in mathematics, English and science. In 2009 it was announced that science tests would be replaced by moderated teachers' assessment. In reading, writing and mathematics, materials have been developed by the QCDA (Assessing Pupils' Progress) to help teachers with their periodic assessment for tracking purposes.[16] These provide criteria in the form of 'assessment foci' derived from Level Descriptions, guidance and some worked examples to help in standardising judgements.

14 Formative, as opposed to summative, assessment is used by teachers to help inform pupils' ongoing learning rather than measure their attainment outcomes at a point in time.

15 Reasons given by the Secretary of State for changes to the assessment and testing arrangements at Key Stage 3 were that they were no longer needed to meet the three principles underpinning external testing: that it should give parents the information they need to compare different schools, enable head teachers and teachers to secure the progress of every child, and allow the public to hold national and local government and governing bodies to account on the performance of schools.

16 The QCA became the Qualifications and Curriculum Development Authority (QCDA) in 2009.

Meanwhile piloting has been going on of single level tests in mathematics and English, which can be taken when a pupil is judged to be ready. They have been abandoned at Key Stage 3 but in mathematics in 2010 schools in the pilot have been allowed to use the results of these tests for reporting at age 11 without taking the national tests. They therefore may well replace the national tests in all schools shortly. However they carry the risk of spreading test preparation throughout Key Stage 2.

2.4.2 Northern Ireland

Although during the period 1990–2007, the Northern Ireland Curriculum for science and mathematics paralleled quite closely the National Curriculum for science and mathematics, their assessment arrangements showed greater divergence.

The Education Reform (Northern Ireland) Order had, as part of its provisions, the requirement that pupils' progress in the specified Programmes of Study be assessed and reported at or near the end of each Key Stage. Following the formulation, and sometimes piloting, of a number of trial schemes, the final scheme for Key Stages 1 and 2 involved teacher assessment in English and mathematics. At Key Stage 3, there was teacher assessment and end-of Key Stage tests in English, mathematics and science, with the tests taking precedence over the teacher assessment.

Unlike England, then, Northern Ireland Curriculum assessment arrangements did not have standardised tests in science at the end of Key Stage 2. There was, nevertheless, high-stakes testing. The possibility of basing the selection procedure at age 11 on the national assessment arrangements was explored but considered to have too many technical difficulties. Instead, starting in the school year 1993/94, a new form of transfer test was introduced, based on written tests in English, mathematics and, for the first time, science, as defined in the statutory Key Stage 2 Programmes of Study. This served to secure science a prominent place in the primary curriculum (at least for those taking the transfer tests). It also served to diminish the quality of that science experience for some children.

Reports by the Inspectorate (DENI 1996; ETI 1999, 2001), supported by research (Harland *et al*. 1999; Murphy & Beggs 2003), drew attention to the distorting effects of the perceived demands of the transfer tests. Preparation for these tests was seen, in some schools, to result in an over-emphasis on the children's acquisition of science knowledge, some of which was too advanced for children at Key Stage 2, at the expense of their participation in practical activities aimed at promoting understanding. Similarly, the impact of tests at Key Stage 3—a statutory requirement from 1996—was investigated in a major research study. Though pupils, by their own admission, were motivated to learn by the tests, nonetheless, it was concluded (Harland *et al*. 2002, p. 277) that they had, overall, 'a deleterious effect on the curriculum . . . with . . . continuity and progression, balance, relevance and manageability all disturbed for the sake of assessment'.

2.4.3 Scotland

National tests in reading, writing and mathematics were introduced for P4 and P7 pupils in March and April 1991. There was significant opposition to national testing and, following a period of consultation, revised arrangements were set out in 1992 that allowed teachers to determine when to test individual pupils at particular levels. There was no national testing in science.

In order to monitor standards over time, the Scottish Survey of Achievement (SSA) was developed and introduced to replace the AAP. Each year, the SSA assessed the performance of a random sample of schools and pupils at P3, P5, P7 and S2 in English language (2005), social subjects (2006), science (2007) and mathematics (2008), as well as a range of core skills. Over the period during which AAP surveys were conducted in mathematics and science, standards achieved were broadly satisfactory at P5 and in need of significant improvement at later stages.

2.4.4 Wales

The national assessment arrangements in Wales were the same as those in England for the most part, until the establishment of the Welsh Assembly Government (WAG) in 1999 and the 2002 Education Act which devolved all educational decisions concerning Wales in the 1988 Act to the WAG. Immediately science and mathematics tests at Key Stage 1 were ended and reviews of the National Curriculum assessment were set up (ACCAC 2004). These reviews recommended the phasing out of testing at the end of Key Stages 2 and 3 from 2005 with the continued reporting of end of Key Stage assessment based on moderated teachers' judgements of National Curriculum Levels.

2.5 Summary of key developments

1. In the relatively short time since 1988 there has been considerable change in the governance of education and its assessment throughout the UK. From being wholly responsible for their curriculum content and methods, schools are now required, or in the case of Scotland expected, to teach the knowledge and skills set out in national curricula or guidelines. Further, in England, a programme and methods for teaching mathematics are set out in the primary and secondaryNational Strategies, which are being abolished in 2011.

2. The first national curricula for England, Wales and Northern Ireland were very similar to each other, identifying science and mathematics as separate subjects, whilst in Scotland science was part of Environmental Studies and only later were separate

guidelines produced for science and the other subjects grouped under this title.

3. It was difficult for the early drafts to find the right balance of ensuring learning opportunities for all pupils and allowing flexibility to meet the needs of different pupils and schools, a balance which changed as teachers became accustomed to meeting national requirements. Therefore the curricula in all nations were constantly revised, both in structure and content, throughout the 1990s and early 2000s. Changes made in science, particularly at the primary level, were greater than in mathematics.

4. Curriculum changes since 2007, in Northern Ireland and Wales, emphasise thinking and learning skills, problem solving and the use of ICT within broad areas of understanding rather than separate subjects. While little change is expected in mathematics, in relation to science at the primary level there is concern that, in the new curricula of these nations, its position appears to have become less secure and the impact on the gains made in the past two decades in relation to recognition of the importance of science needs to be watched.

5. The national testing arrangements were a key factor in teachers' response to the national curricula in the 1990s and frequent changes were made in the testing methods and arrangements. Where results were published and used to evaluate schools, or where they contributed to a procedure for selecting pupils for grammar school places, the tests had a controlling impact on content and teaching methods and on the motivation of some pupils.

6. The use of test results for monitoring national performance was followed by the abandonment of the APU, which sampled performance in science, mathematics and language in some detail in the 1980s.

7. Assessment practices among the nation states diverged following devolution, with Northern Ireland, Scotland and Wales relinquishing tests in favour of moderated teachers' assessment. England is moving more slowly in this direction, retaining testing in mathematics at the age of 11, but developing alternatives for science at age 11 and for both subjects at Key Stage 3. These include in 2010 a sample survey in science at age 11 that assesses a wider range of performance indicators and is less intrusive than population tests.

We now turn, in Chapter 3, to consider the changes in pupils' attainment, as measured by national tests and assessment, that have taken place during these developments in national curricula and assessment arrangements.

3 Attainment trends in science and mathematics among 5–14 year olds in schools across the UK

3.1 Introduction

This chapter examines attainment trends in 5–14 national assessments and surveys of pupil attainment in primary science and mathematics that have been conducted across the UK during our focus period 1998–2009. We begin by looking at the range and quality of information available from the UK's national educational authorities, before turning our attention to the attainment trends themselves.

Throughout this time, a system of end-of Key Stage testing has been maintained in England, Northern Ireland and Wales,[17] together with teacher assessment, as the best yardstick for measuring and monitoring the success of primary/early secondary education in these nations, although the emphasis on national testing has decreased, particularly in the latter two nations. By contrast, in Scotland pupils have been selected for testing when they were considered to be ready, and results were used as a mechanism for confirming teacher assessment judgements.

Where they have been used, huge reliance has been placed on national tests, and the ramifications for schools, parents and pupils have been enormous. While 'league' tables comparing schools' performance in national tests have been abolished in Northern Ireland and Wales, they have been retained in England as an instrument to help drive up standards.

Notably, the tests have been administered under the assumption that they provide an accurate and appropriate vehicle for measuring children's progress. In the light of examining the observed trends, this assumption is questioned.

3.2 The range, quality and nature of data provision in the UK's administrations

'State of the nation' reports are primarily concerned with examining data in the public domain. Therefore, the attainment data reported in this chapter originate either from publicly available statistical publications or other online data produced by the national educational authorities. The exception is Northern Ireland (which does not make such information public), where comparable information was obtained by direct request to the Department of Education.

There is potential for conducting a much more rigorous analysis of the detailed data contained in the National Pupil Database (England and, separately, Wales), but practical constraints precluded this. Consequently, this task was approached very much from the perspective of a public 'user' of information. The observations that follow describe briefly the nature of the data encountered and highlight any particular difficulties or concerns that arose in the course of locating and examining these from the perspective of data presentation and management.

17 These tests are colloquially known as Standard Assessment Tasks or Standard Attainment Tests (SATs).

3.2.1 England

The Government's education department[18] provides regular bulletins on pupils' attainment in Key Stage tests and public examinations. During 1998–2009, data on attainment at Key Stages 1 to 3 were published in a combination of annual reports and more frequently produced statistical first releases (SFRs).[19] The quantity, diversity and detail of information included in the SFRs have greatly increased during this period, partly on account of the inclusion of contextual value-added data (a policy not followed in other UK nations).[20] At the same time the complexity of the Statistical First Releases has increased with the addition of value-added data, the primary purpose of these being a school effectiveness measure to identify which schools enable their pupils to make greater progress after taking account of their prior attainment.

Useful as these publications undoubtedly are, they may also be problematic. While subsequent sections of this chapter and its accompanying Electronic Appendix (see http://royalsociety.org/education-policy-projects/) more or less explicitly evidence the problems listed below, examples of these problems are provided here (i) in order to illustrate the sorts of difficulties faced in building up a clear and accurate picture of simple attainment in Key Stage 1–3 tests during this time-period; and (ii) not to distract attention from discussion of the issues described by the data.

a) The presentation of equivalent data within these publications has changed, sometimes with notable and

18 Between 1998 and 2009, the Department has changed its name from the Department for Education and Employment to the Department for Education and Skills (in 2001) to its current designation as the Department for Children, Schools and Families (in 2007).

19 SFRs are one of the principal mechanisms by which government communicates new statistical information to public users. They have been described as 'the most public face of the government statistical service' (Statistics Commission 2008a), and the public relies heavily on them for consistent and reliable information.

20 Basic value added groups together pupils with the same prior attainment at the end of one Key Stage and assesses the amount of progress they have made by the end of the next Key Stage. Contextual value added (CVA) builds on this by controlling for other factors that influence pupils' progress (eg special educational needs, gender and neighbourhood deprivation). CVA is designed to provide a measure that enables a meaningful comparison between schools with very different pupil intakes.

seemingly irreconcilable inconsistencies becoming apparent.

Examples. Data for maintained schools are sometimes, but not always, distinguished from data for all (ie including independent) schools, and percentage data for boys and girls are sometimes separated, sometimes not. Both of these problems seem apparent in Key Stage 1 assessment data (see Electronic Appendix Tables A3.1 and A3.2). Data are presented for maintained schools only, as independent schools have never been required to use the Key Stage tests.

b) There appear to be inconsistencies in the publication of provisional, revised or final data.

Example. There is a tendency for the Statistical First Releases (SFRs) for Key Stage 1 to include 'provisional' data, and for there to be no 'revised' SFR published. Nonetheless, 'final' data for some previous years are invariably buried in tables detailing the latest 'provisional' data available. For instance, SFR 21/2008 contains the provisional results for Key Stage 1 in 2008, but also includes within this (in table 1) a table giving 'final' data on Key Stage 1 results for 2006 and 2007.

c) Data are scattered among publications.

Example. While it is possible to access composite Key Stage 3 test data results in a single Statistical First Release (SFR 10/2009), data on Key Stage 3 teacher assessments for 1998–2009 are scattered among almost 20 publications (Table A3.3). In addition, data on the numbers of pupils taking these tests have sometimes been published separately, and without obvious good reason, from percentage data on attainment (eg SFR 29/2006). Furthermore, data on performance among ethnic minorities are published quite separately from the data on national performance, creating an awkward disjunct.

d) Data that should be available appear not to be.

Example. The second page of SFR 22/2004 (dated 24 June 2004) promises that 'Additional tables of Key Stage 3 Teacher Assessment results will be available on the DfES Research and Statistics website shortly'. However, if these results were once available there, they appear no longer to be so.[21]

e) The success of Internet searches on the Department's 'Research and statistics gateway' depends very much on what search terms are used.

Example. Figure A3.1 shows the results of undertaking a simple search for Key Stage 3 data for 2003/04 on the Department's 'Research and statistics' gateway. The relevant records displayed on the first page of results is highly confusing, with the same or similar records repeatedly occurring amidst a number of completely unrelated and irrelevant results.

More recently, the former DCSF began producing time-series data on its website. However, these also vary in their quality and usefulness. For instance, time-series data on National Curriculum Key Stage 1 only cover 2000–2004.[22] This is surprising given the technical position of science as a 'core' subject within the curriculum. There are also unexplained differences between the time-series data and the data in the SFRs, which are highlighted in the tables in the electronic appendix. Although these differences may be of the order of a single percentage point, and not statistically significant, their occurrence nonetheless can undermine confidence and trust in the data. It seems likely that the differences may result from using data for all schools as opposed to maintained schools only. If so, this should have been made explicit so as to avoid confusion.

Ultimately, our analysis of the Department's data reveals that its tradition of publishing different data at different times in different formats in a diffuse manner creates potential for confusion. It is notable that in relation to this, while the Statistics Commission praised the Department for introducing 'value added' measures of performance, it also made clear that 'the statistical outputs, in their current form and with the present levels of support, are not yet reaching some sections of the potential audience as effectively as they might' (pp. 3–4) and recommended that '… the producers of statistics should re-assess whether the scope and nature of existing … reports and other outputs … are likely to meet the needs of the full range of potential users' (p. 12) (Statistics Commission 2005, 2008).

Recommendation 1

The Department for Education should carefully review its data publishing protocols with a view to ensuring its releases of Key Stage 1–3 attainment data are clearly and consistently presented, conducive to facilitating comparisons over time. In particular, it should consider dispensing with provisional and revised data, and commit only to publishing final data. Otherwise, it should adopt a consistent approach to publishing, and clearly distinguishing, these different types of data in its publications, and ensure that users can locate them easily. Adopting the second alternative would necessitate the removal of provisional data from open access once they have been superseded, in order to reduce the risk of confusion.

3.2.2 Northern Ireland

The data used for this report were received via direct request to the Department of Education Northern Ireland (DENI), which does not make any Key Stage assessment data available on its website. If it were to do so, as England and Wales have done, then it would need to ensure that

21 See http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000473/index.shtml, accessed on 2 February 2010.

22 See http://www.dcsf.gov.uk/trends/index.cfm?fuseaction=home.showIndicator&cid=5&iid=29, accessed 27 January 2010.

such data are published to allow useful historical comparison.

3.2.3 Scotland

In Scotland, a system of national surveys has been preferred to annual measures of performance adopted across the rest of the UK. These surveys, which drew on data collected from all local authorities, were obtained through the Scottish Government's website.

3.2.4 Wales

Statistics on performance in Key Stage tests in Wales were sourced through the StatsWales website, a free service that allows a user to view and manipulate official data covering pupils in Local Education Authority (ie maintained) schools. The Key Stage 1 to 3 data on this website date back to 1999, and appear to be final data, though this does not appear to be clearly stated. It was possible to gain data for 1998 (pre-Devolution) to 2008 from the PDFs of the generically entitled 'National Curriculum assessment results in Wales', available on the Welsh Assembly Government's website, which also appear to contain final data.

Finally, it is worth noting that the old DCSF website currently contains PDFs of the annual volumes, 'Education and training statistics for the United Kingdom'.[23] For the purposes of this study, only non-English data provided by DENI, the Scottish Government and the Welsh Assembly Government were used.

3.3 Attainment trends in England

3.3.1 Mechanisms of assessment

As described in Chapter 2, the statutory Programmes of Study dictated what should be taught for each of the National Curriculum subjects, and the Attainment Targets set out what should be assessed. At the start of our timeline, broader and more straightforward Level Descriptions had replaced the old Attainment Targets and the number of Levels had been reduced from ten to eight (Table 3.1).

These Levels were designed to capture individual student attainment in a way that, scaled up, would enable comparisons to be made at local, regional and national levels. They have been used both by teachers to define the Level a student has reached (teacher assessment) and for national tests at the end of Key Stages 1, 2 and 3.

These individual Attainment Targets have become the basis for Public Service Agreements, first introduced for education by the Government in 2000 as a means to drive up educational standards and for its performance to be publicly accountable (Table A3.4). Notably though, it remains unclear precisely how these targets were formulated.

3.3.2 Attainment trends in science and mathematics at Key Stage 1 in maintained schools (England)

There have been a number of important changes to Key Stage 1 during the past decade. A revised National Curriculum was introduced into teaching from August 2000, to align with the requirements of the National Literacy and Numeracy Strategies. In May 2003, the Government announced that national testing at Key Stage 1 would be scaled back in favour of an enhanced emphasis on teacher assessments.

Tables A3.1 and A3.2 show teacher assessment and national test data, respectively, for pupils achieving at or above the Level they are expected to have reached at the end of Key Stage 1. It is important to note that national test data for mathematics and English are very similar to the teacher assessment data, but publication of these data was phased out by the DfES (as it then was) after 2004 because of a change in policy that required schools to report teacher assessment results only. However, as Brown has noted, these teacher assessments have been mostly informed by summative task/test activities undertaken by pupils (Brown 2007). For this reason, only teacher assessment data are considered.

Throughout our time-period science at Key Stage 1 has only been tested through teacher assessment (science tests were dropped as far back as 1994). The trends for teacher assessment show consistently that while across all subjects the great majority of pupils have attained or exceeded the expected Level, higher percentages of pupils have attained or exceeded the expected Level in science and mathematics than in English (reading and writing; Figure 3.1). The trends also show that Levels of attainment have remained very constant, varying by no more than 5% across the time-series, as well as a tendency for attainment to level out across all subjects since 2005.

3.3.3 Attainment trends in science and mathematics at Key Stage 2 (England)

Figure 3.2 compares attainment at or above Level 4 (the expected Level) in Key Stage 2 teacher assessments and national tests in science and mathematics, respectively.

National test trend data during these years show a 19 point increase in the numbers of pupils gaining or exceeding the expected Level of attainment (Level 4) in science, although the majority of this increase (a 15 percentage point rise) was reported between 1998 and 2000, apparently reflecting the impact of the National Numeracy Strategy, introduced in 1999 (Jones 2002). This seems plausible, for although the Strategy was non-statutory, most schools adopted it. Certainly Ofsted put the improved performance

23 A final check of the Department for Education's website http://www.education.gov.uk/ was conducted on 7 June 2010.

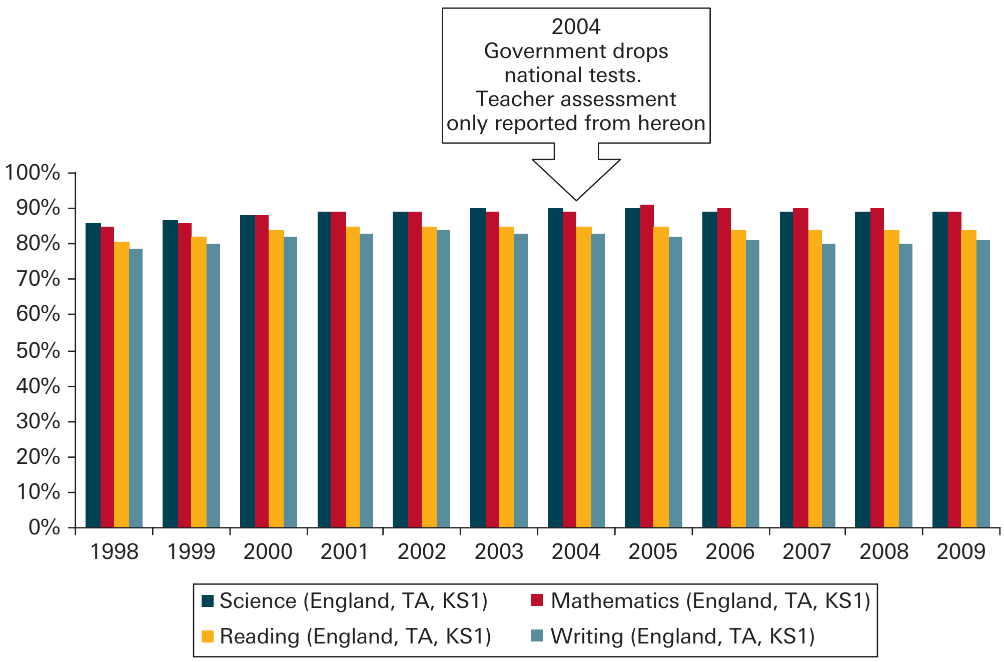
Table 3.1. Levels in the National Curriculum.

Level 8 or higher			●
Level 7			◎
Level 6		●	⊙
Level 5		◎	⊙
Level 4	●	⊙	○
Level 3	◎	○	○
Level 2	⊙	○	○
Level 1	○	○	○
Key Stage (age at time of test)	Key Stage 1 (age 7)	Key Stage 2 (age 11)	Key Stage 3 (age 14)
Age of students	5–7	7–11	11–14
School years	1 and 2	3–6	7–9

Key to symbols: ○, working towards the expected level; ⊙, achieved expected level; ◎, exceeded the expected level; ●, considerably exceeded the expected level.

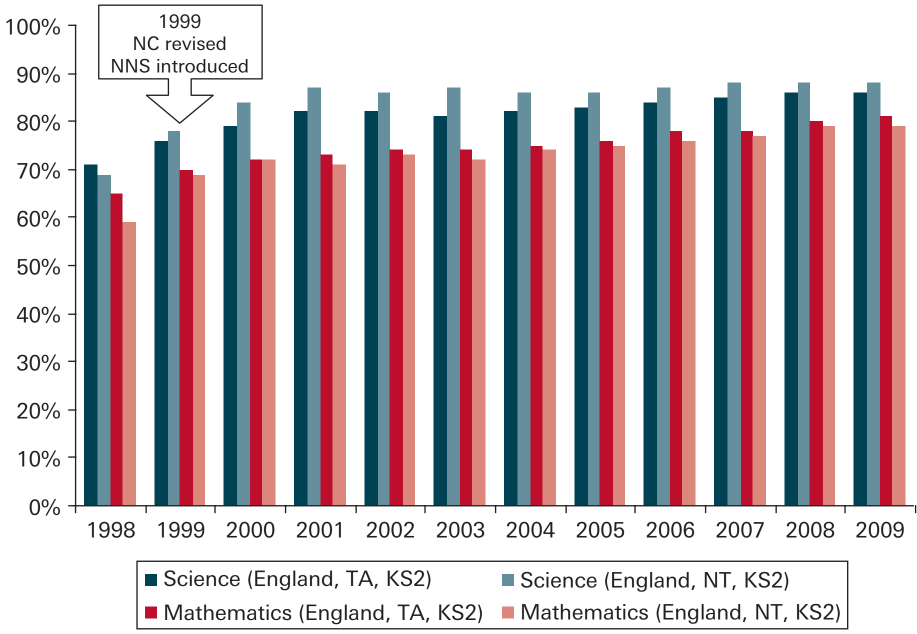
in this interval down to the Strategy, which together with the associated National Literacy Strategy, it claimed had 'had a considerable impact on the primary curriculum' and led to 'an overall improvement in the quality of teaching' in these subjects (Ofsted 2003, p. 17). Even so, Ofsted's conclusions were based on evidence drawn from investigation of 300 primary schools, which is equivalent to about 2% of the number of primary schools in England at the time. The same report noted that, nationally, the Government's 2002 target for attainment at Level 4 in Key Stage 2 mathematics (75%) had been undershot by 2%. Nonetheless, international surveys of mathematical achievement indicated a considerable and significant improvement in mathematics. England's score of 531 in the Third International Mathematics and Science Survey (TIMSS) was a 47 point increase on its 1995 score and was

Figure 3.1. Percentages of all pupils attaining Level 2 or above in Key Stage 1 teacher assessments (TA) in science, mathematics and English (England, 1998–2009).



Source: DCSF.

Figure 3.2. Percentages of all pupils attaining Level 4 or above in Key Stage 2 teacher assessments (TA) and national tests (NT) in science and mathematics (England, 1998–2009).



Source: DCSF.

the largest increase recorded of any of the 15 nations that participated in both the 1995 and 2003 studies (Whetton *et al.* 2007).

Although Key Stage 2 targets for English and mathematics were introduced in 1997, no equivalent target for science was set (Plewis & Goldstein 1998). Neither was the National Science Strategy introduced, as might have been expected given the 'core' nature of science in the curriculum and the introduction of strategies for the other core subjects of English and mathematics. However, greater percentages of pupils gained Level 4 in Key Stage 2 science tests than in English and mathematics, as Torrance (2002) noted, the Government's externally commissioned evaluation of the National Literacy and National Mathematics Strategies was at a loss as to how to explain this. It therefore remains a point of contention as to whether or not the National Strategies may be credited with improving attainment in science.

Between 2000 and 2006, test attainment in science at or above Level 4 fluctuated, averaging 86%, before increasing to 88% in 2007 and remaining constant thereafter (Figure 3.2; Table A3.5). Teacher assessment data for science show a similar trend, although attainment was consistently judged to be lower than that observed through testing. Likewise, attainment trends in mathematics for both teacher assessment and national tests are very similar and closely match the pattern seen for science, but attainment at or above Level 4 has consistently been scored lower in mathematics than in science (the gap averaging 7.1 percentage points for teacher assessment and 11.5 percentage points for national tests from 1998 to 2009). Attainment at or above the expected Level has generally been slightly higher (averaging 0.8% during 1998–2009) in mathematics than it has been in English (data not shown).

However, it is important to note that the published data for 2008 onwards are affected by the removal of borderlining, a process involving rechecking only papers that fall just below the grade boundary, which results in a certain amount of grade inflation. The Department has estimated that since 1999, the mean impact of borderlining across all Levels for Key Stage 2 are increases of 1.2 percentage points in English, 0.2 percentage points in mathematics and 0.6 percentage points in science.[24] It has been estimated that between 1996 and 2008, borderlining led to 300,000 pupils being upgraded.[25]

3.3.4 Attainment trends in science and mathematics at Key Stage 3 (England)

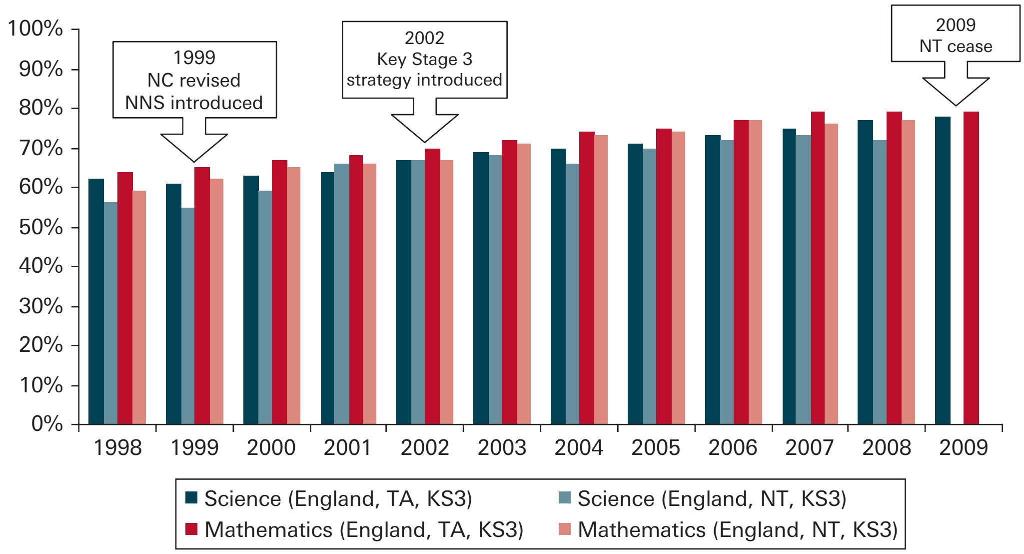
Between 1998 and 2009,[26] Key Stage 3 attainment through teacher assessments in science, mathematics and English rose 16, 15 and 15 percentage points, respectively, an average of just over 1% per year. The increase, as measured through national test results up to 2008, was less in science and English. In the interval between the revision of the National Curriculum and the implementation

24 See http://www.dcsf.gov.uk/rsgateway/AssessmentAndMarkingProcessChanges1.0.pdf, part of SFR 32/2009), accessed on 18 February 2010.

25 See http://www.telegraph.co.uk/education/2281562/Government-blamed-for-exaggerating-Sats-test-marks.html, accessed on 18 February 2010.

26 Following the undermining of confidence in marking the 2008 Key Stage 3 tests in England, in SFR 20/2008 the Department claimed that the provisional national results were 'more than sufficient[ly]' reliable, with coverage at 84% for English and 94% for science and mathematics. Later that year, the Secretary of State abolished national tests at Key Stage 3.

Figure 3.3. Percentages of all pupils attaining Level 5 or above in Key Stage 3 teacher assessments (TA) and national tests (NT) in science and mathematics (England, 1998–2009).



Source: DCSF.

of the (non-statutory) Key Stage 3 Strategy in 2002, attainment at or above Level 5 (the expected Level) in Key Stage 3 in tests and teacher assessments across all three subjects increased gradually, and although attainment across all these subjects continued to increase after 2002, it did so at much the same rate (Figure 3.3; Table A3.3). National test data for science record a slight dip two years after the Strategy was introduced, and teacher assessment data indicate that the percentage of pupils attaining Level 5 or above in mathematics rose 7% in the five years prior to the Strategy being introduced and only by a further 5% in the following five years, remaining constant (at 79%) since 2007.

The Government's national targets, originally set in 2000, to be met by 2007, of 85% achieving Level 5 in English and mathematics were missed by a large margin, as were the intermediate milestones it set for 2004 of 80% achieving Level 5 in mathematics and 75% achieving the same Level in English.

According to the *Next steps* targets, established in 2006 following the launch of the Government's Science and Innovation Investment Framework two years previously, the Government sought to make science a priority in schools and to 'continually improve the number of pupils getting at least level 6 at the end of Key Stage 3' with a view to 'from 2008 for all pupils achieving at least Level 6 at Key Stage 3 to study three separate science GCSEs, to increase progression to, and attainment at, A level science' (HMSO 2006, p. 39). Assessment data for 2008 and 2009 indicate that 41% and 46%,[27] respectively, of all pupils gained this standard, but it is unclear how many of these quarter-of-a-million or so individuals have been able to take advantage of the triple science entitlement, and what procedures have been put in place to measure attainment at or above Level 6 following the Government's decision in 2008 to scrap Key Stage 3 testing.

3.4 Attainment trends in Northern Ireland

3.4.1 Attainment trends in mathematics at Key Stages 1 and 2 (Northern Ireland)

As was reported in Chapter 2, within the Northern Ireland curriculum only English and mathematics have been assessed at Key Stages 1 and 2, and monitoring of these has been conducted and reported through teacher assessment alone. At Key Stage 1, the attainment trends show a consistently high level of performance in mathematics (and also English), with an average of 95% of pupils attaining or exceeding the expected Level over the ten years for which data are available (Figure 3.4; Table A3.6).

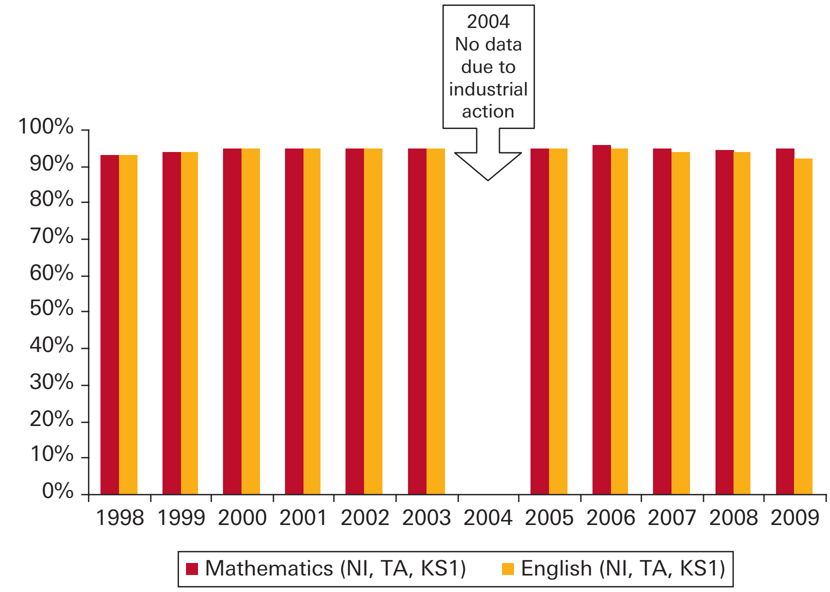
Figure 3.5 shows that from 1998 up until 2006 attainment at or above the expected Level at Key Stage 2 increased gradually in both subjects, there being an 8 percentage point increase in mathematics and an 11 percentage point increase in English (see also Table A3.7). Since 2006, progress in both subjects stalled and in 2008 and 2009 continued to increase slowly. Throughout this time-period, attainment in mathematics at or above the expected Level has consistently been greater than in English, though the gap in attainment between the two subjects has narrowed.

3.4.2 Attainment trends in science and mathematics at Key Stage 3 (Northern Ireland)

The results of Key Stage 3 teacher assessments in Northern Ireland were first recorded in 1999, and teacher

27 DCSF Statistical First Releases SFR 20/2008, table 3 (provisional data) and SFR 30/2009, table 5. Data for 2008 are test data, data for 2009 are teacher assessment data.

Figure 3.4. Percentages of all pupils attaining Level 2 or above in Key Stage 1 teacher assessments (TA) in mathematics and English (Northern Ireland, 1998–2009).

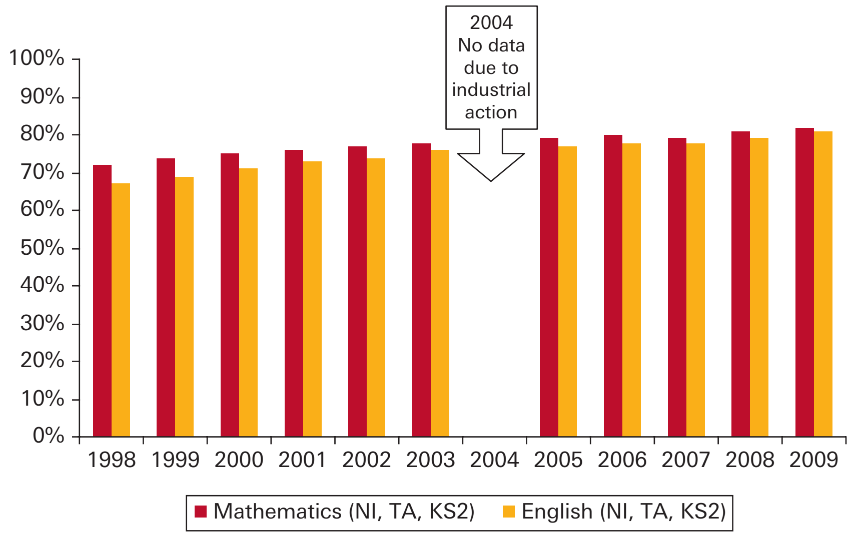


Source: DENI.

assessment data have been recorded since then. Testing became optional from 2007, and no official data appear to have been recorded for 2009. Figure 3.6 shows attainment in Key Stage 3 in teacher assessments in English, mathematics and science, and permits comparison with national test results in these subjects.

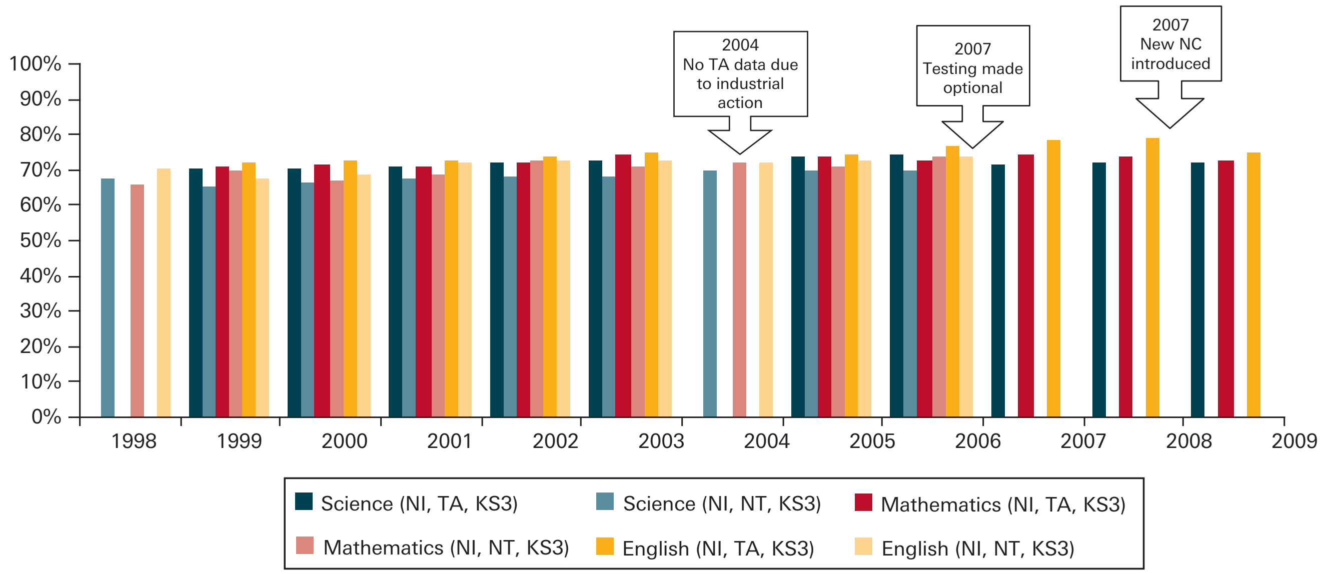
During the 11 years of teacher assessment, attainment at or above the expected Level in science rose by five percentage points up to 2006, and subsequently fell back to the level last seen in 2002. A similar trend is observable in English, although the same degree of gain (of five percentage points) was made between 1999 and 2006, and the fall back since then was less than that observed in science. Mathematics attainment increased modestly throughout the period, but only by a total of three percentage points. National test data closely match those for teacher assessment, although they are generally lower than the latter across all three subjects, the exceptions being in 2002 and 2006, when attainment at or above the expected Level in mathematics tests was one percentage point higher than was measured by teacher assessment. For more information, see Table A3.8.

Figure 3.5. Percentages of all pupils attaining Level 4 or above in Key Stage 2 teacher assessments (TA) in mathematics and English (Northern Ireland, 1998–2009).



Source: DENI.

Figure 3.6. Percentages of all pupils attaining Level 5 or above in Key Stage 3 teacher assessments (TA) and national tests (NT) in science, mathematics and English (Northern Ireland, 1998–2009).



Source: DENI.

3.5 Attainment trends in Wales

3.5.1 Attainment trends in science and mathematics at Key Stage 1 (Wales)

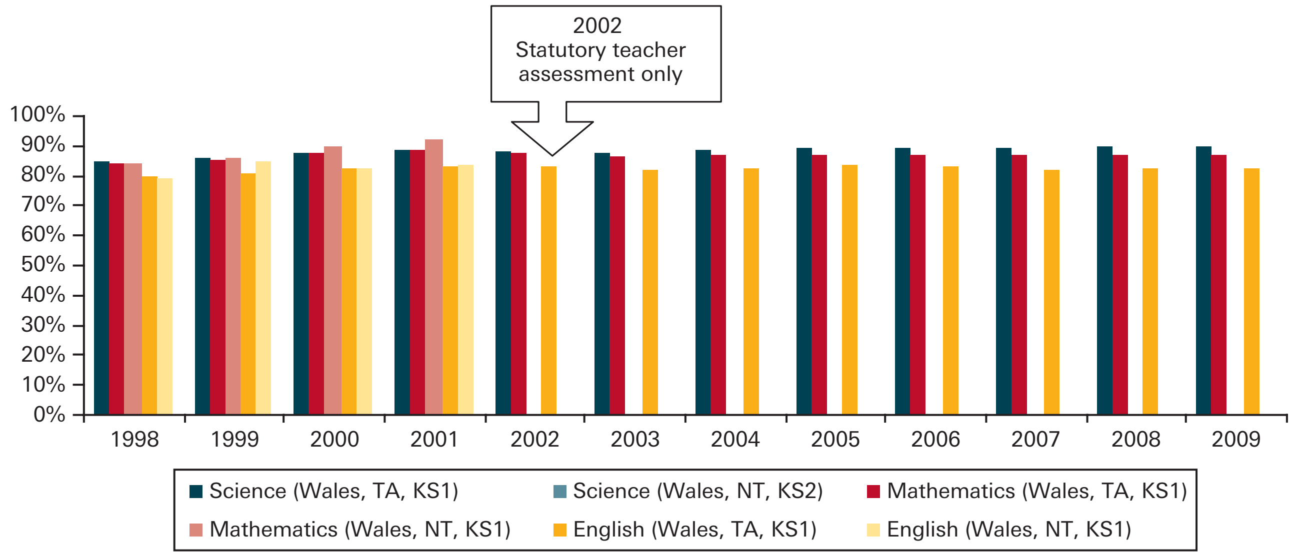
As Figure 3.7 illustrates, from 2002, statutory National Curriculum tests/tasks were abolished at the end of Key Stage 1 in Wales, leaving teacher assessment as the only form of statutory assessment in use. Science was only ever assessed by teacher assessment. Owing to the differing availability of national test versus teacher assessment data, the following commentary focuseson the latter.

The trends for teacher assessment show that the percentages of pupils attaining at or above the expected Levels in science rose by just five percentage points between 1998 and 2009, while the equivalent data for mathematics and English indicate an overall increase of just three percentage points (see also Table A3.9).

3.5.2 Attainment trends in science and mathematics at Key Stage 2 (Wales)

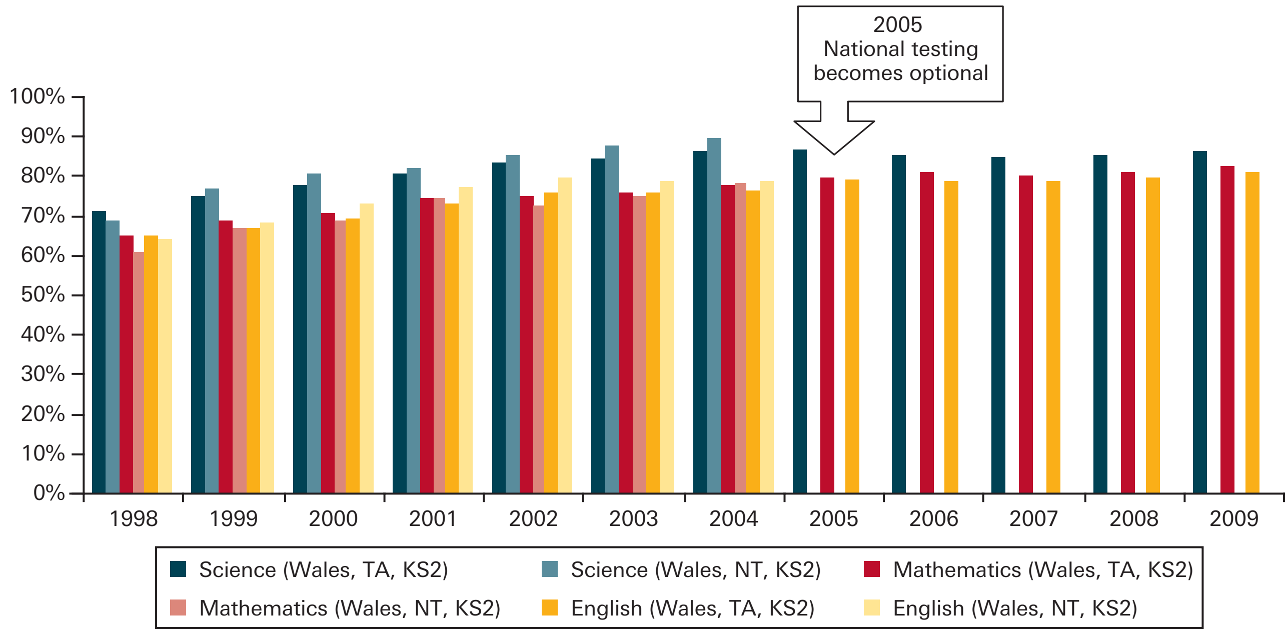
Figure 3.8 shows attainment trends in core science, mathematics and English for end-of Key Stage 2 tests and

Figure 3.7. Percentages of all pupils attaining Level 2 or above in Key Stage 1 teacher assessments (TA) and national tests (NT) in science, mathematics and English (Wales, 1998–2009).



Source: WAG.

Figure 3.8. Percentages of all pupils attaining Level 4 or above in Key Stage 2 teacher assessments (TA) and national tests (NT) in science, mathematics and English (Wales, 1998–2009).



Source: WAG.

teacher assessments in Wales. It shows that the percentages of pupils attaining or exceeding the expected Level have consistently been highest in science (regardless of whether teacher assessment or test data are examined). Nonetheless, the highest percentage point increase in attainment occurred in mathematics for which an 18 percentage point gain was recorded between 1998 and 2009, respectively three and two percentage points more than that recorded for science and English over the same period (Table A3.10).

3.5.3 Attainment trends in science and mathematics at Key Stage 3 in maintained schools (Wales)

A year after the Welsh Assembly abolished national testing at Key Stage 2 it dispensed with testing at Key Stage 3. As a result, only teacher assessment data have been recorded from 2006 onwards. Figure 3.9 shows the percentages of pupils gaining or exceeding the expected Level in core subjects at Key Stage 3.[28] It shows a close match between national test and teacher assessment data for the same subject. The teacher assessment data show that, generally speaking, more pupils gained or exceeded Level 5 in science than was the case in other subjects. Overall, the percentage point increases in teacher assessments between 1998 and 2009 were 16, 10 and 9 for science, mathematics and English, respectively (see Table A3.11).

28 Data for Welsh medium tests are not included.

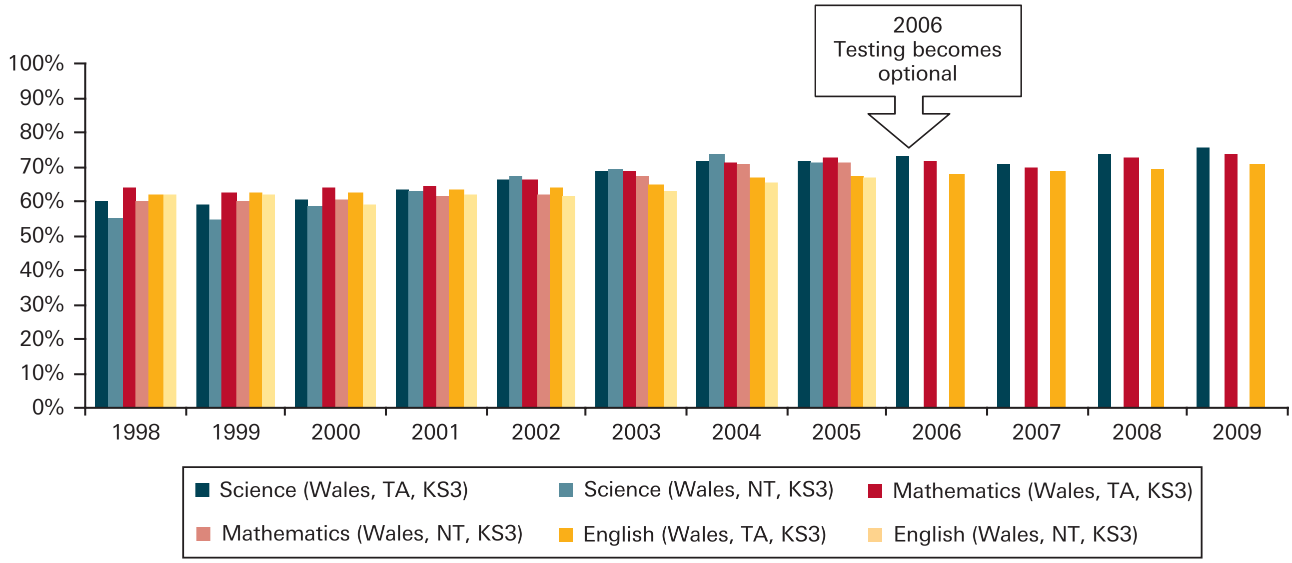
3.6 England, Northern Ireland, Wales: cross-comparisons in science and mathematics attainment

As chapter 2 has clearly shown, the history of national curricula in the UK and the assessment systems that have developed alongside them is complex. There has been little stability overall, with frequent changes in policy that have seen the educational systems of the four UK nations increasingly diverge, the rate of separation accelerating with the devolvement of powers to the Welsh and Northern Ireland Assemblies.

Given these circumstances, like-for-like comparisons of attainment across England, Northern Ireland and Wales are not possible and even comparisons of trends therefore need to be undertaken with caution. The circumstances (eg geographical, demographic and political) within each of these nations differ substantially. Educationally, 'local' versions of the English National Curriculum have operated in Northern Ireland and Wales and there have been differences both in the operation of national testing across the three nations and in the training teachers received for teacher assessment. Further, during the period under comparison, Key Stage 1 covered a period of four years' schooling in Northern Ireland (Years 1 to 4), but only three years' schooling in England and Wales (Reception, Year 1 and Year 2). It is also worth drawing attention to the fact that the data for England show that the focus of testing and teacher assessments has changed over time with, rather strangely for instance, spelling apparently only being specifically tested in 2001 and 2002 (Table A3.3).

Nonetheless, it is interesting to compare the attainment patterns observed. Figures A3.2–A3.7 combine the

Figure 3.9. Percentages of all pupils attaining Level 5 or above in Key Stage 3 teacher assessments (TA) and national tests (NT) in science, mathematics and English (Wales, 1998–2009).



Source: WAG.

information in the preceding sections, and show plots of attainment trends in teacher assessments across the three nations, for which more extensive data exist. Figure A3.2 shows that teacher assessments in Key Stage 1 science closely match across England and Wales, though it seems that while performance at or above the expected Level was measured to be slightly higher in England pre-2006, from 2008 onwards this situation reversed. In mathematics at Key Stage 1, the numbers of pupils gaining or exceeding the expected Level in Northern Ireland were consistently between four and eight percentage points higher than that in England and between six and nine percentage points higher than in Wales for all years for which data are available (Figure A3.3). (Although not shown here, an even higher level of performance is observed in English teacher assessment data for Northern Ireland compared with that in England and Wales, the differential being between 10 and 13 percentage points.)

In Key Stage 2 science, teacher assessment results show that performance at or above the expected Level in both Wales and England followed a similar trajectory, increasing year on year from 1998 to 2001 in both nations, with progress slowing thereafter, first in England and then in Wales (Figure A3.4). In mathematics, the measured Level of performance increased in each nation. However, the rate of progress slowed after 2001 with generally single percentage point increases being achieved, and after 2006, performance fell across all three nations in 2007 and recovered thereafter (Figure A3.5). Again, though, the performance at or above the expected Level is similar across all three nations, and becomes more similar over time.

Figures A3.6 and A3.7 compare performance at or above the expected Level in Key Stage 3 teacher assessments in science and mathematics, respectively. In science, performance across all three nations improved up to 2006, but faltered in Northern Ireland and Wales in 2007, before recovering thereafter. In mathematics, attainment in England at or above the expected Level gradually increased throughout the time-period under consideration, while in Wales gradual increases occurred between 1999 and 2005, after which it fluctuated, reaching a new zenith in 2009. In Northern Ireland, performance has fluctuated since a peak was reached in 2002.

The 2% point improvement in Key Stage 2 English and mathematics teacher assessments in Wales between 2007 and 2009 and the 1% increase in science are not especially convincing, but a research study indicated that teachers in Wales believed that abolishing the national tests had had a positive impact on teaching science at Year 6, with teachers beginning to deploy 'a broader range of teaching strategies' and embrace the new requirements for summative teacher assessment (Collins *et al.* 2008).

3.6.1 Differences in attainment of boys and girls in Key Stage teacher assessments across England, Northern Ireland and Wales

Table 3.2 provides a breakdown of differential performance at four year intervals during the years 1999–2007 in teacher assessments between girls and boys at or above the expected Level for each of Key Stages 1, 2 and 3 across England, Northern Ireland and Wales. These data are representative of the patterns seen throughout the period 1998–2009. The focus is on teacher assessments, for which longer trend data are available.

It is noticeable that there is generally a high level of consistency in the differentials across each subject, Key Stage and nation. Gender differential performance at or

Table 3.2. Percentage differences between the numbers of girls versus boys attaining or exceeding the expected Level in Key Stage teacher assessments across England, Northern Ireland and Wales (1999, 2003 and 2007).

	Science						Mathematics						English					
	Key Stage 2			Key Stage 3			Key Stage 2			Key Stage 3			Key Stage 2			Key Stage 3		
Year	'99	'03	'07	'99	'03	'07	'99	'03	'07	'99	'03	'07	'99	'03	'07	'99	'03	'07
England	+1	+2	+1	+3	+2	+3	+1	+1	0	+2	+4	+1	+12	+11	+10	+18	+15	+13
Northern Ireland	–	–	–	+6	+6	+6	0	0	0	+7	+6	+5	+11	+11	+9	+16	+14	+13
Wales	+2	+3	+4	+2	+2	+4	+2	+3	+3	+3	+4	+2	+12	+11	+11	+17	+18	+16

above Level 4 at Key Stage 2 is generally slight in both science and mathematics, but consistently highest in these subjects in Wales where more girls gain or exceed the expected Level. In English, though, girls considerably outperform boys at Key Stage 2 in England, Northern Ireland and Wales.

At Key Stage 3, girls' performance exceeds that of boys in all core subjects, but again it is in English that the differential is seen to be greatest.

The tendency for girls to outperform boys is in line with the finding that 'girls generally perform better at school than boys' (QCA 2008), despite the view that certainly in England, and in particular respect to literacy, the Key Stage tests—and indeed pedagogical strategies—became more 'boy-friendly' (Henry 2001). The recently published Cambridge Primary Review concluded that the reason girls outperform boys 'cannot be attributed to basic reasoning abilities, and must therefore be a consequence of socio-cultural factors in and out of school' (Alexander 2010, p. 106). Interestingly, there appears to be an inverse relationship between attainment and attitudes. Much attitudinal research has indicated that boys generally have a more positive attitude to school science and mathematics than girls, but that their attainment is lower (*viz.* Chapter 6, this report).

3.6.2 Differences in attainment in Key Stage 2 and 3 teacher assessments among different ethnic minorities (England and Wales)

Owing in large part to the more homogeneous nature of the populations of Northern Ireland and Scotland, data on ethnic minority attainment are only available for England and Wales. Published data on attainment at Key Stages 2 and 3 in these nations are used, these being critical points marking, respectively, the end of primary school and the early years of secondary school. Only data from 2004 onwards are included, following the Government's decision in 2003 to change the categorisation of ethnicities to align them with that used in the 2001 National Census.

3.6.2.1 England (Key Stage 2)

In England (see Figure A3.8), in Key Stage 2 science, it is clear from looking at data from 2004 onwards that only Chinese pupils consistently perform somewhat above the national average, with the differential in percentages gaining or exceeding the expected Level varying between 3% and 5%. Indian pupils also exceed the national average, but more marginally. However, both black African and Caribbean pupils consistently underperform the national average. Nonetheless, it is encouraging to note that while the numbers of black African pupils increased by some 44% between 2004 and 2009, so the gap in attainment below the national average practically halved, from 11 percentage points to 6 percentage points. Similarly, while numbers of Caribbean pupils actually decreased 8% during this period, the percentage of those achieving the expected Level rose by five percentage points and the level of underperformance against the national average fell from eight percentage points to five percentage points. Other Asian pupils also perform below the national average, though it is again notable that Pakistani and Bangladeshi pupils halved the gap between 2004 and 2008, although this increased again slightly in 2009 among the latter.

A similar pattern emerges in mathematics at Key Stage 2 (see Figure A3.9), with Chinese pupils consistently outperforming other pupils and maintaining a double-figure percentage point improvement on the national average throughout the time-period. Again, Indian pupils' attainment at or above the expected Level exceeded the national average, and by a greater amount than is observed in science. Likewise performance of other Asian pupils is below the national average, but the gap has closed, with Bangladeshi pupils reducing this from seven to three percentage points over the six years measured. Attainment at or above the expected Level among black African and Caribbean pupils has also been consistently below the national average, but again this gap has closed by several percentage points in each case.

At Key Stage 3, where data are only available up to 2007, Chinese pupils outperform all others in science (Figure A3.10), with the gap between their attainment and the national average being no less than nine percentage points. Indian pupils also perform consistently better than the national average. However, among the other Asian pupils, both Pakistani and Bangladeshi pupils have consistently performed below the national average, with the gap narrowing only slightly in both (from 20 percentage points to 16 percentage points in the former). Similarly, black African and Caribbean pupils have also performed below the national average.

In mathematics, higher percentages of both Chinese and Indian pupils consistently attain or exceed the expected Level at Key Stage 3 than any other major ethnic group (Figure A3.11). Pakistani, Bangladeshi, African and Caribbean pupils consistently perform at similar levels below the national average.

3.6.2.2 Wales (Key Stages 2 and 3)

Combined data for teacher assessments in science, mathematics and English or Welsh as a first language published in Statistical Bulletin SB 16/2009 indicate similarities with the observations on the England statistics, although the ethnic categorisation differs. The data indicate that, for 2006–2008, Chinese pupils performed above the national average at Key Stage 2 and considerably above the national average at Key Stage 3. They also show that black ethnic minority groups performed considerably below the national average at both Key Stages 2 and 3.

These established patterns of attainment among different ethnic groups are important because they are seen to be repeated in attainment and progression at GCSE and at A-level. Evidence reported in the Royal Society's second 'state of the nation' report showed:

'There are some clear patterns associated with ethnicity in the data examined for England. At GCSE and at A-level there are higher rates of attainment of A*—C grades by Chinese and Indian students in science and mathematics. Worryingly, Caribbean students are attaining A*—C at much lower rates in all core science and mathematics subjects at GCSE and A-level, as well as across the board in GCSE'

(Royal Society 2008, p. 170).

Further, we also know that poor prior attainment among black Caribbean and Bangladeshi pupils leads to them being underrepresented in science and science-related degrees and occupations (Jones & Elias 2005).

3.6.2.3 Differences in attainment in Key Stage 2 and 3 teacher assessments among pupils of differing socioeconomic status (England and Wales)

The proxy indicators of socioeconomic status in understanding educational attainment that are most relied-upon are eligibility for free school meals (FSM) and the Income Deprivation Affecting Children Index (IDACI), each of which has its advantages and disadvantages (Royal Society 2008). FSM-eligibility applies to a pupil living in a family whose income is below the poverty line. It has legal status, but its usage creates a simple binary distinction between those who are and those who are not FSM-eligible. IDACI is a more complex geographical measure of income deprivation, which uses the area where a pupil lives to define their level of deprivation rather than something specific to the individual child.

In the Society's second 'state of the nation' report, it was shown, using IDACI decile data for end-of Key Stage 2 tests in 'core' subjects in 2007, that there was a clear inverse relationship between attainment and 'income deprivation', with higher levels of deprivation correlating with lower levels of attainment (Royal Society 2008, Table 5.9). Here the focus is on FSM-eligibility, because IDACI factor data are not normally reported in Wales and although IDACI factor information is reported in the English statistical first releases, the DCSF cautioned about drawing comparisons between data for 2007–2009, which are based on 2007 IDACI scores, with IDACI data up to 2007, which are based on 2004 IDACI scores.[29]

Table 3.3 clearly demonstrates that pupils who are FSM-eligible perform considerably less well than those who are non-FSM-eligible, with the differential being consistently greater in mathematics than in science. The gap in attainment between FSM-eligible and non-FSM-eligible pupils at Key Stage 3 is even more marked than at Key Stage 2, in spite of the fact that it has been decreasing very slightly (by four percentage points in science, and by three percentage points in mathematics) over the period shown.

Very similar patterns of attainment among FSM-eligible and non-FSM-eligible pupils have been recorded in Wales (see Tables A3.12–A3.13).

3.7 Concerns about reporting attainment: have standards risen?

Caution needs to be adopted in assessing these performance data. What, exactly, do they show or is their significance? How much store should be put by them? The Government's original assumptions that high-stakes national testing at Key Stages 1 to 3 can validly assess a range of specific curricular objectives, that the results of such testing will enable pupils' attainment of these objectives to be represented accurately and that the whole process will sponsor improvements in teaching and learning has been severely questioned. As noted later in chapter 6 the use made of the test results has driven teachers to focus teaching on what is tested and this, plus the increased familiarity with the form of the tests can account for the initial rise in scores and subsequent levelling since there is a limit to what can be achieved in this way. Notably, only England has persisted with a high-stakes approach to measuring (and increasing) performance and only in England have school and college achievement and attainment (ie 'league') tables remained at the time of writing. Both Northern Ireland and Wales dispensed with them in 2001, and Scotland did so in 2003.[30]

29 See SFR 31/2009.
30 See www.literacytrust.org.uk/Database/leagueupdate.html

Table 3.3. Percentages of pupils in maintained primary schools achieving the expected Level in Key Stage 2 and 3 tests by FSM-eligibility (England, 2004–2007).

Science	2004[a] KS2/KS3	2005 KS2/KS3	2006 (P) KS2/KS3	2007 (P) KS2/KS3
FSM-eligible	71/39	72/44	73/48	75/49
Non-FSM eligible	89/71	89/74	89/77	90/77
All pupils	86/66	86/70	86/72	87/73
Mathematics				
FSM-eligible	55/50	56/51	58/56	61/55
Non-FSM eligible	78/77	78/78	79/81	80/79
All pupils	74/73	75/74	75/77	77/76

Sources: All DCSF 2004 data, SFR 08/2005; 2005 data, SFR 09/2006; 2006–07 data, SFR 31/2009 (KS2), SFR 04/2007 and SFR 38/2007 (KS3). Note that data (eg from SFR 31/2009) includes information from pupils in city technology colleges and Academies in addition to that from pupils in maintained schools.)

P, Provisional data.

(a) Data used here are taken from table 3 of SFR 08/2005, see http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000564/index.shtml, accessed on 15 April 2010. This clearly indicates the English results, but the tables for science and mathematics lack titles. We have, therefore, arranged the data according to what is likely, given trends in succeeding years and the ordering of data in table 4 of the SFR.

It is, for instance, clear from the figures that the increases in performance in Key Stage 1 and 2 English and mathematics apparent from the late 1990s were not maintained. Indeed, performance in these subjects levelled off at a level below that set by Government. Although the latest data indicate that approximately 80% of pupils gained the expected Level 4 in their end of Key Stage 2 English and mathematics tests in England, Northern Ireland and Wales, 20% or so of pupils are failing to attain the target standards in these subjects by the time they enter secondary schooling. In England, the percentages of all pupils gaining Level 4 in *both* English and mathematics at Key Stage 2 rose just 4% (from 68% to 72%), meaning that more than a quarter of all pupils fail to gain the required standard.[31] Given the wide recognition that prior attainment is *the* most important indicator of future examination success, this is deeply concerning (DfES 2008; Duckworth 2007).

It is also noticeable that across all three nations, the percentages of pupils attaining at or above the expected Level in the Key Stage teacher assessments drop with every Key Stage, with smaller percentages of pupils' attaining the required Level at each progressive Key Stage (Table 3.4).

It is generally accepted that a pupil should normally attain Level 2 at Key Stage 1, Level 4 at Key Stage 2 and Level 5 at Key Stage 3. However, the Level Descriptions used to determine performance are based on qualitative statements describing what pupils are expected to show. These are, by their nature, open to interpretation, which can change over time. This means that judgements about pupils' attainment are somewhat arbitrary and it therefore matters greatly where the Level boundaries are set. The Level boundaries themselves are subject to pre-test data gained from trialling test papers with representative samples of pupils. Undoubtedly, much rides on where the Levels are set as these are the basis for measuring the national standards and determining whether these are changing over time. The decision to set the boundary lower at a particular Level could make a 2% difference to the percentage of pupils at that Level or above (Stobart 2009), hence the importance of the removal of borderlining in England.

Difficulties in establishing the equivalence of Level judgements are compounded by the fact that the usage of Levels has also changed over time. When Levels were first defined by the Task Group on Assessment and Training in 1987, Level 4 was perceived to be the expected attainment of an *average* 11 year old (TGAT 1987, paragraph 108).[32] However, as Whetton (2009) and the House of Commons Children, Schools and Families Committee pointed out, when Labour first introduced national targets in 1997, this Level became the minimum expectation for *all* pupils, ie there was a far steeper demand on schools to ensure that their poorer performing pupils reached the required attainment Levels. However, the broadly interpretable nature of the Level Descriptions has meant that performance has inevitably been assessed in an arbitrary manner, and this may have led to greater leniency. Indeed, evidence exists in support of this argument, notably in the form of Massey *et al.* (2003),

31 Data extracted from DCSF Statistical First Release SFR 32/2009.

32 See http://www.kcl.ac.uk/content/1/c6/01/54/36/TGAReport.pdf

Table 3.4. Percentages of pupils attaining or exceeding the expected Level of achievement in Key Stage teacher assessments in England, Northern Ireland[(a)] and Wales[(b)] (1999, 2003 and 2007).

	Science			Mathematics			English		
	Eng.	NI	Wal.	Eng.	NI	Wal.	Eng.[(c)]	NI	Wal.
Key Stage 1 (1999)	87	–	86	86	94	85	81	94	81
Key Stage 1 (2003)	89	–	88	89	95	87	84	95	82
Key Stage 1 (2007)	89	–	89	90	95	87	82	94	82
Key Stage 2 (1999)	76	–	75	70	74	69	68	69	67
Key Stage 2 (2003)	82	–	85	74	78	76	72	76	76
Key Stage 2 (2007)	85	–	85	78	79	80	78	78	79
Key Stage 3 (1999)	60	70	59	64	71	62	64	72	62
Key Stage 3 (2003)	69	73	69	72	74	69	68	75	65
Key Stage 3 (2007)	75	72	71	79	74	70	74	78	69

(a) Data for Northern Ireland were received direct from DENI.

(b) Data for Wales were extracted from StatsWales, see http://statswales.wales.gov.uk/index.htm

(c) For Key Stage 1, teacher assessment data are calculated as an average of attainment in reading and writing at or beyond Level 2. Within this report's focus period, data on 'English' at Key Stage 1 are only available from 1998 to 2003 (cf. Table A3.1).

who in an extensive study found that the 1999 Key Stage 2 English tests had been marked more leniently than those of 1996, and that this was even more apparent for comparisons between the 1996 and 2000 results. (However, it should be noted that the same researchers also found 'no suggestion … that standards might vary' in the Key Stage 2 mathematics results for 1996–1999.)

In addition, the changing nature of the tests themselves means that no single standard of testing has been in place, albeit that the tests are considered to be equivalent. For instance, Massey *et al.* (2003) found that 'the children perceived the 1999 paper to be more accessible and user-friendly than the 1996 version' (p. 147). More recently, the NFER admitted that 'the fact that the tests change each year means that the content is varied and differing aspects occur each year' (House of Commons 2008, p. 21). It is, therefore, little wonder that attempts to 'equate the standard of work from one year to that of the previous year and [to translate] this into a single mark at a level boundary' have elicited concerns about over-interpreting aggregated (ie national) data' (Stobart 2009).

When Tymms (2004) challenged the reported improvements in Key Stage 2 national test performance between 1995 and 2000, his findings that these were exaggerated was disputed by the Government, but later backed by the independent Statistics Commission and again more recently by the House of Commons Children, Schools and Families Committee. As Alexander (2010, p. 335) has said, 'what is clearly needed is a better match between the standards we aim for and the standards we actually measure'.

3.8 Latest developments and the future

As mentioned earlier, the policy landscape is changing rapidly, and England has lately been following Northern Ireland and Wales in reducing testing at Key Stages 2 and 3. Following concerns about the marking of Key Stage 3 tests in 2008, the then Secretary of State took the exceptional step of abolishing them altogether. Since then, in the wake of the recommendations from the Expert Group on Assessment, allied to the Rose Review of the primary curriculum, Key Stage 2 tests in science, but not mathematics, have also been scrapped.

The termination of Key Stage 2 and 3 tests in science in England should lead to the sort of flexible and inspirational teaching that will enable teachers to convey the excitement of science and inspire more children both to develop a lifelong interest in the subject and to choose to pursue studying it at A-level and beyond. However, for the many teachers who have grown accustomed to teaching to the test, this change may be hard to cope with and it is unclear what, if any, mechanisms are being put in place to ease the transition (cf. Chapters 4 and 6).

There is a strong sentiment amongst the teaching profession that Key Stage 2 tests in mathematics in England should be abolished. It is argued that by allowing 'teaching to the test' to persist, the tests militate against more innovative approaches to teaching the subjects. They also reduce the breadth of the curriculum and, consequently, put pupils off the subjects before they enter secondary school education. Moreover, the levelling off in performance trends indicates that the tests may have run their course and may need to be replaced by an alternative form of assessment.

Recommendation 2

The Department for Education should dispense with Key Stage 2 tests in mathematics. It should also conduct a review of the assessment system for pupils aged 5–14, ensuring that assessment is light touch and geared primarily to supporting and encouraging their progress.

3.9 Attainment trends in Scotland

Scotland has never adopted the same high-stakes approach to teaching, learning and assessment at primary/early secondary level seen across other parts of the UK. Between 1998 and 2004, a National Survey of 5–14 Attainment Levels was conducted to assess performance in reading, writing and mathematics of all pupils in all publicly funded (ie State) schools, although the results of the 1998 survey were deemed insufficient for publication (Scottish Executive 2002). Following an investigation into testing published in 2003, the decision was taken to adapt the National Surveys and to introduce, from May 2005, a new Scottish Survey of Achievement (Scottish Executive 2003).

3.9.1 National Survey of 5–14 Attainment (2001–2004)

Five Levels, A–E, separated on average by around 18 months' development, were defined in order to measure attainment. These are detailed in Table 3.5. Available data for the percentages of pupils gaining or exceeding the expected Levels at different stages in primary mathematics are presented in Figure 3.10, together with those for English (reading and writing), for comparison. Science was not assessed during this period.

Generally, the data show a consistent improvement in attainment over time. This is, perhaps, only to be expected given the increasing familiarity of teachers and pupils with the expectations of the tests. Performance at the expected Level at P2 and P3 was consistently highest in mathematics. However, at P5 and P7 it dipped below that of reading and was broadly equivalent to writing at P5 and substantially higher than writing in P7.

At secondary level (see Figure 3.11), although the level of performance measured improves year on year, performance in reading is consistently higher than that in mathematics and writing, with the year-on-year increases accelerating over time.

Table 3.5. Levels of attainment used for assessment in Scottish National Surveys of Attainment, 2001–2004.

Level A	Should be attainable in the course of the first three years of primary school education (P1–P3)
Level B	Should be attainable by some pupils in P3 or even earlier, but certainly by most in P4
Level C	Should be attainable in the course of P4–P6 by most pupils
Level D	Should be attainable by some pupils in P5 or P6 or even earlier, but certainly by most in P7
Level E	Should be attainable by some pupils in P7 or S1 (first year of secondary school), but certainly by most in S2

3.9.2 Scottish Survey of Achievement

The Scottish Survey of Achievement evolved out of the National Surveys to report on attainment in key areas of the curriculum, and core skills in the context of each key area, beginning with English language in 2005 and continuing on a four year cycle to include mathematics, science and social subjects. It is a sample survey, so not all pupils are tested. The random nature of the sampling means that the results may only be considered as being indicative of the overall situation in Scotland. Alongside publication of the 2009 Survey, the Scottish Government announced that the survey is being modified to fit the new Curriculum for Excellence and will in future focus on literacy and numeracy only, starting with numeracy in 2011.

Pupils are assessed according to a scale similar to that used in the National Surveys (Table 3.6), and include individuals from both publicly funded and independent schools. At each Level, the following assessment criteria are used:

(i) ≥80% test scores: 'very good' knowledge and understanding;

(ii) ≥65% test scores: 'well-established' knowledge and understanding;

(iii) 50% to <65% test scores: 'made a good start'.

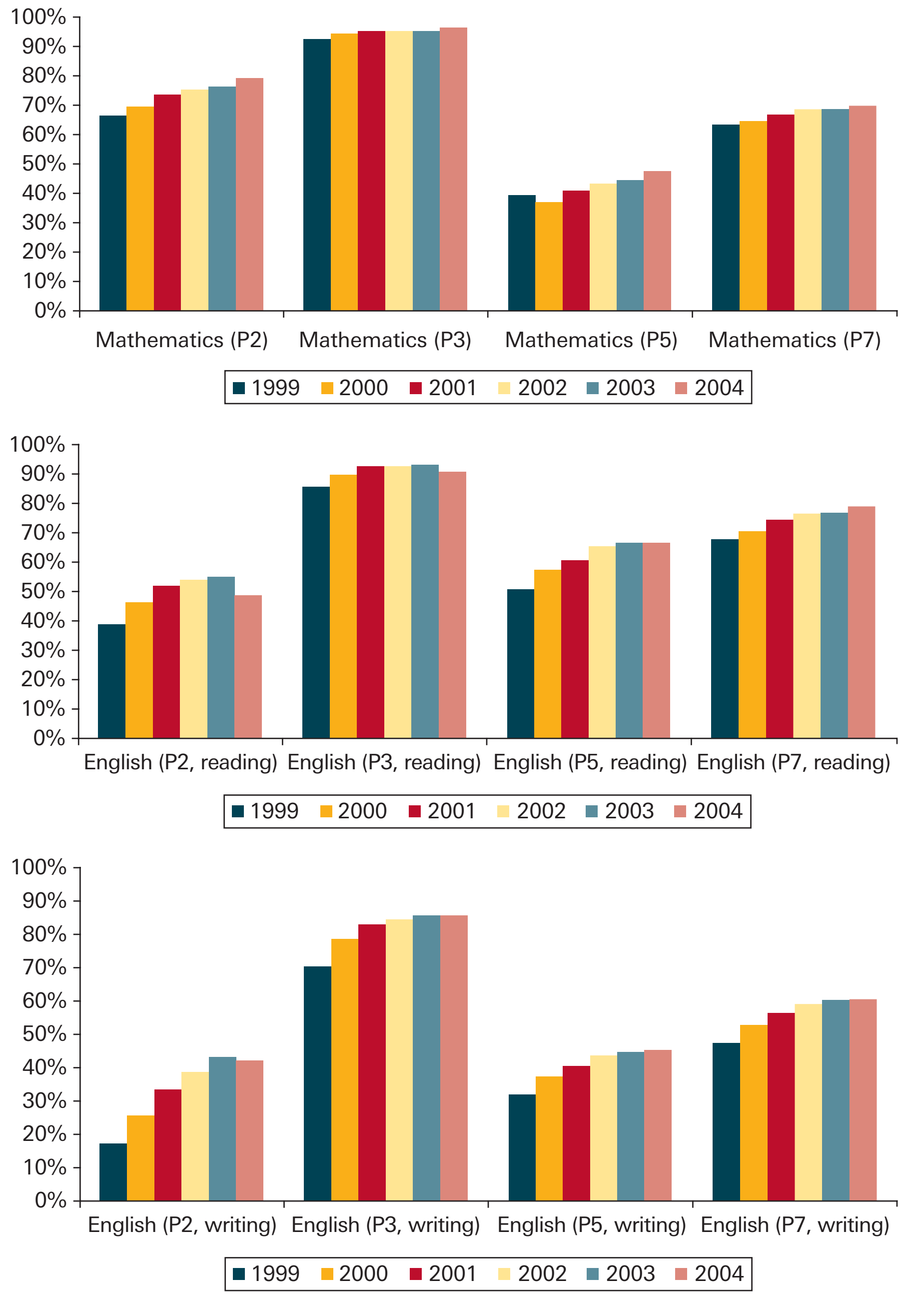
Core skills in mathematics, reading and writing have continued to be assessed through teachers' judgements in the Surveys of Achievement, although mathematics appears to have been excluded from the 2009 survey, which focused purely on reading and writing. It is important to note that not every pupil assessed takes every test.

Attainment data from teacher assessments indicate a high level of consistency across the years (Figure 3.12), with the great majority of pupils in each sample being considered to have performed at or above the expected Levels in the early and middle years of primary schooling, although a noticeable decline is observed relative to expectations at the end of primary education that continues into early secondary testing. According to the surveys, this decline seems to be associated with a decline in pupils' confidence in these subjects.

3.9.3 Scottish Surveys of Achievement in science (2007) and mathematics (2008)

Aggregate data for science do not exist in the same way that they do elsewhere in the UK. Performance in science

Figure 3.10. Percentage of P3, P4, P6, and P7 pupils attaining or exceeding the expected attainment Levels in mathematics and English (Scotland, 1998/99–2003/04).

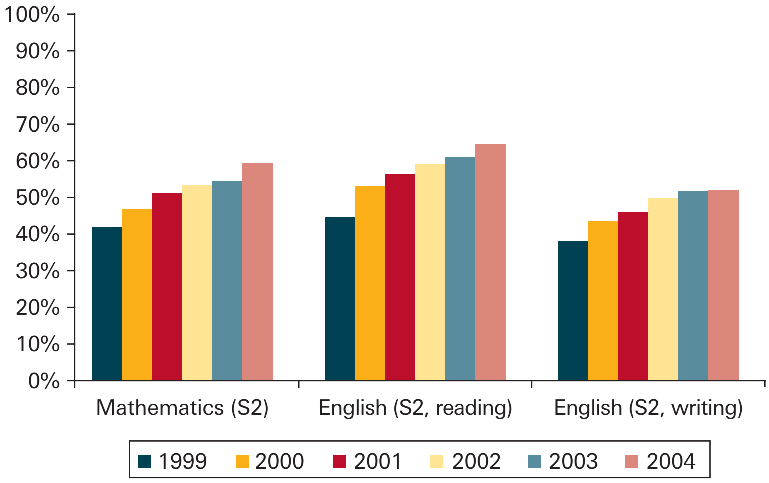


Source: Scottish Government.

was measured through assessing science knowledge and understanding, science literacy and science investigations (denoted Practical, and subdivided into components assessing investigation skills, ICT skills, problem-solving abilities through teamwork and science literacy through one-on-one communication skills with field officers). In addition, writing skills were assessed, within the context of a written science exercise.

The survey report leaves it very much up to the reader to interpret the information presented. However, in the singular instance where test and teacher judgements are compared, the report offers an explanation for the differences. Here the results show consistently large differences between the test data and teachers' judgements of scientific knowledge, with the latter indicating higher levels of attainment. To explain the discrepancies, the SSA report stresses that teachers' judgements are based on a range of knowledge gained about each pupil over a period of time, while test data provide a snapshot indicator that is based solely on performance on the day of the test and pupils' responses to the material they are presented with. Nonetheless, this situation is largely, and more extremely, the reverse of that observed in comparisons of national test and teacher assessment data. Moreover, a very similar finding was noted when the results of the 2009 SSA were published

Figure 3.11. Percentage S2 pupils attaining or exceeding the expected attainment Level in mathematics and English (Scotland, 1998/99–2003/04).



Source: Scottish Government.

earlier this year, which caused a certain amount of consternation.[33]

However, primary and early secondary teachers in Scotland report low levels of confidence in teaching science and mathematics similar to those found elsewhere in the UK. Across the UK, confidence in science teaching has improved over the past decade, yet still half of 300 primary teachers surveyed identified lack of teacher confidence and ability to teach science as the major issue of concern in primary science (Murphy *et al.* 2007) and Murphy & Beggs (2005) previously correlated this with lack of continuing professional development. In the 2007 SSA, just 28% of 3,038 primary teachers surveyed were 'very confident' of teaching topics with a biology theme, and only 10% and 9%, respectively, were equally confident in teaching topics with a chemistry or physics theme. A further 34% and 38% of this sample admitted that they were 'not very confident' in teaching topics with chemistry or physics. Notably 41% of 1,016 P3 teachers, 39% of 1,026 P5 teachers and 34% of 1,003 P7 teachers had had no professional development in science during the past four years. By contrast, respectively 57%, 61% and 47% of S2 teachers indicated they were 'very confident' in teaching topics with a biology, chemistry or physics theme and only 11% of 963 S2 teachers had not had any professional development in science in the past four years.

Table 3.6. Levels of attainment used for assessment in Scottish Survey of Achievement.

P3	Level A (expected Level); Level B (above expected Level)
P5	Level B (expected Level); Levels C and D (above expected Level)
P6	Level C (expected Level)
P7	Level D (expected Level)
S2	Level E (expected Level); Level F (above expected Level)

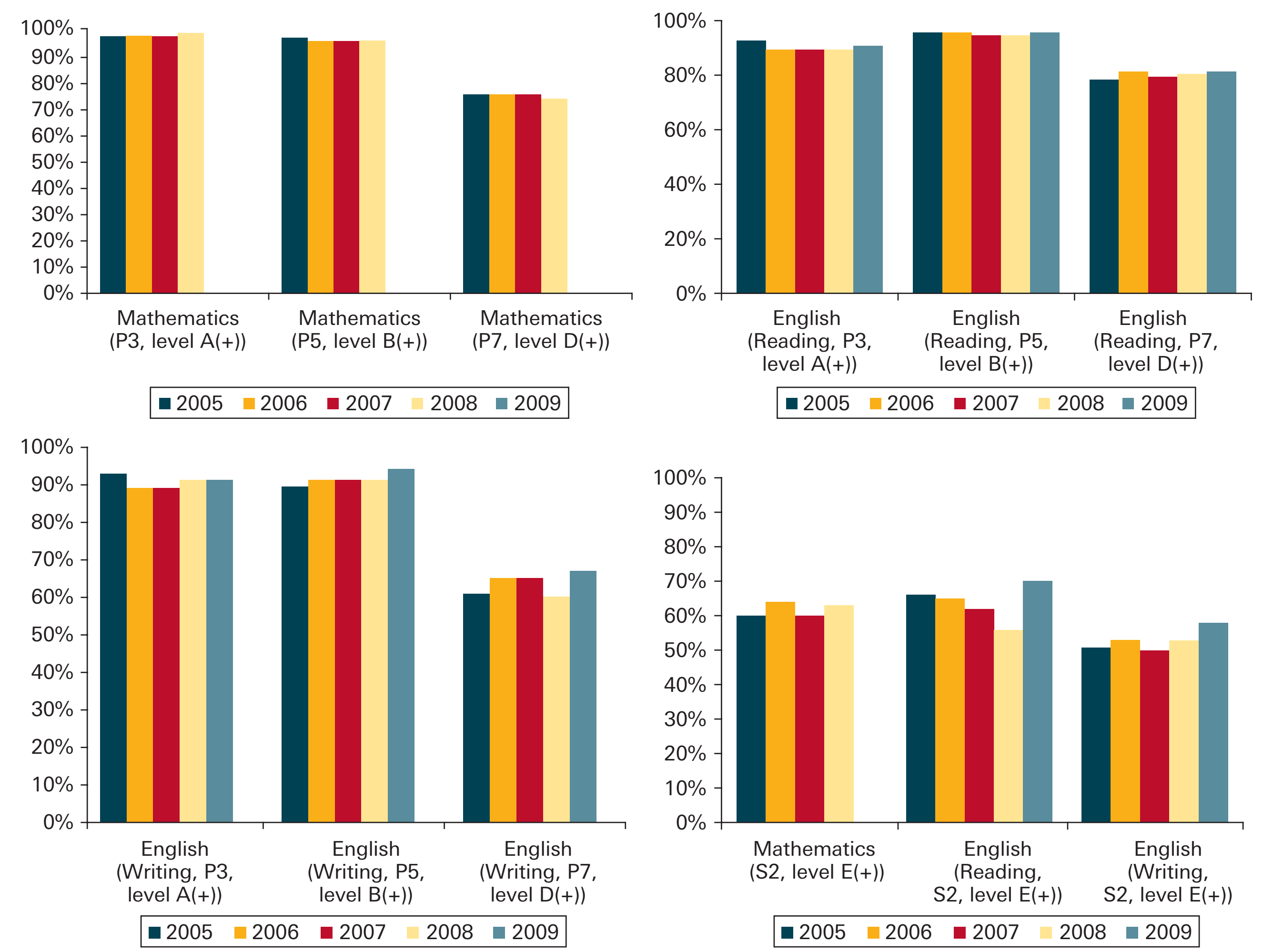
In mathematics, 87% of P3 pupils were estimated to have 'well-established or better' skills at the expected Level, but the proportions attaining at the expected Levels declined throughout primary and into secondary schooling, with just 30% of S2 pupils estimated to be 'well-established or better' at the expected Level at this stage. A similar situation was observed in numeracy attainment estimates, with 92% of P3 pupils estimated to be 'well-established or better' at the expected Level, falling to 43% at S2. As with science, teachers' judgements of the Levels pupils were performing at in mathematics were consistently greater than those indicated by test data, with 98% of P3 pupils estimated to be 'well-established or better' at the expected Level and an estimated 43% of S2 pupils being similarly categorised. Against a range of mathematical skills teacher confidence levels were consistently higher among S2 teachers than among their primary counterparts, although generally confidence increased throughout the primary stages.

3.10 Conclusions

Key Stage attainment trend data across England, Northern Ireland and Wales generally show pupils achieving comparatively well in science and mathematics (with performance in these subjects outstripping that in English, particularly at Key Stages 1 and 2). During the period reviewed, there has been a move away from national testing to teachers' assessments. However, the overall trends hide enormous gulfs in the performance of different ethnic groups and pupils of differing socioeconomic status,

33 See http://news.bbc.co.uk/1/hi/scotland/8484180.stm, accessed 24 February 2010.

Figure 3.12. Percentages of pupils in Scottish Surveys of Achievement samples adjudged through teacher assessment as attaining or exceeding the expected Levels in mathematics and English at P3, P5, P7 and S2.



Source: Scottish Government.

Note: Data on mathematics were not included in the 2009 SSA.

with significantly fewer children eligible for free school meals attaining the expected Levels at Key Stages 2 and 3. These gaps in performance are observable at GCSE and beyond, indicating that their likely future enjoyment of and interest, achievement and progression in these subjects is strongly influenced by their primary school experiences of these subjects.

A great deal of attention has been given to the achievement of national targets and rather less to how realistic and defensible they are. But there is a danger that important debates over the technicalities of Level setting and measurement, and the undoubtedly negative effects that high-stakes testing has had on pupils and their teachers, may unwittingly hide a much greater and far-reaching concern, namely that, as reports across the UK have attested, many teachers simply lack confidence in teaching science and mathematics. Quite simply, the extent to which the hopes and expectations of any curriculum may be met depends on the quality of the teaching workforce.

Consequently, in a bid to understand why this under-confidence exists, the next chapter looks in greater depth at what is known statistically about the make-up of the primary and early secondary teaching workforce across the UK. Chapters 6 and 7 deal with the implications this has for young people being schooled now and in the future.

4 Science and mathematics 'specialists' within the 5–14 teaching workforce

4.1 Introduction

Within the context of formal education in schools, teachers are the most important guiding influence on pupils' personal and intellectual development (McKinsey & Co. 2007). Those who choose to teach in primary schools share the tremendous responsibility and challenge for giving young people what is commonly called 'a good start in life', a large part of which demands stimulating and motivating young, curious and impressionable minds and building up their knowledge and understanding of a variety of subjects.

Consequently, this chapter examines what is known, statistically, about the make-up of the teaching workforce in State-funded primary schools or at lower secondary level across the United Kingdom, including classroom assistants and technicians, but particularly in respect of science and mathematics 'specialists'. It also considers the supply of people with science, technology, engineering and mathematics (STEM) qualifications into primary and primary/secondary teaching and the likely impact of mooted changes in entry standards.

4.2 Operating constraints: what can and cannot be covered

It is important to note from the outset that:

- our analysis focuses on the maintained sector. With the exception of Scotland, consistently updated data on subject specialists in independent primary and secondary schools are still lacking;[34]
- there are currently no easily available or reliable subject-related data on the teaching workforce in Wales;[35]
- although data are available on the numbers of subject specialist teachers in State-funded secondary schools (Royal Society 2007; DCSF/NFER 2008), it is impossible to extract specific official data on practising Key Stage 3 teachers. For this reason, this chapter will primarily be concerned with the maintained primary school teaching workforce;
- while a statistical analysis cannot reflect the infinite variety of circumstances and manner in which subject specialists are deployed in day-to-day teaching, nonetheless, an objective overview of the available data can shed useful light on the challenges facing the profession, and the agencies that are responsible for supporting and sustaining it;
- there is still little evidence of the relevant authorities consulting with the science and mathematics education communities on how teacher recruitment targets should best apply to these strategically important subjects, especially at primary and early secondary level.[36]

4.3 Teachers in the maintained primary sector: general observations across the UK

Throughout the UK primary teachers are expected to teach all subjects. Primary teacher training is generalist in nature, even though entrants may have already studied specific subjects.[37] For this reason, historically, UK authorities have generally paid little heed to the proportions of subject specialists within the primary teaching workforce. Indeed, in response to a Parliamentary Question regarding the number of full-time equivalent music teachers in maintained primary schools for each year since 1997, the then Under Secretary of State, Sarah McCarthy-Fry, admitted: 'The number of music teachers in maintained primary schools is not collected centrally'.[38] This same state of ignorance extends across Northern Ireland and Wales, too, where specialisms of primary teachers are not consistently recorded, although a detailed analysis of STEM teachers was undertaken by the former in 2008.[39] In Scotland figures are consistently available on primary school teachers' subject specialisms in, separately, publicly funded and independent schools, but these are problematic (*viz*. § 4.6.2).

Clearly not all teachers can be specialists in all subjects but it is reasonable for them to have access to specialist advice in order to help enable them to meet the requirements of the curriculum. This is most obviously required in relation to a teacher's subject knowledge, where perceived lack of personal knowledge leads to low confidence and influences teaching approaches. Murphy & Beggs (2005) reported that the issue of most concern to primary teachers in relation to science was their knowledge, confidence and training. Harlen & Holroyd (1997) found that teachers who lacked confidence tended to use teaching methods that confine children's activities to ones that are 'safe', relying heavily on a work book or work

34 We originally report this in: Royal Society (2007). *The UK's science and mathematics teaching workforce*. A 'state of the nation' report, pp. 20–21. Royal Society: London, UK.

35 See http://wales.gov.uk/topics/statistics/headlines/schools2009/hdw200906182/?lang=en for publicly available data, which are collected for the Welsh Assembly Government in an annual snapshot.

36 See chapter 9, especially recommendations 9.1 and 9.2 in the Royal Society's 'state of the nation' report on the UK's science and mathematics teaching workforce (Royal Society 2007).

37 *Op. cit*., note 33, p. 26.

38 PQ 255921, see http://www.publications.parliament.uk/pa/cm200809/cmhansrd/cm090223/text/90223w0099.htm, accessed 4 August 2009.

39 We have also received confirmation from the General Teaching Councils of the UK that they do not keep data on the specialisms of primary teachers (GTCNI, E, W contacted on 30 July 2009).

cards with step-by-step instructions, underplaying questioning and discussion, and avoiding using any equipment that might 'go wrong'. But it is help in relation to knowledge of how to teach certain skills and concepts, not just background knowledge, that teachers need and this is particularly the case in both science and mathematics. Teachers lacking a robust understanding of the subject matter and how to teach it are more likely to be influenced by the content of tests than those who have the confidence to know that effective teaching will achieve good results without teaching to the tests.

The difficulties of reviewing and making recommendations about the provision and role of specialist help in primary schools are compounded by the fact that (i) there is no universal understanding, or definition, of what a 'specialist science' or 'specialist mathematics' teacher is; (ii) the actual ways in which teachers are deployed in schools, ie the amount of time they devote to teaching certain subjects may bear little relation to their educational background (whether or not this is recorded)[40]; and (iii) the fact that little is known about the impact on a national system of teachers who have been trained outside it.

In view of this, it is possible only to measure numbers of science and mathematics teachers according to the way in which they are categorised within each nation. The following sections describe more fully the information gathered for this study about the numbers of teachers within the Home Nations' primary schools that are counted as having science or mathematics specialist skills.

4.4 The primary and early secondary teaching workforce in England's maintained schools

4.4.1 The treatment of teachers in relation to educational reform

It is apparent through reading the history of curricula and assessment reform across the Home Nations described in Chapter 2 that teachers and their support staff appear to be but a secondary concern in the process of such reform.

The curriculum, and its associated assessment framework, is something that has tended to be imposed on teachers from the centre (particularly in England), rather than genuinely developed with their buy-in from the outset. In England, during the past decade and even earlier, teachers have been expected constantly to adapt their practices in response to a relentless and unprecedented stream of policy changes and initiatives. According to Alexander (2010, p. 35) one count estimated that between 1996 and 2004 Government and national agencies issued 459 documents on the teaching of literacy alone, equivalent to more than one every week during this period. Similarly, while the decision to abolish Key Stage 3 tests has been widely welcomed, it has unnerved many teachers for whom 'teaching to the test' has become the default *modus operandi*: 'The response of many secondary English teachers to the scrapping of the [Key Stage 3] tests is testament to this: teachers, whilst deploring the tests, have been trained to teach them and in their absence have been unsure what to do in their place' (House of Commons 2010, p. 28).

Consistently throughout the time-span covered in this report insufficient account has been taken of teachers' needs, desires and training requirements. That teachers should be treated in this way by policy makers is surprising given their recognised pivotal importance in young people's development (see, House of Commons 2008; McKinsey & Co. 2007; Politeia 2007, 2009; Royal Society 2007).

A welcome development that may herald an end to this has been the recent Government-commissioned report of the Science and Learning Expert Group – in its letter to Ministers, which forms the report's foreword, the Group states unequivocally: 'Many of us have good cause to be grateful to a single inspiring teacher that we encountered during our school education. We must ensure that teaching is a profession to which the brightest and best aspire. This can only be achieved if the teaching workforce is empowered to deliver the best education. Our overarching recommendation is that specialist teachers and their subjects need to come to the fore in the delivery of STEM education' (DBIS 2010).

4.4.2 Governance of information on the teaching workforce

Responsibility for managing different aspects of workforce policy and regulation in England has been shared. Until the new Department for Education was formed on 12 May 2010, the DCSF summed up its role as 'leading the whole network of people who work with or for children and young people'.[41] In order to meet its remit, the DCSF devolved responsibility for training and development of the primary and secondary school teaching workforce to the Training and Development Agency for Schools,[42] while responsibility for regulation of teachers and their professional standards is currently under the aegis of the General Teaching Council for England (GTCE), the independent professional body for teaching in England (established by the 1998 *Teaching and Higher Education Act*), although the Government recently announced its intention to abolish the GTCE.[43,44]

Each of these bodies is individually responsible for determining and keeping its own data collections and,

40 *Op. cit.*, note 1.

41 This information was included on the Web page, http://www.dcsf.gov.uk/aboutus/, accessed 3 December 2009. It is now no longer available.

42 The TDA became the successor, in 2005, to the Teacher Training Agency, previously established in 1994, which had controlled teacher-training funding and supply, but unlike the TDA had no remit for professional development.

43 The GTCE was established in order to improve standards of teaching and the quality of learning, and to maintain and improve standards of professional conduct among teachers, in the interests of the public.

44 This decision was announced on 2 June 2010, see http://www.education.gov.uk/news/news/gtcscrapped, accessed 9 June 2010.

separately, for deciding the extent to which these are publicly reported or otherwise made available in response to freedom of information requests.

The inevitable consequence of this cascading structure is that a picture of workforce numbers and flow can only be gained by collecting data from each of these sources. Perhaps inevitably, then, the picture that is obtainable is incomplete. The following sections examine the data that are available from each of these authorities.

4.4.3 Data on overall numbers of primary teachers in England's maintained schools (DCSF)

Despite the fact that disaggregated data on the numbers of nursery and primary schools in England have consistently been made available for many years, the DCSF (and its previous incarnations) persisted in aggregating the numbers of teachers (and, separately, support staff) in its published data collections. Table 4.1 provides a summary of data that are freely available on the teaching workforce in England, and enables comparison of these data with the number of primary schools over time. It shows that while, overall, the numbers of maintained primary schools have fallen 7.2% since 1997 (this may have been a response to falling rolls, which have now reversed),[45] there has been a 42% overall increase in the size of the workforce that is mainly accounted for by a dramatic (182%) growth in the numbers of teaching assistants[46] and a similar (86%) surge in employment of other support staff, both of which reflect the results of the previous Government's policy in this area.[47]

The DCSF acknowledged that it would be possible to disaggregate data on the numbers of teachers in nursery and primary schools, but maintained that this is not normally thought appropriate as there are relatively few separate nursery schools within the maintained sector and some nursery provision is undertaken within the primary sector that cannot be separately identified.[48]

Nonetheless, in response to a freedom of information request for such comparative information over time, the DCSF provided disaggregated data for the primary workforce for two years.[49] These disaggregated data are presented in Table 4.2. They show the percentages of different types of staff working in maintained primary schools in England in 2000 and 2008. It is calculable that this period experienced a 5.7% overall increase in total numbers of full-time qualified teachers, with a further overall growth in the proportion of female teachers. It is also very noticeable that women account for more than two-thirds of all primary school teachers, though the proportion of female heads may well be significantly lower.

Unfortunately, the DCSF was unable to supply information on the subject specialisms of both primary teachers and support staff.

4.4.4 Data on science and mathematics specialists in maintained primary schools (GTCE)

The GTCE was approached in an attempt to gain some sense of the number of science and mathematics specialists in English primary schools. All teachers in maintained schools (including pupil referral units and non-maintained special schools), must register with the GTCE in order to be able to practise in England, but it is optional for teachers in the independent sector to register.[50]

Table 4.3 provides snapshot summary data from the GTCE's database on the numbers of qualified science and mathematics teachers in England that are working in the primary sector.[51] The data regarding registration are constantly changing, so the information included provided here is indicative. The data are split into three categories, according to those who have either a degree in science/mathematics, or an initial teacher training qualification in science/mathematics, or both a degree and an initial teacher training qualification in one or other of these subjects.

(Note: at the time the extract was taken, it was possible to identify numbers of teachers who were not then registered. These teachers may be working in the independent sector and so be 'employed elsewhere'. It is also possible that they may be working where registration is required but have either not applied to be registered and their employer has not checked this, or be in the process of applying.)

Of course, each of these counts provides a different overall view of the number of science and mathematics 'specialists' in England's primary schools. Nonetheless, it is clear that most science 'specialists' have background qualifications in general science or biology, there being considerably fewer numbers of primary teachers with teaching qualifications in chemistry or physics. Notably, whichever type of count is applied, given that there are some 17,064 maintained primary schools currently in England,[52] it is clear that while we know nothing of their actual distribution there are insufficient numbers of primary science 'specialists' to allow each primary school in England to have access to one.

Further confusion about the actual numbers of science 'specialists' arises from the categorisation of the initial

45 See http://news.bbc.co.uk/1/hi/education/8048127.stm, accessed 13 April 2010.
46 These increases stem, in part, from the National Workforce Agreement (2003), which created the role of high level teaching assistants.
47 This umbrella term encompasses, somewhat confusingly, teaching assistants, cover supervisors, learning support workers, examination invigilators, ICT technicians, bursars, school office and secretaries, caretakers, etc (www.schoolsupportstaff.co.uk, accessed 17 November 2009).
48 Richard Howe (School Workforce and Finance Unit, DCSF), personal communication, 9 November 2009.
49 Richard Howe, (School Workforce and Finance Unit, DCSF), personal communication, 30 November 2009.

50 In addition, overseas trained teachers and instructors (unqualified teachers) must now provisionally register with the GTCE.
51 Alison Vale (Data Governance Team Leader, GTCE), personal communication, 9 March 2010.
52 See http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000891/index.shtml, chapter 1, accessed 9 March 2010.

Table 4.1. Full-time equivalent number of teachers and support staff (thousands) in maintained nursery and primary schools in England compared with the number of maintained primary schools (1997, 2001–2009).[a]

Workforce	1997	2001	2002	2003	2004	2005	2006	2007	2008	2009
All regular teachers[b]	191.7	195.0	197.4	197.4	196.6	196.3	198.2	197.1	198.1	198.5
Total support staff	75.7	108.0	122.8	127.6	134.1	144.5	154.4	163.1	172.6	181.4
Teaching assistants	41.9	65.5	71.8	82.3	89.2	97.9	99.0	105.8	115.0	118.3
Other support staff	33.9	42.5	51.0	45.3	45.0	46.6	55.3	57.4	57.6	63.2
Total workforce	267.4	303.0	320.2	325.0	330.8	340.8	352.6	360.2	370.7	380.0
Total no. of maintained primary schools[d]	18,392[c]	18,069	17,985	17,861	17,762	17,642	17,504	17,361	17,205	17,064
Total no. of pupils (5–10 years old)[e]	–	3,469,000	3,795,282	3,456,974	3,411,380	3,381,970	3,381,970	3,338,130	3,294,750	3,254,140

Sources: DCSF, SFR 23/09 (29 September 2009), table 1; DCSF, SFR 08/09 (7 May 2009, updated 11 August 2009).

(a) Excludes direct grant nurseries.

(b) Excludes occasional teachers.

(c) *Source:* DfES, SFR 42/2005 (28 September 2005), table 1.

(d) Includes middle schools as deemed.

(e) *Source:* DCSF http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000130/index.shtml; http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000109/index.shtml; http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000192/index.shtml; http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000288/index.shtml; http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000359/dfes_schools_final.pdf; SFR V09/2003; SFR V05/2004; SFR 42/2005; SFR 38/2006; SFR 30/2007; SFR 09/2008; SFR 08/2009. From 2004/05, data were published in SFR 37/2006; SFR 29/2007; SFR 26/2008; SFR 09/2009.

Table 4.2. Full-time qualified teachers in local authority maintained primary schools by gender in England (2000 and 2008).

	Heads (%)		Deputy Heads (%)		Classroom and others (%)		All teachers (%)	
Year	Males	Females	Males	Females	Males	Females	Males	Females
2000[(a)]	39.1	60.9	25.2	74.8	11.9	88.1	16.3	83.7
2008[(b)]	31.6	68.4	20.9	79.1	12.8	87.2	15.5	84.5

Source: DCSF (Database of Teacher Records).

(a) The overall number of full-time qualified teachers recorded in 2000 was 163,900.

(b) Data are provisional. The overall number of full-time qualified teachers recorded in 2008 was 173,270.

Table 4.3. Numbers of registered and non-registered science and mathematics teachers in England, including those that are currently in service in primary schools.[(a)]

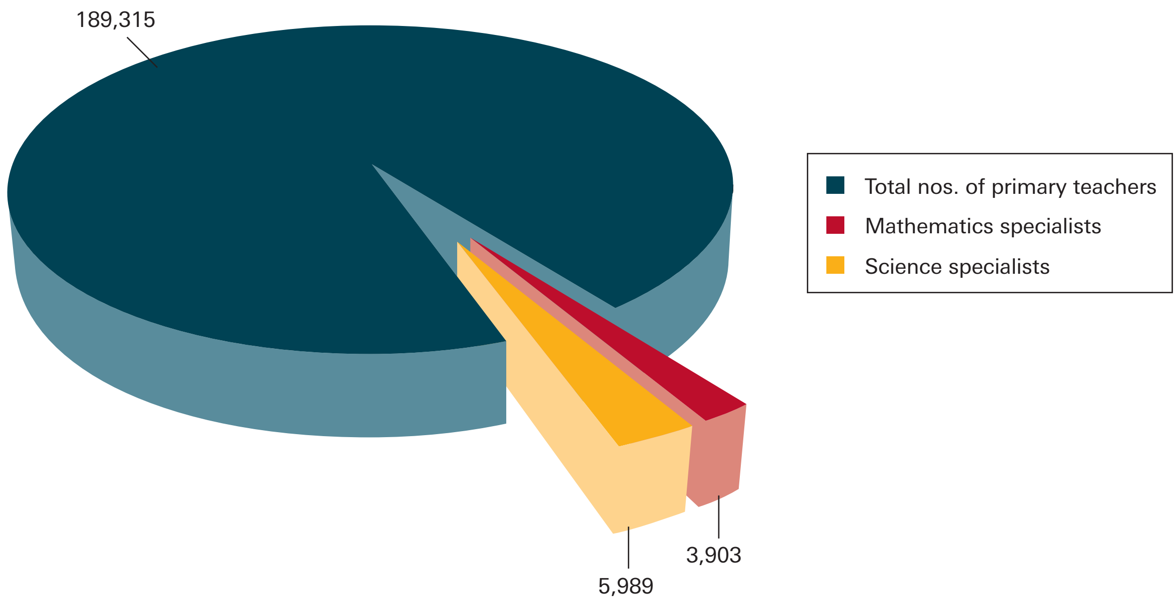
	Registered teachers				
	Biology	Chemistry	Physics	General science	Mathematics
Teachers with QTS and a degree in science/ mathematics	**18,271**	**10,814**	**5,494**	**25,931**	**19,942**
… in service	16,201	9,392	4,702	23,095	17,768
… working in primary schools	4,494	970	262	8,103	4,734
Teachers with QTS and ITT in science/ mathematics	**11,694**	**5,347**	**3,775**	**25,505**	**28,619**
… in service	10,441	4,698	3,299	22,609	25,467
… working in primary schools	2,136	82	54	7,112	5,912
Both degree in science and ITT in science/ mathematics (and QTS) in service	**7,086**	**3,837**	**2,223**	**8,488**	**15,919**
… registered and working in primary schools	1,768	65	40	4,116	3,903
	Non-registered teachers[(b)]				
Teachers with QTS and a degree in science/ mathematics	25,034	22,311	14,678	21,429	33,158
Teachers with QTS and ITT in science/ mathematics	8,616	4,691	4,398	15,677	20,714
Both degree in science and ITT in science/ mathematics (and QTS)	4,825	3,365	2,542	4,947	11,960

Source: GTCE.

(a) Data provided for teachers with QTS are irrespective of the age range the teachers are qualified to teach, ie the data may include teachers who have primary QTS and are working in primary schools and teachers who gained secondary QTS and are now teaching in primary schools. The GTCE is confident, however, that further analysis of the records would show that most of these teachers are qualified to teach pupils whose age spans both primary and secondary schooling.

(b) Non-registered teachers may be working but they may either not be required to register (eg because they work in the independent sector) or may have chosen not to register or have not applied to register or may be in the process of registering.

Figure 4.1. Pie-chart showing separately the numbers of in-service primary teachers with specialist degree and initial teacher training qualifications in science and mathematics as a fraction of the total number of registered practising primary teachers in England.[(a)]



Source: GTCE.
(a) Data on 'specialists' were obtained from the GTCE in April 2010. Information on the total number of in-service registered primary teachers (199,207) was obtained from the GTCE's most recent Digest of statistics for 2008/09.

teacher training qualifications, responsibility for which rests with the institutions that provide the GTCE with its data. For some first degree and ITT qualifications, such as 'home science' or 'rural and environmental science', 'general studies in social sciences', 'science education', 'computer education with science' or 'environmental studies', a detailed knowledge of their syllabi would be needed to ascertain whether or not a course should be included within the general category 'science' or within one of its subdivisions (ie biology, chemistry or physics). For others, such as 'political science', 'history of science'or 'philosophy of science', it is clear that these courses do not cover the physical and biological sciences.

A similar situation exists in mathematics, where the same range of counts for measuring specialism indicates large shortfalls of mathematics specialists working in English primary schools. For instance, the number of in-service practitioners with a degree and an initial teacher training qualification in mathematics represents approximately 2% of all primary teachers in England (cf. Table 4.2).

While, then, it is clear from Table 4.3[53] that science and mathematics subject specialists are too low in number for the needs of all English primary schools to be satisfactorily covered, the seriousness of the shortfall depends on the criteria chosen to measure it.[54] Indeed, if specialism is denoted by the requirement to hold both a first degree and an initial teacher training qualification in the subject, then it is clear that science and mathematics specialists represent only 3% and 2%, respectively, of the total numbers of primary teachers in England (Figure 4.1).

Historically, the most common route into primary teaching has been via a BEd degree, and although some BEd courses offer specialist subject modules in science or mathematics, these specialisms are not reported in the GTCE's register. Whether or not this matters depends on how broadly or narrowly 'specialism' is defined at this level. This is an issue that requires urgent clarification.

Notwithstanding the need to resolve definitions of 'specialist' (eg on the strength of degree and postgraduate training qualifications), the issue of defining a specialist has become complicated by the introduction of the Mathematics Specialist Teacher (MaST) primary programme (*viz*. Chapter 5), which is intended to create specialist mathematics teachers at Masters level by training current practitioners.

For now we must accept that the most detailed picture of science and mathematics subject specialism in the primary teaching workforce comes from a small, but vital, contingent of teachers who hold degrees and/or teaching qualifications in these subjects.

Recommendation 3

In the light of its intention to abolish the General Teaching Council for England, the Department for Education should commit to maintaining the register of teachers in England and clarify how it intends to do this. Together with the Training and Development Agency for Schools, and the science and mathematics

53 Alison Vale (Data Governance Team Leader, GTCE), personal communication, 10 March 2010.
54 See also Williams (2008).

communities, it should collaborate to resolve each of the issues below, and agree a strategy for improving the quality of records on subject specialists within primary and secondary teaching in England.

(i) Clarify the type(s) of qualifications that should be included in recognising subject 'specialism';

(ii) Categorise first degree course subjects for the purpose of identifying science or mathematics specialists;

(iii) Specify the requirements for specialism at different educational phases, from Key Stage 2 upwards.

Recommendation 4

The Department for Education should establish, with the support of the science and mathematics communities, a definition of 'specialist' (see Recommendation 3) that recognises that the criteria for identifying specialism will change from Key Stage to Key Stage. It should then formulate both a target for increasing the numbers of science 'specialist' teachers in English primary schools to ensure that every child has access to a high quality science education, and invest in strategies for achieving this. Given that there are currently more than 17,000 primary schools in England, and based on the identification of a 'specialist' used for Figure 4.1, there is potentially a need to triple the numbers of science 'specialists' in the primary teaching population. The Department should also develop with the Training and Development Agency for Schools a mechanism that enables specialism, and the development of expertise through teaching experience and subject-based and other CPD, to be tracked and recognised throughout a teacher's career.

Recommendation 5

The Department for Education and the Training and Development Agency for Schools should scope out a recruitment and retention programme specifically for primary teachers with science and mathematics expertise. Initial teacher training departments should strengthen their connections with science, mathematics and engineering departments in higher education institutions in order to raise awareness of teaching among students taking STEM degrees.

4.4.5 Data on support staff in England

The DCSF published limited non-specific information on support staff in schools and, with the exception of its consideration of technicians (not all of which are laboratory technicians), did not distinguish between staff in nursery and primary schools. Table 4.4 shows the latest recorded data on the numbers of teaching assistants, higher level teaching assistants and technicians in maintained nursery and primary schools in England (excluding Academies). It shows that the period from 1997 to 2001 witnessed a near-doubling in the numbers of teaching assistants, and that while higher level teaching assistants (HLTAs) were recorded separately from 2006, following their introduction in 2004, these numbers practically doubled again during 2002–2009. In the four years that data on HLTAs have been recorded separately, the numbers of these support staff have more than doubled. A similar doubling in the overall number of technicians has occurred since 2004.

However, these data give no indication of the numbers of teaching assistants and HLTAs with backgrounds in science and mathematics, and the Department has stated categorically that: 'Teaching assistant and HLTA figures are not available broken down by subject'.[55]

However, the TDA does maintain records on the numbers of HLTAs, figures for which are reproduced in Table 4.5. These figures are notable because they indicate that less than 10% of HLTAs in maintained primary schools in England have specialist backgrounds in science or mathematics, and they are important because HLTAs may be responsible for taking whole-class science lessons.[56]

4.5 The primary teaching workforce in grant-aided schools in Northern Ireland

Responsibility for maintaining records of Northern Ireland's teaching workforce falls to the GTCNI which, since it began registering teachers on 1 April 2004, now holds data for some 27,000 teachers on its register. The Council currently neither registers teachers according to phase or subject specialism, nor does it hold any data on subject taught or Key Stage, although it is planning to start collecting the latter in the near future.[57]

Nonetheless, in 2008 the GTCNI undertook to investigate the numbers of teachers on its register that hold one or more STEM teaching qualifications, or other academic STEM qualifications in which the main subject was broken down into the following categories: biology, chemistry, physics, other science, mathematics, technology, engineering.

In all 26,902 registered teacher records covering 110 categories of STEM qualifications were examined in the analysis, and Table 4.6 includes data from the final report, which was produced in September 2008. From this, it is immediately clear, or calculable, that:

(i) the community of registered, contracted STEM teachers accounts for a small fraction (just 14%, or 10% if considering science and mathematics alone) of all teachers registered in Northern Ireland;

(ii) only 23% of registered, contracted STEM specialists are working in primary schools, and the numbers of physics specialists working in this sector is negligible;

55 Richard Howe (School Workforce and Finance Unit, DCSF), personal communication, 7 August 2009.
56 Liz Lawrence (Chair, ASE Primary Committee), personal communication, 12 April 2010.
57 Helen Jackson (Registration Manager, GTCNI), personal communication, 23 September 2009.

Table 4.4. Numbers (in thousands) of full-time equivalent teaching assistants and technicians in maintained nursery and primary schools in England (1997, 2001–2009).

	1997	2001	2002	2003	2004	2005	2006	2007	2008	2009
Teaching assistants[(a)]	24.3	41.5	44.9	55.3	62.1	70.6	71.4	77.6	86.5	90.0
Higher level teaching assistants[(b)]	–	–	–	–	–	–	3.7	6.1	7.9	9.3
Technicians	–	–	0.6	0.9	1.1	1.3	1.5	1.6	1.7	1.8

Source: DCSF, SFR 23/09 (29 September 2009), table 16.

(a) Includes higher level teaching assistants, nursery nurses, nursery assistants, literacy and numeracy support staff and any other non-teaching staff regularly employed to support teachers in the classroom except for special needs and minority ethnic pupils support staff.

(b) Includes laboratory assistants, design technology assistants, home economics and craft technicians and IT technicians, and excludes technicians in nursery schools and pupil referral units.

Table 4.5. Numbers of higher level teaching assistants in maintained primary and secondary schools in England as at end April 2009.[(a)]

	Primary	Secondary	Other	Grand total
Science	53	558	24	635
Mathematics	609	926	48	1,583
Total	662	1,484	72	2,218

Source: TDA (Martin Dore, personal communication, 6 July 2009).

(a) Data were first recorded in January 2005.

(iii) male STEM specialist teachers in primary schools account for just 15% of all STEM specialist teachers in this sector.

Clearly, a snapshot such as this cannot offer any indication of how the population of STEM teachers in primary schools has changed over time, nor is it possible to gain any precise information on the age range of primary science and mathematics teachers in Northern Ireland, although it is worth mentioning that within this analysis, the collated data on STEM teachers (ie avoiding double-counting) indicated that more than half are aged under 40.

4.6 The primary teaching workforce in publicly funded schools in Scotland

Data on the teaching workforce in Scotland are collected by the General Teaching Council for Scotland (GTCS) and the Scottish Government.

4.6.1 GTCS data

The GTCS does not record the specialisms of the 47,000 or so primary teachers on its register, nor is it able to distinguish specialism among early secondary (S1–S3) teachers. Further, the register does not enable distinction to be made between teachers in employment and teachers not in employment.[58]

4.6.2 Scottish Government data

The Scottish Government conducts an annual census of Scotland's teaching workforce each September, an activity that it has undertaken consistently since 2003. Separate surveys are conducted of teachers in publicly funded and independent primary and secondary schools, and the results are published on the Scottish Government's website. Included in the collections are data on 'main subject taught' by teachers and 'other subject taught', which appear to provide survey-based indications of the prevalence of subject specialism within the teaching workforce.

The published reports of these censuses do not show the number of primary school teachers in publicly funded schools whose main degree subject is either science or mathematics, rather they indicate those teachers who have professed that they primarily teach biology, chemistry, physics, science or mathematics (Scottish Government (Table 4.7)). These would appear to indicate that only a tiny fraction of the primary teaching workforce in Scotland may be represented by teachers holding degrees in science and mathematics. The number of primary teachers possessing degrees in mathematics and the sciences is likely to be higher than that indicated judged by the number currently following PGDE courses across the Scottish universities. There are also some curious oscillations from year to year as in mathematics where the numbers were 0 (2005), 18 (2006) and 4 (2007).These data need to be viewed with caution. It is possible that some teachers may have misinterpreted the question in the survey, confusing 'main degree subject qualification' with 'main subject taught'.

There are other specialist teachers that are centrally employed by local authorities in Scotland rather than by individual schools, eg as visiting specialists of music, art or PE, who will only teach their specialist subject

58 John Adams (Teacher Registration Manager, GTCS), personal communication, 26 November 2009.

Table 4.6. Total numbers of registered STEM teachers in Northern Ireland.[a]

	Total nos. of subject-specialists registered	No. of STEM specialists registered that are contracted (temporary/ permanent)	No. of contracted subject specialists as a percentage of all teachers registered	Number of contracted (permanent/ temporary) registered teachers in primary schools		Percentage of subject specialists in primary schools as a percentage of registered, contracted STEM specialists
				Male	Female	
Biology	729	628	2.3	11	125	21.7
Chemistry	429	386	1.4	4	32	9.3
Physics	213	188	0.7	0	4	2.1
Other science	1,005	736	2.7	43	222	36.0
Mathematics	1,058	852	3.2	28	183	24.8
Technology	921	753	2.8	36	154	25.2
Engineering	140	122	0.5	5	2	5.7
Total	4,495	3,665	13.6	127	722	–
Total no. of teachers on register						26,902

Source: GTCNI.

(a) Some teachers are counted twice. If double-counted entries are removed, then the total count of STEM specialist teachers registered in the analysis numbers 3,151.

Table 4.7. Total numbers of teachers identified by 'main subject taught' in publicly funded primary schools in Scotland (2003–2008).

	2003	2004	2005	2006	2007	2008
Art and Design[a]	60	60	57	76	78	80
Music[a]	108	108	86	113	112	98
Physical Education[a]	142	142	117	160	159	147
Biology[b]	1	3	3	2	3	1
Chemistry[b]	0	0	0	0	1	0
Physics[b]	5	2	2	1	1	0
Science (general)[b]	3	14	9	13	11	10
Mathematics[b]	0	2	0	18	4	3
Total no. of teachers (all subjects)[c]	22,321	22,577	22,859	23,486	23,540	23,171
No. of schools[d]	2,248	2,217	2,194	2,184	2,168	2,153
Total no. of pupils (stages P1–P7)[d]	406,015	398,100	390,260	382,783	375,946	370,839

(a) Scottish Government, *Teachers in Scotland 2004, 2006, 2007*; Statistical Bulletin Edn/B1/2009/2, table 2.8, published 27 November 2009.

(b) Scottish Government (Kasia Bejtka, personal communication, 13 August 2009).

(c) Scottish Government, Statistical Bulletin Edn/B1/2009/2, table 2.1, published 24 March 2009.

(d) Scottish Government, Statistical Bulletin Edn/B1/2009/1, table 2.1, published 24 February 2009.

disciplines. However, no data are collected on the sector in which they work.

As is the case across the UK, primary teachers in Scotland are required to teach all subjects in the curriculum, so apart from specialists in the expressive arts and PE, there are unlikely to be any other 'specialists' as such. There would be value in collecting and recording accurately the numbers and distribution of subject specialists both with the teacher education institutes and within the existing primary workforce.

Recommendation 6

Given the Department for Education's intention to abolish the General Teaching Council for England, it is important that it should work with the General Teaching Councils for Northern Ireland, Wales, and with the General Teaching Council for Scotland, on a coordinated approach to recording and maintaining consistent and accurate records of the specialisms of teachers on their registers.

4.7 Recruitment of primary teachers across the UK

There are various undergraduate, postgraduate and employment-based routes into teaching (see Table A4.1). However, available data in respect of recruitment into science and mathematics teacher training courses at primary level are limited, reflecting the generalist perception of primary teaching. In Scotland, undergraduates following a four year BEd course gain little exposure to science, and no recognition is given to prior (eg Highers in sciences) qualifications.

Moreover, the data that are available show that, notwithstanding the aforementioned difficulties of defining what a 'specialist' is at primary level, the supply of science and mathematics 'specialists' (in the broadest interpretation of the term) is poor. For instance, data on recruitment to undergraduate primary-related initial teacher training courses for England show that very few take specialist science and mathematics options. Table 4.8 shows how many first year undergraduates were enrolled in Key Stage 2/3 courses in science and primary initial teacher training courses in England. It demonstrates that overall recruitment to these courses has been poor, and indeed has worsened over time, though it must be acknowledged that recruitment to Key Stage 2/3 courses in these subjects is higher than for some other subjects.

Data from the Graduate Teacher Training Registry (GTTR), the subsidiary of the Universities and Colleges Admissions Service (UCAS) that processes applications for full- and part-time teacher training courses for most providers in England, Scotland and Wales,[59] show that obtaining a full picture of entry into postgraduate primary teacher training courses is complicated by:

(i) the fact that candidates in England may apply for primary courses (generally enabling teaching of children aged 3–11; or aged 3–12 in Scotland) or middle years courses (enabling teaching children aged 7–14) developed for teaching in middle schools,[60] which are deemed either primary or secondary. This means that data on applications and acceptances to initial teacher training courses covering primary teaching also include a small number of individuals studying Key Stage 2/3 courses, an unquantifiable proportion of which will opt, at least in the first place, to become secondary school teachers;

(ii) no data are published by the GTTR on the subject specialist backgrounds of those applying and being accepted for PGCE primary or middle years age range courses, although a small number of courses exist for 'primary specialised subjects'. This means that it is impossible to identify specialism within GTTR figures concerning recruitment to these particular courses;

(iii) some data on specialism within primary may be obtained from the TDA's performance profiles, though these data only relate to undergraduate and postgraduate recruitment to teacher training among providers in England.

Table A4.2 documents the numbers of graduates gaining acceptance to primary PGCE/PGDE and middle years age range PGCE courses across the UK since 1998. It shows that overall acceptances on these courses rose steadily from 1998 to 2005, but have since fallen by 4.5%. However, similar to the situation regarding recruitment onto undergraduate courses, the numbers being accepted onto middle years age range PGCE courses have been falling steadily since 2003. It is possible that this situation may be a response to local authorities dispensing with middle schools in favour of operating a two-, rather than a three-tier education system.

Table A4.3 shows the total number of acceptances to subject specialist primary and middle years age range courses. The data suggest that the number of specialised subject primary PGCE/PGDE course acceptances as a percentage of all primary PGCE/PGDE course acceptances has been falling from a peak of 13.3% in 2002, with the proportion of acceptances to PRS courses increasing in respect of the other types of primary PGCE courses available. This situation contrasts with that of specialised subject middle years age range PGCE courses, which have consistently accounted for over 90% of all acceptances to middle years age range courses since 2000, and may be

59 The GTTR does not process PGCE applications to providers in Northern Ireland, the University of the West of Scotland (formerly the University of Paisley), the Open University and some school-centred initial teacher training (SCITT) centres.

60 Middle schools were a recommendation of the 1967 Plowden Report, which advocated a three-tier schooling structure including first schools (for 5–8 year olds), middle schools (for 8–12 year olds) and secondary schools. Middle school numbers increased reaching a peak of over 1,400 by 1983, but the introduction of the National Curriculum, with set Key Stages appealed to the old primary/secondary model and subsequently the numbers of middle schools have fallen steadily and now number less than 300.

Table 4.8. Numbers of first year undergraduates on Key Stage 2/3 science and mathematics courses compared with the total numbers of undergraduates taking Key Stage 2/3 courses and primary courses (TDA profiles 1998–2009).

	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Science (KS2/3)	110	106	99	73	60	73	50	36	48	47	38	52
Mathematics (KS2/3)	55	82	51	49	42	39	26	22	34	33	31	46
All KS2/3 courses	316	467	497	434	317	328	243	224	275	244	230	244
Primary	7,432	6,933	6,497	6,197	6,537	6,268	6,421	6,517	6,889	7,043	6,808	6,527

Source: TDA, see http://dataprovision.tda.gov.uk/public/page.htm?to-page=publicDownloadTheProfiles

connected with a greater need for specialism at Key Stage 3, as teaching about 'science' becomes recognisably separated into what at Key Stage 4 become identified as biology, chemistry and physics.

In 2007 the Society reported figures from the TDA indicating few and falling numbers of STEM graduates entering primary PGCE courses since 2004, with these accounting for no more than 4% of the total of all graduates entering these courses (Royal Society 2007). Here we take a more detailed look at recruitment data on primary PGCE entrants in England, much of which is non-subject-specific.

Both the DCSF and the TDA provided summary information on the numbers recruited into primary teacher training in England. The TDA provides a breakdown of the broad subject specialisms only of those recruited into Key Stage 2/3 initial teacher training courses, but does not disaggregate similarly for the larger numbers that enter primary designated courses. These data are combined in Table A4.4. They show overall decreases in the numbers of science and mathematics first year undergraduates and postgraduates taking Key Stage 2/3 initial teacher training courses, and in the proportional representation of these subjects as a fraction of the total numbers being recruited into primary teacher training.

4.7.1 PGDE/PGCE (Scotland and Wales)

Tables A4.5 and A4.6 show separate data for acceptances to primary PGDE and primary PGCE courses in Scotland and Wales, respectively. In Scotland, there have been steady increases in the numbers of people accepted onto primary PGDE courses, there being a 50% leap in 2004 and a 59% increase since then. By contrast, Wales has experienced a 17% overall decrease in acceptances since 2000. These trends cannot be explained by simple changes to the number of providers in these nations, nor by the variety (or lack thereof in Scotland) of courses.

4.7.2 Completers (England only)

As has been pointed out previously (Royal Society 2007, 2008) recruitment onto initial teaching training courses does not equate with recruitment into teaching. Indeed, even after qualified teacher status (QTS) has been awarded, not all newly qualified teachers will take up teaching posts. Table 4.9 shows QTS awards among STEM graduates taking primary and KS2/3 teacher training courses. While total numbers gaining primary QTS have increased over recent years, the number of STEM graduates being awarded primary QTS has fallen overall. The total numbers of STEM graduates being awarded KS2/KS3 QTS are much smaller and have also fallen overall, but have risen as a proportion of the whole.

Table 4.10 shows equivalent data for STEM graduates gaining primary QTS by employment-based routes into primary teaching compared to all graduates gaining primary QTS by this route. It shows that while most STEM entrants successfully complete the course, their numbers have decreased both overall and as a proportion of the total number of successful completers.

4.8 Raising the requirements for entry into teaching, and the standards thereby

Both the numbers and supply of those with a 'specialist' background in science and mathematics make up a small percentage of the primary teaching community. Further, the high percentage of females in the primary teacher population (a situation that is reflected internationally), and the fact that teaching is no longer perceived as a lifelong career contribute to poor retention, with around 20% of primary teachers in England leaving the profession after three years (Politeia 2009). These problems are compounded by the fact that the teaching population is ageing.

Nonetheless, growing concerns about the quality of teaching, fuelled by doubts over the calibre of teachers hired to fill vacancies (especially in the secondary sector, and in relation to science, mathematics and other hard-to-fill subjects) have led to calls to raise the GCSE entry requirements for teacher training from a grade C to a grade B in English and mathematics (and, for primary teachers, science), and to raise the minimum qualifications for entry into a PGCE to a 2.2 (Williams 2008; Gove 2009; Politeia 2009) or even, eventually, to 'an upper second or above' (House of Commons 2010).

Table 4.9. Total numbers of STEM graduates being awarded QTS on primary and middle-age range PGCE courses (2004/05–2006/07).[(a)]

Academic year	Subject of first degree	Primary QTS awarded		Total gaining QTS	KS2/KS3 QTS awarded		Total gaining QTS
		Male	Female		Male	Female	
2004/05	STEM	299	1,621	1,920	30	97	127
	All	1,135	7,152	8,287	81	284	365
2005/06	STEM	282	1,623	1,905	24	61	85
	All	1,025	6,399	7,424	61	193	254
2006/07	STEM	266	1,482	1,748	33	73	106
	All	1,614	8,972	10,586	62	207	269

Source: TDA.

(a) Reliable data only available from 2004/05.

The House of Commons Select Committee on Children, Schools and Families determined that if the QTS tests are sufficiently 'robust', then there should be no need to raise the minimum GCSE entry requirements. However, it concluded that 'the Training and Development Agency's skills tests are not at present providing a sufficiently high hurdle in this regard' and, in inferring that they needed to be made more challenging, recommended that such tests 'should be made an entry requirement for initial teacher training, rather than an exit requirement, with a maximum of just two attempts at each test permitted' (House of Commons 2010, pp. 21–22).

These generalised assumptions about the basic intellectual abilities of people based on their qualifications need to be treated with caution for they do not necessarily reflect accurately an individual's *aptitude* for teaching, especially at the primary level where early years pedagogical skills may be of even more importance (Royal Society 2007). From the perspective of primary teaching, a 2.1 or 2.2 degree in history is not going to help with, or indicate to an initial teacher training provider, understanding of science or how to teach it. Moreover, raising the first degree requirement for PGCE entry would slash the supply of people into science and mathematics teacher training by about 50% (Royal Society 2007, p. 50). Raising the bar in this way would merely exacerbate recruitment problems and mean that some potentially good teachers with poorer degrees would be precluded from joining the profession. We cannot afford to do this.

Instead, while gate-keeping mechanisms for entry into teaching need to be robust, efforts to 'professionalise' teaching should focus on ensuring that both trainee and qualified science and mathematics specialists in primary and lower secondary teaching are able to, and do, develop

Table 4.10. Number of STEM graduates (by gender) compared to the total number of graduates taking up employment-based routes into primary teaching and the total number of STEM and other graduates completing employment-based routes into primary teaching.[(a)]

Academic year	Subject of first degree	Number awarded primary QTS by gender		Total gaining QTS by EBITT	Percentage of STEM entrants completing
		Male	Female		
2004/05	STEM	164	438	602	100
	All	573	2,326	2,899	n/a
2005/06	STEM	204	472	676	74
	All	617	2,543	3,160	n/a
2006/07	STEM	127	363	490	70
	All	443	2,244	2,687	n/a

Source: TDA.

(a) Reliable data only available from 2004/05.

their subject knowledge, pedagogical and leadership skills through quality assured opportunities for training and professional development. For instance, high quality Masters programmes with the correct blend of subject, cognitive and pedagogical knowledge and understanding would, in the long run, be a far more useful yardstick and a much more appropriate and meaningful way to, over time, raise the professional standards of the workforce. These and other forms of CPD are considered in the next chapter.

Inevitably, changes in teaching standards cannot be made overnight, and longer-term solutions will be more effective than swift changes in regulations. Nonetheless, decisive action is required.

4.9 Conclusions

Data on the UK's teaching workforce are held by different national organisations and in many cases (i) are not sufficiently detailed; (ii) and do not cohere across nations.

However specialism is to be defined at primary and secondary level, official data need to tag teaching specialism so that the density and distribution of specialists may be continually tracked throughout their teaching careers, as well as the phase(s) of education they are practising at.

Nonetheless, from the evidence that is available, there appear to be few professionals in the primary sector who have specialist training in science and mathematics subjects, reflecting the shortages seen in the secondary sector (Royal Society 2007). It is important to monitor more closely the variety of subject expertise among teachers teaching at these phases, both because of a lack of subject specialists in primary teaching and because subject specialists in secondary education tend to be deployed in teaching GCSE or A-level classes (Moor *et al*. 2006). It stands to reason that a clearer picture of the teaching workforce should inform future curriculum-planning processes, and that this will be crucial in ensuring that the good intentions behind curricular reform are successfully met.

Finally, while professional standards always need improving, this may better be done by ensuring high quality, tailored ITT and CPD provision rather than by raising the entry requirements to the profession, especially for those teachers who have excellent pedagogical abilities. Further evidence concerning this matter is required.

5 Subject-specific continuing professional development (CPD) for teachers of primary and early secondary science and mathematics

5.1 Introduction

Regardless of whether they work in primary or secondary schools, teachers must know what to teach and how to teach it. A governing principle of the profession is that teachers should continually seek to develop or update their professional skills and knowledge. If teachers are to inspire and enthuse their students about science and mathematics, they must have sufficient mastery of their subject. As was described in Chapter 2, right across the UK there have been substantial changes to curricula and assessment strategies in recent years, all of which have been geared to helping children become, in the sort of parlance favoured of late by the Rose Review[61] and Scottish Curriculum for Excellence, 'successful learners, confident individuals, effective contributors and responsible citizens'. This has increased pressure on teachers to continuously improve their knowledge and skills. In this chapter the focus is on teachers' access to subject-specific CPD in science and mathematics, which includes both subject knowledge and subject-specific pedagogical skills.

5.2 The range of subject-based CPD opportunities on offer in the UK

Subject-based CPD can be provided in various ways and varying contexts. All teachers continue to learn from their daily experiences. The concern here is with activities that are designed to improve subject understanding and pedagogical skills, even though they may appear informal and take place within the class or school, rather than a centre or institution providing formal courses. For example, such learning opportunities include:

- action research conducted individually or with colleagues;
- mentoring by a more experienced colleague or adviser;
- in-school formal or informal meetings and discussion groups;
- formal professional learning courses in groups;
- membership of professional subject associations;
- recognition through national awards, often associated with subject associations;
- giving and receiving information about practice at conferences and inter-school in-service meetings;
- external courses provided by local authorities, further education colleges, universities and private consultants;
- virtual contacts with colleagues and more formal courses presented partially or wholly on-line; and
- industry-based placements to reacquaint teachers with scientific research, enthusing and re-energising their teaching.

61 *Op. cit.*, note 12.

It is generally the case that no convenient repository of information on the whole diverse range of opportunities that are available for subject-specific CPD, or on their impact, exists. Indeed, data on some of those vehicles cited in the preceding list come from reporting of discrete research projects (NET/Sutton Trust 2009) or reviews of subject-based CPD provision (EPPI 2003; NCETM 2009). The following sections are concerned with exploring some of the key national programmes of work in this area, in respect of science and mathematics.

There is no established central record of the CPD activities of individual teachers, nor of the uptake of courses offered by universities, local authorities and independent providers. The main sources of data in this chapter come from the National Science Learning Centre (NSLC), which has a remit through the regional centres to provide CPD to teachers and support staff in England, and has itself a UK-wide remit for delivering provision, and the National Centre for Excellence in the Teaching of Mathematics (NCETM), which is remitted to providing CPD to teachers and support staff in England, although practitioners across the UK may benefit from certain aspects of the CPD it offers. Neither is able to give a truly comprehensive view of participation in CPD across the nation as it is extremely difficult to collect these data. This is a natural consequence of a semi-decentralised model of CPD provision being operated: the NSLC is able to provide information on courses run through the Science Learning Centres, but not elsewhere. The NSLC and NCETM have provided us with their own measures of national participation in science and mathematics CPD activities, but it should be noted that number of hours spent on courses is a crude measure of CPD activity in the context of the description of CPD given above, as it quantifies only one form of activity. Moreover, it tells us nothing about the impact of this investment on pupils and other teachers. These unknowns should be borne in mind throughout this chapter when interpreting the data.

5.3 Science and mathematics-based CPD programmes in England

5.3.1 Science-specific CPD

With joint funding from the Wellcome Trust and the (then) DfES, a network of Science Learning Centres (SLCs) was established from 2005 onwards to provide CPD for primary, secondary and college teachers and support staff involved in science education in England. The NSLC, which is based at the University of York, is funded by the Wellcome Trust to provide CPD for teachers and support staff across the UK. It collaborates with agencies in Northern Ireland, Scotland and Wales, to enable its courses to be delivered UK-wide, and it leads the network of nine regional centres funded by the DCSF, one in each Government Office Region, providing locally based CPD. The majority of science CPD for primary and secondary teachers is provided through the Science Learning Centre (SLC) network, with a minority of courses being offered by subject associations, higher education institutions, local authorities, independent consultants and companies. The only records of actual training days attended in England are those kept by the NSLC. These records include numbers of training days at each centre broken down by categories of staff and the subject of the training. The data were provided for the year April 2008 to March 2009.

5.3.1.1 Training days provided by Science Learning Centres in England

A total of 4,717 training days were provided for primary school teachers and 4,670 for Key Stage 3 teachers in secondary schools. For the purposes of calculating percentage uptake within a region, it was assumed that all of the primary schools accessing a regional centre are from within that region. Table 5.1 shows how these percentages vary across the regional centres and between primary and secondary schools. This table shows that take up of CPD was much greater and less variable among secondary than primary schools/staff. The greater take up among secondary schools reflects the priorities of the regional centres as determined by the (then) DCSF.

Training days for primary teachers in England formed 30% of all days provided. Those for Key Stage 3 teachers formed another 24% of the total provision (see Figure 5.1).

A small percentage of primary schools across England has taken up professional development through the Science Learning Centre network, reflecting the extent of primary professional development currently available through the network. There is potential for increased capacity in provision of primary CPD through the Science Learning Centres. The introduction of the Primary Science Quality Mark (PSM) may also fuel further demand for CPD in primary science (*viz.* § 5.7.2).

5.3.1.2 Attendance on courses

Table 5.2 provides an indication of the numbers of different types of staff who attended CPD days for primary and early secondary schooling at the national and regional SLCs during 2008/09. These data need to be viewed with a certain caution as it is not possible to tell from them the extent of any double-counting that may have arisen as a result of the same individual(s) being recorded as participating in more than one activity.

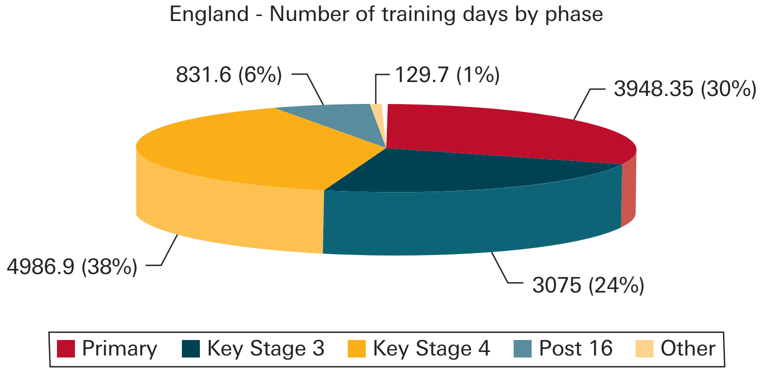
Table 5.1. Number of training days provided by Science Learning Centres and uptake in English Government Office Regions (2008/09).

	Primary schools			Secondary schools		
	Days of training	Number of primary schools per region	% take up of training by primary schools across each region[a]	Days of training for Key Stage 3	Number of secondary schools per region	% take up of training by secondary schools across each region[a]
National Centre	768.5			1,594.5		
North East	397.1	896	21.7	324.0	196	82.9
South East	171.0	2,632	6.3	337.0	484	71.6
West Midlands	315.0	1,806	9.8	82.5	386	69.5
Yorkshire & Humberside	633.5	1,843	19.1	397.0	307	72.1
London	576.5	1,804	12.9	564.0	383	71.2
South West	495.1	1,906	24.9	479.0	317	73.2
East Midlands	326.1	1,660	13.4	165.8	292	69.8
East of England	670.6	2,022	25.9	241.7	413	68.9
North West	363.5	2,498	15.4	483.0	450	72.6

Source: National Science Learning Centre.

(a) These percentages have been calculated by averaging the percentage take up of schools in each local authority within a particular region.

Figure 5.1. Number of training days by phase (2008/09).



Source: National Science Learning Centre.

From Table 5.2, it is possible to calculate that across all the SLCs, 23% of those attending CPD days for primary schools were science coordinators. Class teachers made up 69% and learning support teachers a further 1%. Less than 1% of those attending primary courses were secondary teachers, while about 2.5% of those attending early secondary CPD days were from primary schools.

Table 5.2 shows that the East of England stood out as providing more CPD days for coordinators than other SLCs (*viz*. § 5.7). In comparison with the other SLCs, in both the Yorkshire and Humberside and London SLCs particularly high numbers of classroom teachers undertook training. The National Centre provided 16% of all CPD training days for primary teachers.

A similar pattern is seen in the Key Stage 3 take up, where the National Centre, East of England and London SLCs provided more days for heads of science departments than other centres. The National Centre also provided four times as many days for secondary science teachers as any regional centre. In total, the National Centre provided just over one-third of all training days at Key Stage 3.

5.3.1.3 Themes of the training

The training days were categorised under the themes shown in Table 5.3, which shows the differences between the provisions of regional centres as a whole and the national centre in York.

At both primary and secondary level it is clear that the NSLC focuses on leadership and management to a far greater extent than the regional centres. For primary schools, 20% of days provided by the NSLC were concerned with management, while only 1.5% of regional centre courses had this theme. This corresponds with the high proportion of days attended by science coordinators, shown in Table 5.2. The general 'primary' theme was the focus of 64% of NSLC training days and 86% of regional centre days at primary level.

For Key Stage 3 there is a similar pattern of attention to management and, in contrast with primary provision, to assessment and new initiatives. This may possibly be explained by the implementation in September 2008 of a new Key Stage 3 curriculum in science, while the review of the primary curriculum was only in its early stages.

5.3.2 Mathematics-specific CPD

Two national programmes of mathematics-specific CPD have been operating in England in recent years. Since they began operating in 1998, the National Strategies have been charged with raising 'standards of achievement and rates of progression for children and young people'. In respect of mathematics, various CPD resources have been rolled out, apparently to varying effect. In its most recent assessment of their impact, based on meetings with 12 local authorities and subsequent visits to 33 primary schools and 21 secondary schools within these same authorities, Ofsted found that these were, without exception, 'considered to have the potential to add value to school improvement work and were often recognised as being of high quality', albeit that more often than not tension was reported 'between a national agenda driven by the National Strategies and local need'. Significantly, in just under half of the 54 schools inspected, a mixed pattern of effects of the Strategy consultants and Strategy materials on achievement and standards was found, although it was noted that too rushed introduction of new initiatives had reduced the potential for consultants and the material to positively influence standards (Ofsted 2010).

The National Strategies will be abolished next year, with responsibility for improvement support being devolved to schools. Although the (previous) Government has promised that 'the legacy of high-quality programmes and guidance continues to be accessible', it remains to be seen if this will happen (DCSF 2009a). Inevitably, the responsibility for ensuring an effective national CPD mathematics provision exists will therefore rest almost entirely with the National Centre for Excellence in the Teaching of Mathematics (NCETM), which was established with DCSF funding in 2006.

Table 5.2. Training day attendance in England by different categories of staff (2008/09).

	Primary CPD days attended by different categories of staff					Key Stage 3 CPD days attended by different categories of staff				
	Co-ordinators	Teachers	Support staff	Secondary teachers	Other	Head of science	Primary teacher	Support staff	Secondary teachers	Other
National Centre	375.0	103.5	20	156	114	113	0	0	1,477.0	4.5
North East	29.0	360.6	7	0	0.5	14	0	121	189.0	0
South East	0	163.0	0	8	0	42	0	88	207.0	0
West Midlands	0	315.0	0	0	0	0	0	19	63.0	0.5
Yorkshire & Humberside	11.0	622.5	0	0	0	60	21	57	259.0	0
London	10.0	564.5	2	0	0	84	30	85	365.0	0
South West	155.5	305.6	34	0	0	76	0	37	357.0	9
East Midlands	215.6	110.5	0	0	0	17	0	41	107.8	0
East of England	251.5	394.1	6	8	11	92	44	0	105.7	0
North West	36.0	311.5	9	0	7	26	26	35	396.0	0
Totals	1,083.6	3,250.7	78	172	132.5	524	121	483	3,526.5	14

Source: National Science Learning Centre.

Table 5.3. Themes of CPD days provided by the National Science Learning Centre and the regional centres (2008/09).

	Primary		Key Stage 3	
	NSLC	Regional centres	NSLC	Regional centres
Contemporary science	0	0.5	10	3
Developing ICT	35.0	0	0	32
Enriching learning	70.0	200.0	302	790.7
How science works	0	5.0	0	204
Leadership and management	153.0	59.5	322	2
New initiatives in the curriculum	0	56.0	300.5	348
Practical work	0	21	27.5	135
Primary	490.5	3,397.9	0	121
Science for non-specialists	0	0	227.5	563
Supporting science teaching	20.0	76.5	0	389
Teaching, learning & assessment	0	100	405	218.8
Other	0	32.0	0	180.5
Totals	768.5	3,948.4	1,594.5	2,987

Source: National Science Learning Centre.

The NCETM was formed after the national network of Science Learning Centres and according to a different model that focused on co-ordinating, as opposed to providing, mathematics CPD through an online portal.

The primary aim of the National Centre is to ensure that all learners of mathematics receive an increasingly high standard of teaching by supporting the CPD of teachers of mathematics. The NCETM provides teachers with information about opportunities to attend regional and national events that are designed to stimulate the uptake of further CPD opportunities and encourage a continuous process of reflection on a teacher's professional development.

It aims to achieve this through a national infrastructure and tools, online through its portal and face-to-face, which together enable teachers of mathematics to develop their pedagogy, to collaborate and to share good practice. The NCETM offers free CPD support for teachers at any point in their career, within and across all phases of education, from early years to post-16. It does not espouse one model of CPD, but rather promotes effective practice relevant to the local situation based on evidence or research.

The NCETM provides a national standard, a quality holder for mathematics CPD, and forms a unified focus for the mathematics teaching community. Its success depends on coordination and its partnerships with stakeholder organisations to audit and fill gaps in provision.

5.3.2.1 The nature of mathematics CPD provision: standards and directories[62]

In mathematics most CPD courses are offered by local authorities or independent providers. As a result, while each type of provider has applied its own quality control assurance, there has been no national commonly agreed professional standard by which the different courses are measurable. This seems to be changing now, as the NCETM has developed a standard for CPD to help mathematics staff and their institutions access information about the appropriateness and quality of the CPD provision on offer. For the CPD providers a commitment to such a standard will enable them to gain access to a wider audience of CPD participants via the NCETM portal (www.ncetm.org.uk/cpdstandard). The total number of providers deemed to have met the required standard is expected to reach 40 by summer 2010.

The NCETM provides teachers looking for mathematics CPD with a directory of courses available across the nation. The Professional Development Directory (www.ncetm.org.uk/cpd/professional-development-directory) currently contains 1,206 courses from almost 700 providers.

62 Data included in this section and in the subsequent section were provided by Tim Stirrup (Director for Communications, NCETM) on 24 March 2010.

Table 5.4. Breakdown of the number of CPD activities organised by the National Centre for Excellence in the Teaching of Mathematics being undertaken by type of teacher and region (October 2009 to February 2010).

	Primary	Secondary	FE	Any[(a)]	Total[(b)]	Primary (%)
National	0	0	0	0	231	unknown
East of England	256	82	25	28	391	65.5%
East Midlands	180	77	0	0	257	70.0%
London	826	356	125	43	1,350	61.2%
North East	135	166	21	0	322	41.9%
North West	671	299	107	32	1,109	60.5%
South East	10	200	28	0	238	4.2%
South West	53	254	0	49	356	14.9%
West Midlands	469	222	17	72	780	60.1%
Yorkshire & Humber	428	294	59	19	800	53.5%
Totals	3,028	1,950	382	243	5,834	51.9%

Source: NCETM.

(a) The 'Any' category relates only to the February 2010 data.

(b) The 'Total' column will not always be the sum of the categories, for instance if an attendee could not be classified.

5.3.2.2 Quantifying participation in mathematics CPD

One of the best measures of teacher engagement with the NCETM across the nation is through the number of registered users. At 17 March 2010, 15,836 primary teachers were registered, equivalent to around 8% of all primary teachers (cf. Figure 4.1). There were 13,964 registered secondary users, from a teacher population of 29,500 at 3,367 schools. In total over 40,000 individuals have registered with the portal so far; the total using the self-evaluation tools is approaching 10,000 and the number using the personal learning space exceeds 5,000.

Since September 2006, the NCETM has awarded (not including regional funding) over 172 grants (now called funded projects) ranging in value from £1,500 to £25,000 in eight rounds of applications. This includes 22 new Teacher Enquiry Funded Projects (TEFPs) awarded on 15 March 2010.

Fifty-six Mathematics Knowledge Networks (MKNs) ended in February 2010, with the next round due to be awarded in summer 2010. Each project comprises a group of teachers who work collaboratively on their chosen theme, reporting the outcomes of their project on the NCETM's portal and at its events.

5.3.2.3 NCETM events to stimulate uptake of CPD

In the 12 months to February 2010, 9,267 teachers from primary, secondary and further education attended events that encourage further CPD, from 4,603 institutions. For the five months from October 2009 to February 2010, the totals may be broken down by region and phase, (Table 5.4).

5.3.2.4. The Mathematics Specialist Teacher (MaST) primary programme

The Mathematics Specialist Teacher (MaST) primary programme was established in 2009 following the Williams Primary Mathematics Review of 2008,[63] which in turn built on an Advisory Committee on Mathematics Education (ACME) recommendation of 2006 that:

'. . . the DfES, the TDA and the NCETM work together to ensure that, wherever possible, each primary school has at least one teacher who is enthusiastic about mathematics and knowledgeable about the teaching and learning of mathematics (and can enthuse and inspire others), and prioritises support for any teacher who wishes to develop his/her subject knowledge as part of improving the quality of his/her teaching of mathematics'.[64]

The MaST programme has created a unique partnership between local authorities and higher education institutions. It represents a national commitment by the Department to offer a comprehensive CPD programme available to all primary teachers in maintained schools that is geared to helping participants enhance their knowledge, skills and understanding of mathematics and related pedagogical issues. The programme's aim is to create a crop of highly

63 In June 2008, in response to recommendations from the Williams Review, the Secretary of State for Children, Schools and Families (DCSF) allocated £187million over ten years to pay for 13,000 mathematics specialists, aiming for every English primary school to have access to a 'maths champion'—an outstanding teacher who would also mentor and coach colleagues. DCSF (2008), Independent Review of Mathematics Teaching in Early Years Settings and Primary Schools Final Report and http://www.acme-uk.org/page.asp?id=112 .

64 See http://www.acme-uk.org/downloaddoc.asp?id=38, accessed 12 April 2010.

skilled and effective practitioners who will help to drive up pupil attainment and progression in mathematics and create within their local communities a much more positive attitude towards mathematics among pupils and their parents or guardians.

It represents an ambitious attempt to overturn a deeply ingrained pervasive culture in society that 'it's OK to be bad at mathematics'. More fundamentally, though, it has tremendous potential to up-skill the primary teaching workforce, and is a model for long-term planning and improvement that, with due quality assurance, will need to be sustained in the long-term. The programme is currently being evaluated by the Department and, with the first cohort of MaST participants due to graduate in July 2010, it is too early to assess its success. Nonetheless, despite some teething problems and concerns about guaranteed long-term funding, there seem to be good grounds for optimism.[65]

5.3.3 UK-wide CPD offered by the National Science Learning Centre (NSLC) and regional Science Learning Centres

Teachers in Northern Ireland, Scotland and Wales are able to access courses at the NSLC, and those from maintained schools and colleges may apply for an ENTHUSE award, which the NSLC makes available to teachers attending its courses and that cover the cost of the course fees, supply cover, travel, accommodation and subsistence. In addition, the NSLC undertakes outreach work, running certain courses outside England.

5.3.4 Other forms of science and mathematics CPD in England: provision for non-specialists in early secondary schooling

The Training and Development Agency (TDA) for Schools' remit includes an obligation to review the quality and supply of CPD. The TDA has established a national CPD database on its portal that provides details of CPD opportunities available for teachers and support staff in England. While the providers listed on the database need to have met the terms of the TDA's code of practice, the TDA does not endorse any of the activities on offer.

In addition, following a two year pilot, the TDA has rolled out nationally its own programmes to support non-specialist secondary teachers of mathematics, physics and chemistry.

65 '. . . there has been an enormous amount of enthusiasm for the national MaST programme from teachers . . . I receive regular email enquiries via the NCETM microsite about the programme mainly from teachers from sectors that are not included such as special schools and independent schools who are disappointed not to be able to join the programme. I think the important thing to note here is that this really is the first of its kind.' Laurie Jacques (Director for Policy and Quality, NCETM, personal communication), 11 February 2010.

The Science Additional Specialism Programme (SASP) is available for secondary science teachers. Those teaching physics or chemistry but without a physics or chemistry degree or a secondary ITT specialism in these subjects, can attend a 40-day course that aims to develop their subject knowledge and pedagogical skills in these disciplines. Courses are provided at five universities and six Regional Science Learning Centres. According to the Science and Expert Learning Group: 'Early evidence from TDA suggests that courses that train non-specialists, such as the Science Additional Specialism Programme (SASP), have a positive impact on raising the quality of learning and teaching in STEM subjects' (DBIS 2010, p. 29).

The particular problem of mathematics being taught by non-mathematicians in secondary schools is being addressed by the Mathematics Development Programme for Teachers (MDPT). This enables those teaching mathematics in secondary schools, but not having a degree or initial teacher training (ITT) specialism in mathematics, to undertake training, free of charge. The 40-day course begins in the summer and extends throughout the following school year, with supply cover provided by the TDA. The course offers academic accreditation at honours level, with the option of taking some Masters level credits. After piloting in three regions during 2007–2009, it is now available across England through ten universities and one independent company.

Finally in respect of science, it is worth mentioning the Royal Society of Chemistry's 'Chemistry for Non-Specialists' programme, which is a three year funded programme of courses designed to increase the expertise and confidence of non-specialists teaching chemistry in UK (predominantly English) secondary schools at Key Stage 3 and/or Key Stage 4, and run through the network of Science Learning Centres.[66] An evaluation conducted by the NFER in 2008 indicated 'strong evidence' of the programme's success in meeting its aims, with positive 'knock-on' effects in respect of pupils' enjoyment and understanding of, and interest in, chemistry (Jones *et al.* 2008).

5.4 Science and mathematics-based CPD programmes in Northern Ireland

While subject-specific CPD in science has decreased over the last five years as a result of a greater emphasis on the Northern Ireland Revised Curriculum and whole school issues, there has been a high level of interaction between Heads of Science and Mathematics and the Advisory Officers. Indeed the CPD for mathematics teachers has increased significantly and CPD for science teachers and Primary World Around Us coordinators is now steadily increasing due to additional funding from the Regional Strategic STEM Group.

66 The programme was launched in 2007 and is jointly funded by the Royal Society of Chemistry, GlaxoSmithKline and the DCSF.

The CPD offered across Northern Ireland specifically in science includes:

- revised curriculum training in science focusing on developing pupils' thinking skills and active engagement in practical investigations;
- Heads of Science training;
- ICT in science with emphasis on data logging and Interactive whiteboard training;
- Four days' training for Beginning Teachers;
- health and safety courses (in collaboration with CLEAPSS);
- technician courses organised by the Interboard Science Technicians' Group in association with ASE Technicians section and CLEAPSS;
- current CPD courses in association with the NSLC York;
- Chemistry for Non-Chemistry Specialists in association with the Royal Society of Chemistry; and
- Heads of Science conferences held intermittently across the five Education and Library Boards.

Other CPD opportunities are facilitated by the Queen's University Belfast and the University of Ulster. The Association for Science Education organises CPD opportunities for primary and post-primary teachers, as do the Institute of Physics and the Royal Society of Chemistry. Under STEM regional funding primary and post-primary teachers have received support to attend the ASE's annual meetings. The number of CPD opportunities available to teachers has increased in the last two years as a result of collaboration between the Advisory Services and the National Science Learning Centre in York. Teachers can apply for ENTHUSE bursaries to travel to York for a course or apply to attend one of several courses sponsored by the NSLC and delivered in Northern Ireland. The recent commissioning of 'STEM Module', an extendable, articulated truck equipped with state-of-the-art science and technology equipment to deliver high quality courses to pupils in 17 STEM specialist schools across the north of Ireland, has been used to provide INSET to 'Science and Technology and Design' teachers. This resource, funded by the Departments of Education and Enterprise, Trade and Investment, is in great demand by schools beyond the STEM specialist schools.

Since the establishment of the Education and Skills Authority has been delayed indefinitely, there is an essential need for all stakeholders in the provision of CPD to STEM teachers to produce a coordinated plan for professional development of teachers in these areas. Recommendation 14 of the STEM Review clearly highlights the issue (DENI/DELNI 2009). Other recommendations state the need for increased focus on Key Stage 2/3 progression and the promotion of STEM subjects from an early age. The goal must be to have a seamless progression in science and technology from early years to post-16 level with an increasing knowledge and understanding of potential STEM careers interwoven into the learning and teaching. As a result of the STEM Review there exists a willingness and enthusiasm across all the education sectors and industry to promote science and technology whenever and wherever possible, and this groundswell of support for STEM should be used as a launching pad for future development in the area.

5.5 Science and mathematics-based CPD programmes in Scotland

In Scotland, where there is a contractual requirement to undertake 35 hours of CPD per year, CPD for science teachers and technicians is provided through a project 'Support for Science Education in Scotland through CPD'. Funded by the Scottish Government and managed by the Scottish Schools Equipment Research Centre (SSERC) the project supports the implementation of the new Curriculum for Excellence. Initially funded for the period June 2007 to March 2008, the project was then extended until 2011. The CPD for primary and secondary teachers, curriculum leaders, technicians, probationary teachers and students on PGDE courses, is provided by SSERC and its partners in the project. These partners include the ASE in Scotland, the Faculties of Education of six universities, the Institute of Physics, the Royal Society of Chemistry, Science and Plants for Schools and the Scottish Technicians Advisory Group. Uptake of courses is reported in the next section. As well as working with a wide range of partners, the SSERC also employs seconded teachers to devise innovative practical work for primary and secondary schools. These teachers, who have recent classroom experience, are viewed as having high credibility by attendees at SSERC courses.

5.5.1 Training days for science education in Scotland

Table 5.5 gives the number of training days provided by the 'Support for Science Education in Scotland through CPD' project for 2007/08 and 2008/09 for different categories of staff. Not included in the table are conferences such as the annual ASE Scotland conference for all concerned with science education and a special conference for CPD providers. Courses for curriculum leaders were run in association with the NSLC at York.

Given the 2,153 primary and 376 secondary schools in Scotland, the proportion of schools taking up two-part residential courses is small. However, without a breakdown of those taking part in non-residential courses, it is not possible to arrive at a figure of national take-up. SSERC reported that all courses were heavily over-subscribed and it will require an increase in capacity to satisfy demand.

The project evaluation commissioned by SSERC was started in early 2009 by researchers at the Scottish Centre for Research in Education (SCRE) at the University of

Table 5.5. Numbers attending and training days provided in different courses provided by the Support for Science Education in Scotland through CPD project.

Course	2007/08		2008/09	
	Nos. attending	Training days	Nos. attending	Training days
Two-part residential for secondary sciences	87	348	79	474
Two-part residential for primary sciences	70	280	51	306
Two-part residential for curriculum leaders	31	108	28	98
2 day residential for probationer secondary teachers			19	48
Non-residential (half or whole day) for teachers and technicians	965	736	766	381
SQA accredited courses for technicians	189		189	
2 day residential for PGDE secondary student teachers	178	356	223	446

Source: SSERC.

Glasgow.[67] Overall, the findings indicated that the CPD had had a substantial impact on many participants and had been translated into changes in the practice of many teachers and technicians. Almost all teachers reported that they had introduced or tried new materials and resources and 64% reported trying new methods of teaching as a result. Phase 2 of the project will concentrate on following up teachers who participated in SSERC CPD over the period 2008–2010.

In 2005, HMIE produced a report on *Improving achievement in science* (HMIE 2005), in which it was recommended that the Scottish Executive should 'establish a sustainable national mechanism to deliver high quality professional updating to all teachers of science to allow them to keep up to date with developments in their subjects' (HMIE 2005, p. 38). Unlike England, Scotland has no national or regional science learning centre, and SSERC currently does not have the capacity to meet the demand for CPD that is coming from teachers and technicians.

No similar project exists for mathematics but Learning and Teaching Scotland produces materials and videos to support the implementation of all subjects in the Curriculum for Excellence. The Scottish Mathematical Council runs annual conferences and a journal which both cater to some extent for mathematics teachers.

5.5.2 Chartered Teacher status

In 2002 the General Teaching Council Scotland established Chartered Teacher status to provide opportunities for experienced teachers to extend and revitalise their knowledge, understanding and skills. The award of Chartered Teachers status is a Masters-level qualification intended to show recognition of teaching expertise, and awardees are expected to contribute to the development of other teachers' professional development. The award may be conferred upon teachers in primary, secondary or special schools. Recently, it was announced that the 1,000th Chartered Teacher had been awarded.[68]

5.6 Science and mathematics-based CPD programmes in Wales

The Welsh Assembly Government has decided to cut the General Teaching Council of Wales' (GTCW) CPD grants programme entirely from 2010/2011 onwards after nine years of funding commitment. These grants to individual primary and secondary school teachers have specifically excluded subject-based research/content development, but a trawl of the projects undertaken indicates the following numbers which have included science or mathematics in their titles (see Table 5.6).

The Welsh Assembly Government is currently reviewing the model and the way it funds CPD for Welsh teachers. In the meantime, discussions have been ongoing between the Department for Children, Education, Lifelong Learning and Skills (DCELLS) and the National Science Learning Centre regarding accessing funding for development and delivery of CPD courses in Wales, taking account of the local colour of the Welsh national curriculum. In addition, Techniquest, the NSLC and DCELLS have been establishing a programme of CPD.

67 See http://www.science3-18.org/images/CPD2009/SSERC_Eval_interim_rep_Sept09_v3_merged.pdf http://www.gla.ac.uk/faculties/education/aboutus/

68 See http://www.gtcs.org.uk/News/1000-chartered-teachers-celebrated.aspx, accessed 25 March 2010. This is not the same as chartered status as recognised of professions by the Privy Council.

Table 5.6. Numbers of CPD grants in science and mathematics awarded by the GTCW (2004 to 2009).

Science	School type				
Year	Primary	Secondary	Other	Subject total	Total number of grants funded
Phase 4 (2004–2005)	72	70	3	145	3,124
Phase 5 (2005–2006)	61	90	9	160	3,136
Phase 6 (2006–2007)	54	134	5	193	3,701
Phase 7 (2007–2008)	57	170	5	232	4,560
Phase 8 (2008–2009)	45	136	1	182	3,700
Mathematics	**School type**				
Year	**Primary**	**Secondary**	**Other**	**Subject total**	**Total number of grants funded**
Phase 4 (2004–2005)	64	30	4	98	3,124
Phase 5 (2005–2006)	58	50	5	113	3,136
Phase 6 (2006–2007)	86	81	4	171	3,701
Phase 7 (2007–2008)	79	79	4	162	4,560
Phase 8 (2008–2009)	93	90	2	185	3,700

Source: GTCW.

5.7 CPD opportunities and recognition offered by professional subject associations

5.7.1 Opportunities

As mentioned in § 5.2, subject associations are an important source of bespoke CPD resources and initiatives for practitioners and offer a form of membership to schools or teachers. Yet the relative attention given to CPD for primary teachers—as opposed to secondary teachers—is low amongst many of the professional bodies. For instance, both the Institute of Physics and the Royal Society of Chemistry provide a range of workshops or other hands-on CPD training activities for teachers, but while a number of these benefit Key Stage 3 teachers, none is aimed at Key Stage 1 or Key Stage 2 teachers.[69,70]

This situation may well reflect these organisations' membership profiles, which in turn will have developed according to the varying types and foci of their activities. A complicating factor in understanding the apparent bias towards secondary teacher CPD provision is the fact that physics, chemistry and biology are grouped under the generic heading of 'science' in primary and early secondary education. Moreover, primary teachers have to teach all subjects and cannot afford membership of each and every subject association. Understandably, their expenditure priorities will normally be registration with the relevant General Teaching Council and teachers' union(s).

This, perhaps, best explains low primary, when compared to secondary, membership of the Association for Science Education, which is the UK's largest science association dedicated to the teaching of science and, by definition, has interests and activities that spread across biology, chemistry and physics.

In order to shed some more light on this issue, an analysis of the primary school and primary teacher memberships of the Association for Science Education was undertaken for this study. This found that approximately 560 primary schools across the UK are members of the Association for Science Education,[71] which represents but a tiny fraction of the 21,568 primary schools in the UK (DCSF 2009b, table 1.1). Similarly, analysis of the Association for Science Education's individual membership (see Table 5.7) also revealed that the numbers of primary teacher members is very low compared with the GTCE's estimate of the numbers of teachers in England who hold specialist science qualifications (cf. Chapter 4), that the average age of members exceeds 40 in all Government Office Regions and that the membership is very strongly female-biased.

While these characteristics of the individual membership somewhat reflect the situation nationally,[72] it is concerning that apparently so few primary teachers with specialist

69 Charles Tracy (Head of Education Pre-19, Institute of Physics), personal communication, 18 March 2010.

70 Amanda Middleton (Project Manager, Chemistry for Non-Specialists, Royal Society of Chemistry), personal communication, 16 March 2010.

71 Sharon Rolland (Manager, Registration and Accreditation, ASE), personal communication, 25 November 2009.

72 Provisional estimates suggest that in 2008 (the latest year for which information were available) 87% of nursery and primary classroom teachers in England are female, 42% of whom are aged 40 or over (DCSF 2009*b*, tables D2 and D4).

Table 5.7. Breakdown of the Association for Science Education's individual primary membership by gender, age and region.[(a)]

UK Government Office Region	No. of primary teachers recorded	Average age (rounded up)	Males[(b)]	Females[(c)]	% Males	Doctorate-holding members
East Midlands	67	46[1]	11	52	16	4
East of England	115	46[2]	21	89	18	5
London	98	42[3]	15	79	15	4
North East	39	44[4]	3	34	8	2
North West	128	47[5]	19	100	15	9
South East	193	45[6]	28	160	15	5
South West	89	47[7]	17	63	19	9
West Midlands	79	44[8]	20	59	25	0
Yorkshire and the Humber	78	49[9]	12	61	15	5
Northern Ireland	14	55[10]	1	9	7	4
Scotland	26	48[11]	1	24	4	1
Wales	39	47[12]	8	26	21	5
Grand total	965		156	756		

Source: ASE.

(a) Data show current membership as at 19 October 2009.

(b),(c) These data exclude a small number of members that hold doctorates and whose gender could not be identified from the information provided. Their number is included in the right-hand-most column.

Notes:

[1]Based on 52 out of 67 records (78%); [2]Based on 76 out of 115 records (66%); [3]Based on 51 out of 98 records (52%). [4]Based on 23 out of 39 records (59%); [5]Based on 79 out of 128 records (62%); [6]Based on 133 out of 193 records (69%); [7]Based on 61 out of 89 records (69%); [8]Based on 48 out of 79 records (61%); [9]Based on 52 out of 78 records (67%); [10]Based on 11 out of 14 records (79%); [11]Based on 22 out of 26 records (85%); [12]Based on 27 out of 39 records (69%).

subject expertise in science belong to their subject association and are availing themselves of the benefits (such as the unique and valuable CPD resources on offer and potential for recognition and career advancement) that such membership affords. The picture may look even worse in other subjects.

5.7.2 Professional recognition accredited by the science and mathematics communities

5.7.2.1 Primary Science Quality Mark

In order to help boost the quality of science teaching and learning in primary schools in England, the Association for Science Education (ASE), the National Science Learning Centre and Barnet Local Authority have collaborated to sponsor a Primary Science Quality Mark across England, which schools may be awarded subject to successfully completing a programme of compulsory training and mentoring. Following a successful two year pilot, the ASE has been awarded £200,000 by the Wellcome Trust to support the national rollout of the award scheme. The scheme, now being disseminated across England, was initially piloted through the East of England SLC and the London Borough of Barnet, which had the highest uptake of primary CPD days in the London area.

5.7.2.2 Chartered Teacher status

Chartered Science Teacher status (CSciTeach) and Chartered Mathematics Teacher status (CMathTeach) are new schemes that have been introduced to help raise the profile of and respect for science and mathematics teachers, promote high quality science and mathematics teaching and learning, recognise professional expertise and evidence a firm commitment to CPD.

Chartered Science Teacher status is available to primary and secondary teachers who are members of the ASE and normally have a minimum of four years' post-qualification science teaching experience. It is conferred by the ASE under licence from the Science Council.

Chartered Mathematics Teacher status may also be conferred on teachers in primary, secondary and tertiary education, and the designation is awarded by the Association of Teachers of Mathematics, the Institute for Mathematics and its Applications, the Mathematical

Association and the National Association for Numeracy and Mathematics in Colleges.

Recommendation 7
The Institute of Physics, the Royal Society of Chemistry and the Society of Biology should explore with the National Science Learning Centre and others in the science community the development of a cross-disciplinary 'science for non-specialists' course for Key Stage 2/3 teachers and higher-level teaching assistants.

Recommendation 8
Subject associations and professional bodies should continue to ensure they provide suitable opportunities and incentives for primary schools and/or teachers to become members or affiliates, in order to drive up exposure to science and mathematics CPD opportunities provided by these organisations and others.

Recommendation 9
In considering the impact on progression and attitudes of early educational experiences, subject associations and professional bodies should review the balance of their CPD provision with a view to having an increased focus on primary education.

5.8 CPD and professional qualifications

Since the Society reported on CPD opportunities for teachers in its first 'state of the nation' report (Royal Society 2007), momentum has been growing to 'professionalise' teaching. Heavily influenced by the situation in Finland, where teaching is a Masters-level profession, this is consistent with the growing pressure in certain quarters (highlighted in Chapter 4) to raise the bar in terms of the minimum qualifications that must be held by trainee teachers.

The Masters in Teaching and Learning (MTL) is a fully Government-funded programme initially designed to help newly qualified teachers (NQTs) continue to hone their practical classroom management, subject knowledge and leadership skills as they embark on their professional teaching careers and, through undertaking research, gain Masters credits. The first cohort will be starting the MTL programme in April 2010, and it is hoped that by the time the seed-funding runs out in 2012, the MTL will have proved its worth and that in time all teachers will aspire to gaining the MTL.

The MTL has the potential to integrate CPD into the fabric of the teaching profession as never before, but concerns have been raised that the content of the programme lacks focus on the essential subject-specific knowledge and that, with initial teacher training failing to provide this sufficiently, the MTL may not serve one of its key purposes.[73] Equally, the future of other Masters programmes, such as the Postgraduate Professional Development (PPD) programme, which are reported to have been successful, is unclear (Noble-Rogers 2010).

5.9 The licence to teach

In its last White Paper on education, the previous Government advanced the notion of introducing a 'licence to teach' in order to drive up the quality of teaching and to raise the status of the teaching profession (DCSF 2009a). The plans for the licence appeared vague, but it seemed the licence would be linked to an 'entitlement' for professional development, that it would need to be renewed at regular intervals to ensure that teachers are fulfilling their obligations under its terms, and that it could be revoked. It would appear that at least one of the teachers' unions objects to the 'licence' on principle, the concerns being that that 'teachers are angry about the imposition of a cogs and wheels approach to improvement' and that any such licence 'must not be a substitute for a professional development strategy' (Bangs 2010). The idea of the 'licence' could represent an opportunity to overcome the historical reticence of schools and some teachers, perhaps caused by the pressures of high-stakes testing, to take advantage of the myriad CPD opportunities that exist. However, careful consideration would need to be given to working out how initiatives such as the MTL and CSciTeach/CMathTeach would all work within such a 'licence'. However, were it to be properly established, the licence should help engender a sea change in attitudes towards professional development that would, by turns, boost the numbers of science and mathematics teacher, and school membership, of organisations such as the ASE, the Mathematical Association and the Association of Teachers of Mathematics.

5.10 'Rarely cover': an obstacle to maximising CPD uptake

In an important change to the original 2004 National Agreement on Raising Standards and Tackling Workload, the Workforce Agreement Monitoring Group (WAMG), whose membership comprises teachers' unions, the former DCSF and the Welsh Assembly Government determined that from 1 September 2009 the 38 hour annual limit on the amount of cover that teachers could undertake would be scrapped and that teachers should only 'rarely cover' for absent colleagues, and in unforeseen circumstances. While the object of the reform was to reduce teachers' workload, it appears that it has had the highly undesirable effect of reducing the opportunities teachers have to attend CPD events and organise out-of-classroom educational activities for their pupils.

73 These concerns were particularly expressed in a letter of 8 February 2010 from the Advisory Committee on Mathematics Education to the Chair of the TDA, see http://www.acme-uk.org/downloaddoc.asp?id=186, accessed 28 February 2010.

Although hard to quantify, the effect of 'rarely cover' appears to have very negative unintended consequences, leading teachers to abandon undertaking the very sort of outside-the-classroom activities championed by Government in its eponymous 2006 Manifesto.[74] The National Science Learning Centre and the National Centre for Excellence in the Teaching of Mathematics reported fall-offs in attendance and enquiries of 25% and 50%, respectively, in the first six months following implementation of the new policy.[75] The Royal Society of Chemistry has also reported a 'significant drop' in numbers for its Chemistry for Non-Specialists courses.[76]

Anecdotal evidence suggests that the problem with 'rarely cover' lies not so much with the policy itself, but with schools' understanding and interpretation of it.[77]

5.11 Conclusions

The increasing focus on providing high-quality CPD, and the recognition that, like medical practitioners, teachers must be obliged to continually update and develop their subject knowledge and pedagogical skills, is very welcome and must be sustained. It is clear, though, that while many new initiatives are happening, little is being done to coordinate these, and inadequate attention is being paid to the needs of primary teachers.

However, there are three particular concerns about CPD resourcing, as follows.

(i) Measuring the true impact of CPD provision is very hard to do, as many of its benefits are intangible or hard to quantify. Ultimately, however, returns on investment in education are most often measured in terms of pupil attainment and progression. There is, therefore, a need to invest in longitudinal studies to determine whether a clear positive correlation can be identified between CPD provision and pupil attainment and progression.

(ii) There are significant problems with teacher retention (cf. Chapter 4). However, CPD should not be seen as a 'silver bullet' that will resolve this problem. Rather, the initial impact of an effective national CPD strategy should be to drive out those who are less committed and less passionate about teaching, and to encourage those who have the talent and the enthusiasm to succeed as teachers to join and remain in it.

(iii) When assessed objectively, the need to develop mathematics 'specialists' at Masters-level in England is a practical response (a) to there being too few people with a relevant academic background opting to train to teach in primary education; and (b) initial teacher training courses generally being too short to equip trainees with adequate levels of subject-based knowledge, cognitive and pedagogical skills. Assuming that in the current and foreseeable economic climate, there is no scope for undergraduate and postgraduate training routes to be lengthened, the only other way to increase the number of specialists is through high quality provision of subject-specific CPD. The recommendations that follow recognise action needs in the present time. However, a strategic review of initial teacher training, such as that being undertaken currently in Scotland, is required.[78]

Recommendation 10

The National Science Learning Centre (NSLC), regional science centres and the National Centre for Excellence in the Teaching of Mathematics must be allowed to continue their important work in supporting the drive to improve professional standards through subject-specific CPD. For this to happen, continued Government investment will be needed when current funding arrangements end in 2011. In addition, the NSLC's remit needs to be modified to enable a greater focus on providing primary teachers and teaching assistants with CPD in science.

Recommendation 11

The Scottish Government should also consider providing funding beyond 2011 in order to allow the Scottish Schools Equipment Research Centre and its partner agencies to deliver high quality CPD to primary and secondary teachers.

74 See www.lotc.org.uk, accessed 12 April 2010.
75 See http://www.tes.co.uk/article.aspx?storycode=6036325, accessed 12 April 2010.
76 Amanda Middleton (Project Manager, Chemistry for Non-Specialists), personal communication, 16 March 2010.
77 ACME (unpublished survey).
78 Royal Society (2010), CASE (2010). Graham Donaldson, former chief inspector of schools, has embarked on a review of teacher education and CPD in Scotland and is due to report in autumn 2010.

6 Factors affecting attainment in 5–14 science and mathematics

6.1 Introduction

Following consideration of school-workforce-related issues, this chapter examines some key factors that may influence pupils' attainment and engagement in mathematics and science education within and beyond the classroom. It begins by examining the principal issues that need to be considered for 5–14 provision in science and mathematics from the perspective of research on learning within the field of developmental psychology. Any attempt to improve the effectiveness of education must look at the characteristics of children as learners, and how learning processes are affected by the nature of different forms of educational provision and infrastructure. What happens in the classroom is, however, only a part of children's experience and their attainment and progress in science and mathematics are affected by a variety of factors outside the classroom and school including their individual and family characteristics, access to high-quality pre-school education, and participation in informal learning activities.[79] Attitudes to science and mathematics education, considered in the final main section, are often thought to be both a result of children's experiences and a factor in determining their willingness to engage in relevant activities. Some evidence is considered of the relationship between attitudes and attainment and how the attitudes of primary and lower secondary pupils to mathematics and science change as pupils progress through school, though these areas require further research.

6.2 Children's individual characteristics

Characteristics such as gender, ethnicity, birth weight, having English as an additional language, or special educational needs, can all correlate with attainment and progress at school. A recent report by the National Equality Panel (Hills *et al.* 2010), looking at gender and ethnicity among other factors, found that girls generally perform better at school than boys (cf. Chapter 3, this report); Pakistani, Black Caribbean and Black African boys, and traveller and gypsy children of both sexes have lower than average attainment at age 16 compared with other ethnicities. Boys in the category White British with lower than average GCSEs are less likely to progress to higher education than ethnic minorities with equivalent scores. The EPPE (3–11) project (Melhuish *et al.* 2006a) investigated progress of children in English, science and mathematics between Key Stage1 and Key Stage 2 in English primary schools, and found similar gender and ethnicity effects, although some were subject specific. For example, boys progressed more in mathematics than girls, and Caribbean boys progressed less well than White boys; in science, Chinese children progressed more than White children. These findings are consistent with data on GCSE and post-GCSE attainment (Royal Society 2008). In addition, the EPPE (3–11) project (Melhuish *et al.* 2006a) showed that being younger in the school year (ie summer born), or having English as an additional language, correlated with greater progress between Key Stage 1 and Key Stage 2; and having special educational needs unsurprisingly correlated with poorer progress. Many of these characteristics are compounded by social class, as measured by parental education, parental occupation, eligibility for free school meals or deprivation indices related to postcode. Data suggest that in mathematics the differences between the attainment of children with different social backgrounds is of the order of a year's development (Brown *et al.* 2003).

However, taking into account all these different background characteristics does not by any means explain the wide variation in children's attainment in mathematics. Brown *et al.* (2008) suggested that there is a gap of at least five years between the age at which a child at the 95th percentile understands a mathematical idea and the age when the same idea is understood by a child at the fifth percentile.

6.3 Classroom factors

6.3.1 The curriculum as a conceptual organisation of learning experiences

Learning in science and mathematics can be regarded as comprising three elements: knowledge of definitions, facts and procedures; understanding of concepts; and competence with scientific and mathematical processes. However, these aspects are not distinct; eg, procedures are easier to recall when there is a firm conceptual basis for them; and processes such as induction also depend critically on conceptual knowledge. Although much current teaching practice emphasises the learning of facts and procedures, conceptual understanding lies at the core of scientific and mathematical understanding (Wellington & Osborne 2001; Nardi & Steward 2003; Ofsted 2008; Cowan & Saxton 2010; Dowker & Sigley 2010; Nunes *et al.* 2010). Development of conceptual understanding is a key component in the overall cognitive development of children (Piaget 1974; Mareschal *et al.* 2009). However, often with the guidance of parents and others, children have already begun to form concepts about the world around them well before they enter school, through observing regularities in experience and inferring causality from noticing that some effects follow from action or change, whether initiated by themselves or other people. Some intuitive concepts are in conflict with scientific principles and teachers need to be aware of ideas that pupils bring to the classroom so that they can help pupils

79 There are various characteristics of 'informal learning', see http://en.wikipedia.org/wiki/Informal_learning

to articulate and extend or revise them by 'testing' them against experience and conventional usage.

The development of explicit conceptual understanding is a gradual process, and there is evidence that during the primary years scientific concepts may develop at different rates in relation to different aspects of physical phenomena with little sign of formation of overall integrating concepts (Howe 1998). However, there is wide agreement that concrete experiences are organised with the help of language into generalisable concepts. In mathematics, perception of number and quantity slowly becomes organised into a consistent conceptual structure and while weaknesses in children's perceptual systems can lead to weaknesses in attainment (Price *et al.* 2007; Iuculano *et al.* 2008), there is evidence that supporting a conceptual understanding of mathematics can help overcome this barrier (Dowker & Sigley 2010).

A key part of the education process involves pupils, with guidance, being able to derive broadly applicable knowledge from specific experiences. Generalisation involves a widening of a particular concept, and as such, a change in the underlying structure of that concept. A related process involves the extension of the same concept to a new context. Both of these processes are assumed to take place during classroom learning; however, the mechanisms by which generalisation and re-contextualisation occur are neither well-researched nor understood. Curriculum structure proposes a logical sequence in which scientific and mathematical concepts should be learned; however, this is unlikely to map onto the most appropriate sequence or speed of coverage from the point of view of the learner's generalisation processes. When a move to provide children with more uniform learning experiences through a tightly specified framework of teaching in the National Numeracy Strategy was implemented, it resulted in a wider range of attainment than previously when teachers perceived that they had more freedom to adapt the curriculum for individuals or groups (Brown *et al.* 2003). Research suggests that children's ability to generalise science and mathematical concepts is aided by a greater degree of experience of the phenomenon, and more explicit use of language, especially more commonly used or generic terminology that helps to link experiences (Howe 1998; Reynolds 2010; Tolmie *et al.* 2010).

6.3.2 Use of language and other symbols

There are two main theories about the relationship between concepts and language. The Piagetian perspective is that concepts are constructed internally by the learner, who then acquires language to express them. The Vygotskian perspective is that learners construct ideas through attention being drawn to relationships by language used by others. Both these processes might apply at different times and in different circumstances, and research suggests that productive learning of scientific concepts occurs when the level of internal construction of the concept matches the external language or instruction used to describe it (Pines & West 1986; Philips & Tolmie 2007; Philips 2008).

In the classroom setting, matching the level of external instruction given by teachers to the existing internal concepts of the pupils is difficult because of the amount of individual variation present among pupils, both in terms of their existing concepts and their language ability. Data reveal a wider attainment gap between English and EAL (English as an Additional Language) pupils in science than in mathematics across Key Stages 1 and 2 (Sammons *et al.* 2006; DCSF 2009c,d), demonstrating the particular importance of good language skills for scientific learning. In mathematics, there is also a wide and growing divergence in rates of learning as children progress through primary school (Brown *et al.* 2008). Although mathematical attainment correlates quite strongly with English attainment in national tests, the causation behind the correlation is unclear; both require memory for symbols and derivation and use of patterns. Sensitive use of language can certainly encourage connections to be made between mathematical concepts children experience in everyday life and what they experience in the classroom (de Abreu 1995).

6.3.3 Effective pedagogy

There have been many changes in teaching methods that have been prescribed by the National Strategies and suggested by others in recent years, including direct interactive whole class teaching, three-part lessons, statements of lesson objectives and success criteria, etc. However, it is not clear that any of these factors on their own has raised standards. Brown *et al.* (2003) suggest that evidence points to changes in the curriculum rather than in pedagogy as producing the small rise in numeracy standards. Askew *et al.* (1997) showed that the form of teaching (whole class, group or individual) in mathematics made little difference. Rather, classes that made the highest gains were those of teachers who did not rely mainly either on pupils working out relationships and procedures for themselves, or on explaining and then teaching procedures, but who had a connected view of what they were teaching, and knowledge of different ways of teaching it, how pupils learn, and their own pupils' attainment. Literature reviews (Hattie 1999; Wiliam 2009) suggest that formative assessment and feedback and cognitive acceleration are among the most effective teaching approaches, with class size, setting, computer use, textbooks used, etc, having a very small effect in comparison.

Aspects of formative assessment have been incorporated into Assessment for Learning methods, including improving questioning, non-graded marking, sharing intentions and peer and self-assessment (Black *et al.* 2003; Hodgen & Wiliam 2006). However, the success of these strategies in turn depends on the connectedness of teachers' subject knowledge, and therefore on the quality of teaching.

Cognitive acceleration techniques have been used in the UK in schemes like Cognitive Acceleration in Science Education (CASE) and Cognitive Acceleration in Mathematics Education (CAME) and have been shown to raise standards (Shayer & Adey 2002). Philosophy in schools' projects has also been shown to be effective (Topping & Trickey 2007). All these programmes involve group discussion aiming at abstract and critical thinking.

Group work can help tackle some of the issues caused by individual variation in pupil abilities. This is because input of other group members is always likely to be closer to the current level of any individual than that which teachers can provide at a whole class level. Research demonstrates that collaborative group work improves scientific and mathematical conceptual understanding, providing there is a range of knowledge amongst the group members (Webb & Palincsar 1996; Howe & Tolmie 1998; Davenport & Howe 1999; Slavin *et al.* 2003). It is therefore encouraging that group work is most commonly used in these two areas of the primary curriculum (Christie *et al.* 2004), although in mathematics tasks set do not often encourage active discussion and collaboration.

Group work requires careful planning in order to be effective. It needs to be structured so that it has a clear set of goals, but be open enough to allow exploration of ideas. All individuals in the group should be involved in the decision-making processes that allow emerging ideas to be tested and refined (Howe & Tolmie 1998). In terms of group size, there is consensus that three to five pupils is the optimum number (Baines *et al.* 2008), although this requires teachers to manage and support a number of groups in parallel. Appropriately trained teaching assistants may be able to help facilitate this, although it should be noted that Blatchford *et al.* (2009) demonstrated that when all other variables were controlled, the greater the time spent by children with teaching assistants the lesser the gains in attainment made. The language used by teachers to assist group discussion is important in helping pupils' conceptual understanding (Webb 2009). See also § 6.5 on primary–secondary transfer.

6.3.4 Development of abstract and critical thinking

As children pass through primary school to early secondary school, there is an increased need for them to develop abstract and critical thinking. It is thought that children find critical thinking difficult because of problems disentangling the content of information from its source (Tversky & Kahneman 1974). There have been claims of a decline in some abstract scientific thinking abilities among pupils in early secondary school (Shayer *et al.* 2007; Shayer & Ginsburg 2009). There has generally been little change in mathematical thinking over the same period (Hodgen *et al.* 2009), but there appear now to be more students with a very weak performance. Group work has been proposed as an intervention that might aid development of critical thinking skills (McGuiness 1999; Kuhn & Udell 2003; Topping & Trickey 2007), but oral modes of communication can make separating content and source information more difficult than is the case with written texts (McGuiness 1999).

6.3.5 Use of ICT

Information and communication technologies (ICT) provide powerful tools for supporting learning in science and mathematics. They can be used for communication, data collection and analysis, information seeking, simulation of systems and solving mathematical problems (Hoyles & Lagrange 2010). Pupils in primary schools are familiar with the interactive white board (or smart board), tablet PCs or laptops, sensors, data loggers, digital microscopes and cameras. In secondary schools and some primary schools the use of technologies has dramatically changed the way in which students can capture evidence, find information from secondary sources, and display findings. It enables them to access museum collections from the classroom; it allows them to collect more data than before, over a longer timescale, through automated devices; and to communicate and exchange data with other pupils and scientists across the world (McFarlane & Sakellariou 2002).

However, what matters in learning is what sense students are making of these experiences; whether they can form effective links between new information and existing ideas as needed for the formation of more generalised concepts. Therefore there are warnings about the over-use of ICT to the exclusion of well-established teaching practices. While computer simulations may be useful in relation to dangerous or inaccessible processes or events, they can never replace real laboratory activity and field work in science. Similarly, communication through the written word via computers or mobile 'phones cannot replace the direct sharing of experience and ideas through talk, discussion and argumentation—although written communication may help promote critical thinking. If using computers means working alone, pupils are missing an important contribution to their understanding from their peers. Indeed there is some evidence that computers (Cuban 2002) and interactive whiteboards (Moss *et al.* 2007) do not generally result in a rise in pupil attainment. Finally, and most importantly, research emphasises the critical role of the teachers in, among other things, ensuring that the use of technologies 'adds value' to learning activities (Osborne & Hennessy 2003).

6.3.6 Teaching to the test

The high-stakes use of pupils' Key Stage test results for setting targets for schools and local authorities often means that teachers' focus is geared to getting their pupils through their end-of Key Stage tests, or early GCSE modules in Key Stage 3. This inevitably means that teaching becomes narrowly focused on achieving the required results, and that pupils tend to be drilled to make the grade, creating stress among teachers, pupils and parents alike. It has been tentatively estimated that teachers are spending the equivalent of a week of contact time and pupils about three weeks of learning time solely in practising and taking tests (Harlen 2007, p. 61).

However, despite all this preparation, the national results presented in Chapter 3 appear to suggest that while the pressures of high-stakes testing had a limited initial positive impact on measured achievement, improvements in the percentages of pupils reaching the expected Levels essentially stalled following the start of the new century. There is also some doubt as to whether part of these early rises was due to grade inflation (Tymms 2004). Stobart (2009) observes that through increased effort and expectations high-stakes testing has a tendency to generate short-term gains, but that these soon diminish as ways to 'play the system' are exploited to improve results, at the expense of teaching and learning. Familiarity with, and the pressures of, high-stakes testing would seem to breed contempt among teachers, while pupils' performance will improve through increasing familiarity with the test requirements rather than necessarily as a result of real improvements in learning (Green & Oates 2007).

In science, the effects of teaching to the test appear to have led to an artificially inflated estimation of the extent of pupils' knowledge and understanding of the subject. Although it appears that little research has been conducted to discern the extent (if any) to which the tests assess conceptual understanding of the subject knowledge rather than only factual knowledge, the NFER acknowledged to the House of Commons Children, Schools and Families Committee that scientific enquiry had been omitted from science tests and using and applying had been left out of the mathematics tests (House of Commons 2008, p. 21), aspects which are fundamental parts of these subjects. Indeed, there are many concerns over what is being taught and tested, that '. . . the demands of a test may measure something other than what the test claims to be measuring, eg a high level of reading difficulty in a mathematics test may mean it rewards skilled readers rather than skilled mathematicians (who may have difficulty understanding the questions)' (Stobart 2009, pp. 167–168), and that this narrowly focused teaching has a negative impact on children's all round education and career interests. In mathematics, the focus on teaching to the test has been credited with affecting pupils' test results, but at the cost of 'equipping them well enough mathematically for their futures' (Ofsted 2008, p. 4).

These points maybe helpful in understanding the paradox that is apparent between the national results and teachers' reported lack of knowledge and low confidence in teaching these subjects (cf. Chapter 3), which appears to be a UK-wide phenomenon (for a review, see Scottish Government 2008; Tymms *et al.* 2008). They may also help to explain why, across England, Northern Ireland and Wales, the percentages of pupils gaining Level 5 in Key Stage 3 science are much lower both than the percentages of pupils gaining Level 4 in science at Key Stage 2 and when compared with similar attainment across Key Stage 2/3 in English and mathematics.

Changes in testing policy, the varying nature of the subjects and the manner in which they have been assessed, how they are taught and the characteristics of those responsible for teaching them, may all have influenced, in ways that cannot easily be distinguished, the reported performance data. Notably, however, most of the Government's targets for England have never been reached (with the exception of science at Key Stage 2) and although it is unclear whether these were ever based on realistic expectations, their long-term effect has been to reduce confidence and breadth in teaching and learning, and made it more difficult to address the multiple aims that a primary education should perhaps have (Alexander 2010).

6.3.7 Nutrition

The findings of some initial research appear to indicate that there may be a correlation between healthy eating and attainment in science. In a report into the impact of the 'Jamie Oliver Feed Me Better' campaign, Belot & James (2009) compared performance in Key Stage 2 tests among pupils in Greenwich before and after the start of the campaign. Test score data showed that the campaign appeared to have led to the percentage of pupils reaching Level 5 (above the expected Level) in science increasing by three to eight percentage points (with a similar increase being measured among pupils gaining the expected Level in English). However, test scores did not increase among pupils eligible for free school meals, as might have been expected, indicating that more research is needed to establish the strength of any effect between nutrition and attainment.

6.4 Effects of school infrastructure

6.4.1 Impact of resources

Investment in school education has increased in real terms across the UK over the past decade, with spending on schools in England outstripping that elsewhere (Table 6.1).

A crucial question concerns the returns on this investment. While outcomes such as children's engagement and motivation for learning, understanding and perception of themselves, and their relationships with their peers, teachers and other adults are tremendously important, the most tangible way by which such returns may be assessed is through measuring improvements in pupils' attainment.

In England, the numbers of pupils taking Key Stage 1 tests decreased some 15% across all subjects, from around 627,000 to 533,000, the number of primary schools also fell 6%,[80] and class sizes also dropped. The observed

80 These figures are taken from comparing data for 2000/01 with equivalent data for 2008/09, published in: Education and training statistics for the United Kingdom, 2009 (Internet only), Table 1.1, see http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000891/index.shtml, accessed 16 February 2010. Unfortunately, no complete time-series data exist on school type.

Table 6.1. Comparative annualised average real growth rates in education spending, schools spending and schools spending per pupil.[(a)]

Period	Education (UK)	Schools (England)	Schools, per pupil (England)
Labour 1 (97–98 to 00–01)	3.8%	6.4%	7.7%
Labour 2 (00–01 to 04–05)	6.1%	7.0%	8.4%
Labour 3 (up to 06–07)	3.5%	3.5%	3.2%
Labour to date (97–98 to 06–07)	4.8%	6.0%	6.4%
CSR (07/08–10/11)	3.4%	2.9%	3.4%

Source: Sibieta *et al*. (2008).

(a) Spending on schools in England up to 2006–2007 includes extra expenditure undertaken by local authorities, whilst per-pupil spending relates only to central Government expenditure. Per-pupil spending also includes capital expenditure undertaken through the Private Finance Initiative, whilst schools' spending in England does not.

trends (cf. Chapter 3) show that attainment in science and mathematics, measured by teacher assessments at the national level, remained flat throughout this period. However, with the percentages of pupils achieving or exceeding the expected Level fluctuating between 89% and 91% in these subjects, and the need to take account of a range of possible mitigating factors, it is difficult to know the extent to which improvements in performance could realistically have been expected.

At Key Stage 2, though, claims have been made that increased investment does lead to improved attainment. For instance, from their study of English National Pupil Database records for 2001/02–2005/06, in which they compared 11 year olds' test scores to the scores they achieved in their Key Stage 1 tests when aged seven, Holmlund *et al.* (2008) found that there appeared to be 'a positive and significant influence of school expenditure on attainment at the end of Key Stage 2' and concluded that 'an increase of £1,000 in average expenditure per pupil would increase the number of people attaining the expected standard (Level 4) or above by 2.2, 2.0 and 0.7 percentage points in English, Maths and Science respectively'. However, these findings must be viewed with some scepticism since the largest rise in mathematics scores in national tests occurred in 1998/99 prior to the effects being felt of additional spending in primary schools. The fact that nearly all the spending on National Strategies occurred in numeracy and literacy and yet, although national test scores rose in all three subjects, they rose highest in science (cf. Figure 3.2), suggests that these rises may have been more to do with teaching to the test rather than to the resources put into schools. Similarly, at Key Stage 3, it has been found that resources have a small yet significant impact on pupil attainment in science and mathematics (but less impact on attainment in Key Stage 3 English) (Levačić *et al.* 2005).

These studies also indicate small, but significant, impacts of additional resourcing on attainment at Key Stages 2 and 3 are particularly evident among pupils from low-income families. This is encouraging given that it has been estimated, based on an analysis of data for 2006/07, that in England both primary and secondary schools may attract more than 70% extra funding per FSM-eligible pupil (Sibieta *et al.* 2008).

In addition, the Longitudinal Study of Young People in England showed that although it is not the case that social class and social disadvantage are sufficient to explain significantly poorer comparative performance by black Caribbean pupils in Key Stage 3 tests (cf. Chapter 3), nevertheless interventions, such as the Black Pupils' Achievement Programme, merit continued investment (Strand 2007).

6.4.2 Primary–secondary transfer

The specific difficulties associated with educating children in science and mathematics during the transfer from primary to secondary schooling are considered in Chapter 7 of this report. In the context of considering learning experiences to promote conceptual growth and generalisation, however, the structural changes at this point may make it difficult for pupils to make connections with their primary school science and mathematics.

The teaching of science changes in some fundamental ways, both in terms of the formal content of the curriculum, and in the manner in which it is taught. There is an expansion of use of terminology that may be unfamiliar to pupils and activities that are less contextualised than in primary science. The net result may be confusion, overreliance on rote learning or, indeed, demotivation (Gray 2009). Whilst the change may not be so abrupt in terms of content for mathematics the degree of conceptual challenge may be substantially increased for more able students who are likely to find themselves in top sets. While many primary schools now set for mathematics in the older age groups, the practice is almost universal in secondary schools.

Group work practices in science also alter at this juncture, with a tendency for them to be briefer and to be more focused on data collection, and less on discussion, and to be more closed in character (McGregor 2008). Secondary teachers are often more reluctant to make use of group work, on account of classroom control issues, and where this approach is taken, groups are typically smaller to help assure manageability (Topping *et al.* 2007). Recent research undertaken with secondary students in Scotland suggests that ability to develop effective work relationships in the science classroom may provide a buffering effect against dips in science attainment after transition from primary education (Thurston *et al.* 2010).

6.5 Extra-classroom factors

6.5.1 Characteristics of children's families

Family support can play an important role in counteracting the disadvantage faced by children who originate from families of low socioeconomic status, or who have special educational needs (Save the Children 2009). In the EPPE (3–11) project (Sylva *et al.* 2008), home learning environment (which is a measure of quality relating to the nature of learning activities undertaken in the home) and mother's highest level qualification were the two largest background factors influencing children's attainment at age 11. However at younger ages, the type of home learning environment parents provided for their children had a larger impact on their children's intellectual and social development than parents' occupation, qualifications or income (Sylva *et al.* 2004; Melhuish *et al.* 2006a,b, 2008; Sutton Trust 2010). The Growing up in Scotland project showed that the extent and range of activities children participated in before the age of 34 months (equivalent to a high quality home learning environment) affected their cognitive ability, and could also moderate the effect of coming from a disadvantaged household (Scottish Government 2009).

It is interesting to note that in terms of educational deprivation, the UK as a whole ranks between 7th and 17th in OECD countries, with 9% of children having fewer than 10 books in their home, and 20% not having access to six basic educational resources out of a list that includes a desk, a quiet place to study, a computer, a calculator, a dictionary, an Internet connection, school textbooks and educational software (UNICEF 2007). Social class and parental income are correlated with a lack of 'school readiness' of pre-school children, and inequality increases throughout the years of compulsory schooling (Hills *et al.* 2010). Free school meal eligibility, often used as an indicator of low socioeconomic status (ie low household income), has been shown to correlate with poorer progress between Key Stage 1 and Key Stage 2 (Melhuish *et al.* 2006a,b).

It has been recommended that extra educational support should be given to the poorest children to break the cycle of deprivation caused by the link between poor educational attainment of parents and severe child poverty. Notably, since January 2010, the Home Access programme, piloted in 2008/09, has begun to be rolled out to provide low income families in England with grants for the purchase of computers and access to the Internet.[81]

6.5.2 Access to effective pre-schools and primary schools

The quality of childcare available before children enter formal education impacts on their future educational wellbeing (UNICEF 2007). Attending a high quality pre-school has both intellectual and social developmental benefits for children, even when controlling for all other background characteristics (Sylva *et al.* 2004; Melhuish *et al.* 2006a,b, 2008). These benefits are evident throughout primary school up to Year 6. High quality pre-schools are those which have a balance of education and care, and whose staff have good knowledge of the curriculum and child learning and development. Attending a high quality pre-school can also counteract the negative or disadvantageous effects suffered by children who have English as an additional language, special educational needs, a poor home-learning environment or parents with few qualifications. However, for children with no or poor quality pre-school experiences, these disadvantages can also be counteracted by attending an effective primary school (Melhuish *et al.* 2006; Sammons *et al.* 2007). In Northern Ireland, children who attended pre-schools that rated highly on the provision of science made greater progress in numeracy at the end of Year 2 (Melhuish *et al.* 2006). Overall, the combination of attending a high quality pre-school and effective primary school could give an equivalent boost to children's attainment as having a high quality home learning environment or parents qualified to degree level or higher. Conversely, children who suffer from various forms of disadvantage and who do not have access to effective early learning and educational experiences may fall further behind their better-off peers in terms of their attainment.

The four Home Nations have policy measures in place to provide children with integrated education, childcare, health and family support.[82] In England, Scotland and Wales, all three and four year olds are guaranteed a free, part-time, pre-school place and some children in Northern Ireland are also eligible. Each Home Nation has developed a pre-school curriculum, in which science (in the form of knowledge and understanding of the world) and mathematics are explicitly mentioned.[83] The Sutton Trust recommends that this pre-school entitlement is supplemented by effective parenting programmes for the most disadvantaged families (Sutton Trust 2010).

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81 See www.becta.org.uk/homeaccess, accessed 10 June 2010.

82 England: Sure Start Children's Centres. Northern Ireland: Sure Start. Scotland: Sure Start Scotland. Wales: Cymorth—the Children and Youth Support Fund.

83 England: Early Years Foundation Stage. Northern Ireland: Curricular Guidance for Pre-School Education. Scotland: Early Level in the Curriculum for Excellence. Wales: Foundation Phase.

6.5.3 Access to informal learning opportunities

Learning takes place in a wide variety of places and not just in formal educational settings. Unstructured learning in science and mathematics can take place in the home, in science and discovery centres and museums, through TV and other media, in zoos, aquaria, botanical gardens, youth clubs and through participation in competitions and awards. Informal learning can also take place within science and mathematics lessons in school. In that these activities are voluntary, they are likely to be enjoyed by children and have the potential to influence their attainment and attitudes towards science and mathematics.

Evidence for informal learning raising aspirations, changing attitudes, increasing knowledge and skills or impacting attainment and progress is patchy. Informal learning opportunities may have immediate, short-term effects, such as a heightened enjoyment of the subject or the learning of new facts;[84] they can also have longer-term effects, such as a meeting with a role model inspiring a child to become a career scientist several years later.[85] Children's attitudes to science can be affected several months after a visit to a science centre (Jarvis & Pell 2005); museum visits can have a positive impact on pupil attainment (Watson *et al.* 2007); 'out of school hours' learning (which includes informal learning) correlated with better progress in mathematics at age 11 (Sylva *et al.* 2008); and teachers believe visits to science and discovery centres make science more enjoyable for pupils and increase their knowledge and understanding (Ecsite-uk 2008).[86] Teachers, parents, and children themselves all have influence over the degree to which children access and benefit from informal learning.

Access to a rich variety of informal learning opportunities can complement the benefits of good quality classroom teaching. Appropriately, across the UK, the new and revised curricula for science stress the importance of linking formal and informal learning (eg by encouraging a critical exploration of science in the media) and the value of providing pupils with opportunities to experience science outside the school environment.

The value of informal learning in science education was recognised in the 2006 House of Lords report (House of Lords 2006), which gave strong support to the importance of enriching science teaching through various methods, including the use of ICT and the use of science and discovery centres. The OECD also recognises the value of informal learning, but acknowledges that its impact is poorly understood, and therefore has commissioned research to investigate benefits of formal recognition of informal learning.[87] However, despite the availability of certain forms of informal learning opportunities in mathematics, eg NRICH,[88] there is a lack of inspiring mathematical displays in museums, nor is there a museum dedicated to mathematics in the UK.

Certain measures have been put in place to help coordinate and provide quality control over the large array of informal learning schemes within science and mathematics. These include the development of the Generic Learning Outcomes framework by the Museums, Libraries and Archives Council as a means to evaluate museums and science and discovery centres (MLA 2008); the use of a Quality Badge to kitemark informal learning activities, developed by the DCSF in partnership with the Council for Learning Outside the Classroom;[89] and the production of the online STEM Directories,[90] which collate and categorise the many informal learning schemes taking place across all four Home Nations.

6.6 The role of attitudes to science and mathematics

6.6.1 Meaning and measurement of attitudes

Attitudes are potentially important determinants of behaviour, describing the state of being prepared or predisposed to act in a certain way in relation to particular objects, persons or situations. In the context of science and mathematics they are made evident in the liking for, interest in and confidence in learning these subjects, though the attitudes that should be part of conducting science, eg open-mindedness, curiosity, persistence, are equally important. Attitudes are most often measured by the extent of self-reported agreement with written statements about liking or disliking specific activities, rather than through observation of behaviours which indicate certain dispositions. So there is some justified doubt about exactly what is being reported as 'attitude' towards science or mathematics, particularly as there is evidence that an affective response is not so much associated with the whole subject as with specific topics or activities within it, and is mediated by learners' concepts of themselves as someone who does (or does not) get on with those topics or subjects (Joffe & Foxman 1984; Russell *et al.* 1988; Martin 2010).

Nevertheless research into attitudes often reports on the subject as a whole even though this may be based on a small number of items variously concerned with liking, interest or perceived ability in the subject. The interpretation of research findings should take account of the particular form of statements to which pupils have been asked to respond and the instructions for responding.

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84 74% of school pupils attending the Royal Society's Summer Exhibition in 2009 said they agreed with the statement 'The exhibition has increased my interest in science.'

85 A survey of scientists for the Royal Society report *Taking a Leading Role*, showed that one-fifth of respondents claimed their career choice was influenced by a role model.

86 On 1 April 2009, Ecsite-uk became The Association for Science and Discovery Centres.

87 See http://www.oecd.org/document/25/0,3343,en_2649_39263238_37136921_1_1_1_1,00.html, accessed 10 June 2010.

88 See http://nrich.maths.org/public/, accessed 10 June 2010.

89 See http://www.lotcqualitybadge.org.uk/home, accessed 10 June 2010.

90 See http://www.stemdirectories.org.uk/, accessed 10 June 2010.

6.6.2 The relationship between attitudes and performance

Attention to attitudes may be prompted by an assumption that positive attitudes are associated with high attainment. Investigations of the relationship between attitudes and attainment are inevitably ones where associations are in the form of correlations rather than experimental manipulation of variables. A correlation cannot be taken as indicating cause and effect, although it can be used to propose an underlying model. In the case of attitudes to subject domains there are alternative explanatory models: positive attitudes could conceivably lead to greater effort and therefore higher attainment; or, success may create positive feeling and liking for the area of study, though a recent study by researchers at King's College London found no link between achievement and enjoyment in mathematics education (Askew *et al.* 2010).

That studies of association cannot decide between these models is not such a problem in the present case since many studies reveal little association between attitudes and attainment. For example, in their study of 50 primary schools in the London area, Mortimore *et al.* (1988) collected attitude measures from pupils annually for a period of three years and found that attitudes to mathematics and reading were 'almost independent of attainment' (p. 115). Albone & Tymms (2004) found no correlation between attitude and attainment for mathematics or science in the primary phase. Ma & Kishor (1997) conducted a meta-analysis of the relationship between attitude and attainment to mathematics. A very small positive association between attitude and attainment was found. Gender did not have a significant effect on the relationship. Other reviews of mathematics (Knuver & Brandsma 1993) and of science (Schibeci 1984; Weinburgh 1995) found only very weak associations between attitudes and attainment of pupils in primary schools.

Comber & Keeves (1973), analysing data from 17 countries in the first international survey of science attainment, found low correlations between science interest and attainment amongst 14 year olds. Higher correlations were found for older pupils in the final year of secondary school. At that stage, science was an optional subject for pupils, so the strengthening of the association is not surprising. In his review of studies that investigated the relationship between attitude and achievement, Fraser (1982) concluded that for science the relationship was weak and suggested that science teachers should focus directly on improving achievement and not on improving attitudes towards science as a means of improving achievement.

The most recent international study of science and mathematics, TIMSS 2007, (see § 6.6.4) shows that for both 9–10 year olds and 13–14 year olds, those with more positive attitudes to mathematics had higher average achievement in mathematics than those with less positive attitudes. This was also the case in relation to science for the younger pupils, although the picture was less clear for older pupils, as it varied across separate sciences, due to a more positive attitude towards biology than to Earth science, chemistry and physics.

Other evidence suggests that attitudes only partially overlap with academic self-concept, and that it is the latter which is the stronger predictor of outcome (Martin 2010).

6.6.3 Change over time and with age

There is evidence on the stability of attitudes of cohorts of primary pupils of the same age across years from analysis of data collected between 1998 and 2010 in England and Scotland by the Performance Indicators in Primary Schools (PIPS) project based at the University of Durham (see Figure 6.1a and b).[91] This showed that, in the case of both science and mathematics, attitudes to the subject remained at the same level, year on year, in England, whilst data from Scotland showed attitudes becoming slightly more positive over time. Individual items showed that boys tended to consider mathematics to be easier than girls and liked solving problems more than girls, whilst girls tended to like counting, learning new things and drawing graphs more than boys. In science, boys in Scotland and England responded more positively than girls to all but one item: 'I like learning about plants and animals'.

Data on changes as pupils become older depend on cross-sectional studies of samples of pupils at different ages. A decline with age has consistently been reported. Studies have indicated that this starts in late primary school, particularly with regard to girls (Institute of Electrical Engineers 1994; Osborne *et al.* 1998, 2003; Francis & Greer 1999; Murphy & Beggs 2001, 2003; Pell & Jarvis 2001).

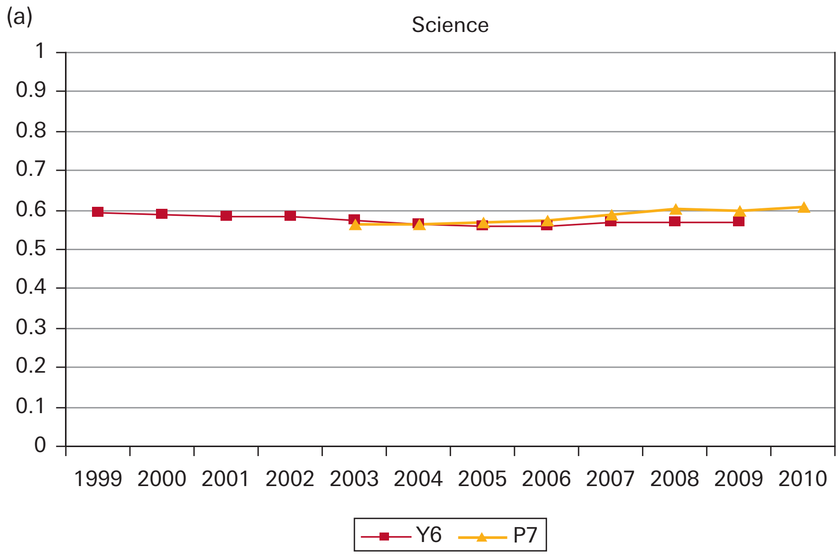
6.6.4 International comparisons

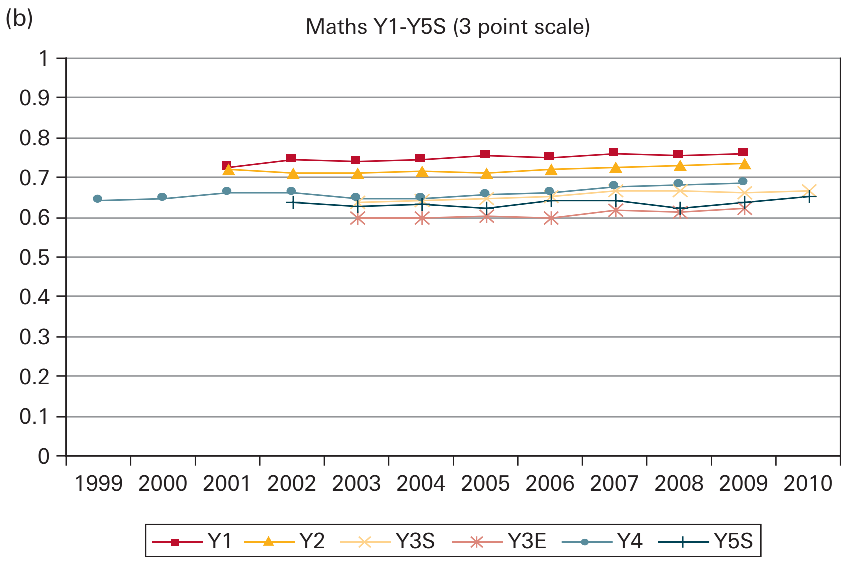
The Trends in International Mathematics and Science Study (TIMSS) conducted in 2007 involved 67 countries and benchmarking regions (Mullis *et al.* 2007) including England and Scotland. Pupils aged 9–10 and 13–14 were asked to respond to several statements about mathematics and science by indicating the extent to which they agreed or disagreed with them. From the results two indices were created.

The first of these, expressed in the case of mathematics as an index of pupils' 'Positive Affect Towards Mathematics', was based on pupils' responses to three statements: 'I enjoy learning mathematics'; 'Mathematics is boring'; and 'I like mathematics'. The results were used to assign pupils to high, medium and low levels. Pupils aged 9–10 years generally had very positive attitudes toward mathematics, almost three-quarters across all countries being at the high level. For England the results were considerably lower than the average and lower than results in the 1995 TIMSS

91 Performance in Primary Schools (PIPS) is a project of the Centre for Evaluation and Monitoring (CEM) at Durham University. Schools and LEAs pay to take part. Schools administer the tests provided by the Centre; these are marked and analysed by the Centre. The Society is very grateful to Dr Christine Merrell and colleagues for their analysis of unique CEM data for use in this report.

Figure 6.1. Attitudes to science for Year 6 (England) and Primary 7 (Scotland) pupils and attitudes to mathematics for the end of Year 1 to start of Year 5 assessments (England) as measured by the PIPS project.





Source: Merrell *et al*. (2010).

survey. In Scotland, just over a half of pupils had attitudes at the high level; very much lower than the average. No figures are available for Scotland for 1995. For pupils aged 13–14 years, the international results for this index were less positive than for the younger pupils. The result for England was lower than for 1995.

The equivalent results for science placed the 9–10 year olds in England the second lowest of the participating countries and, as for mathematics, there has been a considerable decrease since 1995. For Scotland, a greater proportion of pupils were in the high category than for England, but this was still below the international average. Results for the 13–14 year olds in science followed a similar pattern as for mathematics.

The second index was of students' 'Self-Confidence in Learning Mathematics', based on pupils' responses to four statements about their mathematics ability: 'I usually do well in mathematics'; 'Mathematics is harder for me than for many of my classmates'; 'I am just not good at mathematics'; and 'I learn things quickly in mathematics'. In this case the international average for 9–10 year olds was much lower, and pupils in both England and Scotland were above the international average. The results for pupils aged 13–14 years showed a similar pattern but with lower international averages. In England, Scotland and internationally, boys were more confident than girls.

In the measures of pupils' self confidence in science, primary pupils in England were less positive than the international average but for Scotland they were more positive. Internationally, girls' self confidence was above that of boys', but for England and Scotland boys' self-confidence was above that of girls'. For pupils aged 13–14 the international average was again lower than for younger pupils and for both England and Scotland the results were above the international level. As for mathematics, boys in

England and Scotland at this age were more confident than girls.

For the older pupils only, views were sought on the value of mathematics and the value of science. For mathematics, the results for England fell just below the international average, which was high, and those for Scotland were above the international average. For science, results for both England and Scotland were below the international average, although higher than in 2003.

An international project concerned with attitudes towards science, the Relevance of Science Education (ROSE)[92] project found that there was a very strong negative correlation between people's attitudes to certain aspects of science and the human development index (HDI) of the country where they live.[93] Although focused on attitudes of older students and adults, these attitudes originate in earlier years and suggest that pupils in the UK grow up in a society that does not value science as much as far less well developed countries.

6.6.5 Factors affecting attitudes

Although attitudes to science and mathematics, as currently measured, do not appear to be strongly associated with attainment, they are nonetheless deserving of attention given that attitude is an overall term that includes interest, liking and confidence in being able to succeed. These are dispositions that are likely to affect decisions about future involvement in science and mathematics and their decline with age, noted earlier, is therefore a matter of concern. Indeed intention to study science in later education falls from primary through secondary education (Reid & Skryabina 2002). Since there are insufficient graduates of STEM subjects, particular interest and importance at the present time is attached to decisions taken, in later school years, about studying STEM subjects (Osborne & Dillon 2008). It is therefore important to consider why pupils' positive attitudes to science and mathematics diminish as they move into and through secondary schooling (Bennett & Hogarth 2005).

6.6.5.1 Classroom experience

Studies that have looked at enjoyment of different activities within science have found that children preferred practical over non-practical activities (Pell & Jarvis 2001). Murphy *et al.* (2004) found that increasing the amount of practical, investigative work in primary science increased enjoyment of science experienced by pupils. Galton *et al.* (2003c) reported that 'dips' in attitudes and engagement occur in science and mathematics at transfer from primary to secondary school. Their classroom observations suggest that the Year 7 curriculum at that time (2000 and 2002), was not sufficiently challenging or different from that the pupils experienced in Year 6.

In the Scottish Survey of Achievement (SSA)[94] of science in 2007, pupils were asked about confidence in various classroom contexts. They felt confident more frequently when they were conducting experiments, talking about science with their teachers, or talking about science in small groups, than when they were talking about science in front of the class or talking about science with an adult other than the teacher. Generally, a higher proportion of boys than girls reported that they 'very often' felt confident in science especially at S2 (age 13). In mathematics Nardi & Steward (2003) show a fairly desolate picture of Key Stage 3 classrooms, with children's attitudes generally summarised as 'quiet disaffection'. They relate this to perceptions of work in mathematics lessons as boring, individual (rather than collaborative), procedural, elitist (aimed for those who are good at it) and depersonalised.

The teachers' enthusiasm for and knowledge of science and has been identified as an important influence on pupils' response to science in primary and the early years of secondary school (Tymms & Gallagher 1995; Osborne & Collins 2001; Bennett & Hogarth 2005). Similarly in mathematics the role of the teacher, particularly in the kind of help provided, has been found to be more important than the textbook or scheme being used (Askew *et al.* 1997; Nardi & Steward 2003).

6.6.5.2 Gender

Gender differences in attitudes to science have been widely reported ((Harding 1983; Kahle & Lakes 1983; Erickson & Erickson 1984; Schibeci 1984; Smail & Kelly 1984; Johnson 1987; Robertson 1987; Becker 1989; Breakwell & Beardsell 1992; Colley *et al.* 1994; Sjoberg 2000) and appear to increase in the secondary school. Reid & Skryabina (2003) found that at the end of primary school in Scotland both girls and boys were positive in their attitudes to science and looking forward to studying it at secondary school. By the end of the second year at secondary school, a significant decline in girls' attitudes relative to boys' was observed with twice as many boys as girls being attracted to the further study of physics. This ratio remained through to the end of compulsory education. Certainly, girls remain in the minority when it comes to pursuing careers in the physical sciences (Woodward & Woodward 1998; Osborne & Dillon 2008).

A common speculation as to the reason for gender differences suggests that they result from cultural socialisation which offers girls far fewer opportunities to engage in science and scientific activities (Kahle & Lakes 1983; Kelly *et al.* 1984; Whyte 1986; Johnson 1987; Jones *et al.* 2000). Another possible explanation lies with the content of extant curricula and the finding that it is of far less interest to girls than boys (Osborne & Dillon 2008). In mathematics the TIMSS results suggest that although boys

92 See http://www.ils.uio.no/english/index.html, accessed 10 June 2010.
93 Human development index (HDI) is based on a country's GDP, life expectancy and general level of education.

94 Scottish Survey of Achievement, in which samples of pupils at P3 (aged 7/8), P5 (aged 9/10), P7 (aged 11/12) and S2 (13/14) are assessed (see Chapter 2).

and girls have similar attainment scores, boys continue to be more confident in their own ability than girls.

6.7 Conclusions

It is clear that a wide range of factors relating to the individual characteristics of children, their experience within the classroom and outside the school can affect their attainment and attitudes to science and mathematics.

In relation to experiences within the classroom, children's conceptual development is best served by ensuring that the teaching methods and activities provided are sensitive to students' understandings and interests. Language has a key role in the important process of generalising concepts so that larger, more widely applicable ideas are formed. Whilst a range of experience is necessary for this process, it is also important for the terminology used to reflect and encourage links between related objects and phenomena. Dialogue and discussion are therefore important—both for the teachers to hear and monitor the children's ideas and how they are expressed, and for the children to hear how the teacher uses language to categorise and describe phenomena. The use of symbols and diagrams and written text is also important for children to broaden, connect and apply scientific and mathematical concepts.

Group work provides the context for dialogue and discussion and therefore for cognitive development in science and mathematics. Group work needs to be well designed and managed by teachers and teaching assistants who understand the role of language in learning and the criteria for effective group work. This applies equally in the lower secondary school as in the primary school. Thus the evidence that group work happens less often and tends to be briefer in secondary school than in the primary school should be addressed in teacher education. Other changes that occur at transfer from primary to secondary school relevant here include the introduction of new terminology and a more formal structure to lessons, which make science, particularly, but also mathematics, a rather different experience than previously. Primary to secondary transfer issues are considered more fully in the next chapter.

Evidence suggests that the influence of league tables based on national tests encourages teachers to employ more narrow and procedural methods in order to teach for passing tests. This means much less use of effective teaching methods such as formative assessment and feedback, discussion and cognitive challenge.

The burgeoning use of ICT in all classrooms has the potential to expand pupils' experiences and provide tools and information that support their learning. However, for cognitive development in science and mathematics, particularly in the primary school, pupils require opportunities to manipulate real objects and for talk and discussion. Thus the use of ICT should be used to provide more opportunity for direct interaction and discussion, not less.

Children's cognitive development is influenced by the environment for learning that their home provides and by the mother's level of education. These factors are evident in children's attainment at age 11. Measures are therefore needed to address attainment by children belonging to specific ethnic groups and those who experience impoverished home environments. Children from all home backgrounds benefit from high quality pre-school attendance. The Government's drive to ensure the majority of three and four year olds in the UK have access to pre-school education through the Sure Start and Cymorth programmes will help boost the attainment and progress of disadvantaged children, and will provide more support for parents to assist with their children's learning in the home.

Opportunities for informal learning, eg through membership of science and mathematics clubs, and visits to science centres and museums with parents or organised by the school, make science enjoyable and interesting, but the evidence of its impact on attainment is patchy. However, there is general agreement that children should have access to informal learning opportunities within the fields of science and mathematics, whether mediated by parents, by schools or via the Internet.

The meaning of attitude to science and mathematics combines interest in, liking for and confidence in success in these subjects. The evidence of the considerable difference in levels of liking and self-confidence for the same pupils in relation to mathematics and science throws some doubt on measures that combine these with a single entity of 'attitude'. Further, the validity of methods generally used in assessing attitudes also suggests some caution in interpreting results.

The most recent international study of science and mathematics provides some evidence of more positive attitudes being associated with higher average achievement, in contrast with some earlier studies. However, perhaps the chief reason for the importance of attitudes lies in their influence on choice about pursuing science and mathematics related studies. The need for attention to attitudes towards mathematics and science is clear in the evidence that even children as young as seven years of age, indicate less positive attitudes to mathematics than to reading and school. Thereafter attitudes continue to decline for both mathematics and science as pupils move through the primary years and into secondary school. There is particular concern about the large drop for pupils aged 11–14, when most pupils have transferred to secondary school.

The downward trend in attitudes is apparent in international studies as well as in England and Scotland. Across all countries taking part in the TIMSS, the international indices reported were lower for 13–14 year olds than for the 9–10 year olds. Pupils in England and Scotland had lower levels of positive affect to the subject but higher levels of self-confidence than international averages for both science and mathematics. Without further evidence it is difficult to account for these results.

There is difficulty in interpreting coarse data about attitudes towards a subject as a whole. Where a more detailed picture is possible it is clear that pupils enjoy some aspects of the subjects—for instance practical investigations and group work—more than others. Further research is needed to explore reasons for the consistent fall in attitudes which may lead to points for action.

The reasons behind the reduction of interest in science and mathematics among young people are clearly very complex. Almost certainly the problems admit of no simple or single solution. Many, moreover, may well lie beyond the sphere of influence of the school. However there is a strong suggestion that how science is taught, the knowledge of the teacher and the extent to which pupils are actively involved in studying something of interest and relevance to them, may well be contributing factors in forming the attitudes of both boys and girls towards science and mathematics and in the gap between boys and girls in attitudes towards science. There remains, however, a worrying lack of evidence in this regard with much existing research providing relatively low-level information, identifying problems, but offering little by way of explanation. Consequently there is a pressing need for research that investigates these issues through high quality, longitudinal, multidisciplinary studies using a range of methodologies. Such research should be linked to a broader programme that includes research on the primary–secondary transfer (cf. Chapter 7).

Recommendation 12

Knowledge of the factors that promote pupils' cognitive development in science and mathematics should be incorporated within high quality training and continuing professional development for teachers and teaching assistants, coordinated by the National Science Learning Centre and the National Centre for Excellence in Teaching of Mathematics.

Recommendation 13

The Economic and Social Research Council and other education research funders should encourage more investigations into the long-term benefits of informal learning in science and mathematics and parent participation within it, as well as the development of opportunities in mathematics that complement those in science in the use of museums, travelling resources and Web-based resources.

7 Primary–secondary transfer in science and mathematics

7.1 Introduction

The proposal that all children should pass from a 'primary' to a 'secondary' stage of education at about age eleven was formally advanced in *The education of the adolescent* (Board of Education 1926) and further developed in *The Primary School* (Board of Education 1931). In making this recommendation, however, the Hadow reports (as they are commonly known) also drew attention to the dangers attendant on creating disjunctions in children's schooling. Mindful of the possibility of a loss of momentum in learning, they stressed the need for teachers in 'receiving' schools to keep in close touch with teachers in their 'contributory' schools with a view to ensuring that:

> '… the process of education, from the age of five to the end of the secondary stage, should be envisaged as a coherent whole, that there should be no sharp division between infant, 'junior', and post-primary stages, and that the transition from any one stage to the succeeding stage should be as smooth and gradual as possible'

(Board of Education 1931, p. 70)

For a particular subject in the secondary school:

> '(a)ny course … designed for pupils in post-primary schools should be regarded as a continuation and development of previous work done up to the age of 11+'

(Board of Education 1926, p. 190)

While advocating the establishment of separate primary and secondary schools, then, the Hadow committee was acutely aware of the need for primary–secondary coordination. Indeed, it considered this 'among the most important of the issues immediately calling for attention' (Board of Education 1926, p. 40).

The realisation of this principle, however, has proved problematic. Almost 80 years later the Department for Education and Employment (2001, p. 40) could describe provision for continuity of learning across the primary–secondary interface as an issue which 'has been neglected or swept aside as an intractable problem'.

7.2 Successful primary–secondary transfer: aims and objectives

Children experience change, year on year, as they proceed through a school and as they move from school to school. In this chapter, in keeping with much of the present literature on the subject the former will be described as transition and the latter as transfer.

Essentially, the aim of primary–secondary liaison is to facilitate the transfer of pupils from one school to the next. This process is commonly represented as having two broad objectives. The first, often characterised as 'pastoral', is concerned with helping children adjust to their new surroundings and to establish new friendships. The second, characterised as 'academic', is concerned with helping children to sustain their interest and progress in learning. The two intentions are interrelated: one would expect a child's adjustment to a new school to affect his or her academic performance within it; equally, one would expect a child's academic performance in his or her new school to affect attitudes toward it. Nonetheless, the distinction is helpful and will be used in this discussion.

Many writers have stressed that a commitment to easing transfer does not imply that there should be no change. Research shows that many pupils, even the anxious, are eager to meet new challenges in their new environment. The move is seen almost as a 'status passage' from childhood to adolescence (Measor & Woods 1984). This suggests that, while continuity should be the dominant goal, there is also a place for what Derricott (1985) has termed 'planned discontinuity'. In no way does this imply a 'clean break', however, rather, a careful management of change.

7.3 A review of primary–secondary transfer, pre-1988

Most early studies of cross-phase transfer had as their primary focus pupils' adjustment to their new school and it was only in the mid-Seventies that the research began to concentrate, substantially, on curricular continuity in relation to specific subjects. Interest in curricular continuity in science developed even later, reflecting the slow rise of primary science itself.

A number of common themes emerge from this research. It was found that schools' efforts, typically, were directed towards the 'pastoral' rather than the 'academic'. In this regard, their interventions appeared largely successful and most children seemed to settle quickly in their new surroundings. There were some, though, who failed to do so, tending to be the 'younger, less mature, less confident, and [pupils] of non-academic dispositions, often from a poor socio-economic background' (Hargreaves & Galton 2002, p. 6, for a more nuanced account see West *et al.* 2010). The picture, nonetheless, was predominantly positive.

In contrast, research showed that systematic intervention to promote continuity and progression in relation to subject programmes and pedagogy was rare (eg Birmingham Educational Development Centre 1975; SCCC 1983; Stillman & Maychell 1984; ILEA 1986, 1988). Where it occurred, some curricular areas were accorded a higher liaison priority than others with initiatives more likely in

English and mathematics than science. As HMI commented (DES 1983, p. 5)

'Apart from English and mathematics, continuity in the primary curriculum has been subject to much neglect. Continuity … from primary to secondary education has suffered a similar fate. Science suffers at least as much as other subjects, and perhaps more than some, from discontinuity.'

Indeed, it could be recorded that 'Secondary school science work largely ignores anything which might be done earlier' (Harlen 1983, p. 25). Similarly, in Scotland a survey of primary–secondary continuity in Environmental Studies showed a substantial under-expectation on the part of secondary teachers in respect of pupils' previous experiences (SCCC 1983).

Many reasons were offered for this state of affairs: lack of time, logistical problems, differing classroom cultures, poor record-keeping and transfer, stereotypical perceptions, sensitivities, inadequate external support, etc. The most significant, however, was considered to be the autonomy of schools and the resultant diversity of practice. As Gorwood (1986, p. 4) observed, 'There are many advantages in allowing … teachers considerable freedom but the promotion of continuity is not one of them'.

7.4 Primary–secondary transfer and centrally devised curricular frameworks

As noted in Chapter 2, a National Curriculum for England and Wales was introduced in 1989 and the Northern Ireland Curriculum in 1990. This reform was introduced with the assertion (DES 1987, p. 4):

'A National Curriculum will … help children's progression within and between primary and secondary education and will help to secure the continuity and coherence which is too often lacking in what they are taught.'

In Scotland, the document launching the 5–14 Development Programme (SED 1987, p. 7) indicated it would address '… curricular discontinuity, especially in the four years between P6 and S2'.

It was widely accepted that such curricular frameworks had potential for mitigating some of the problems of primary–secondary transfer. The initial formulation of the National Curriculum, for example, contained a number of features which could contribute to cross-phase continuity. The curriculum was presented as a single publication spanning primary and secondary schooling. Pupils were required to follow common Programmes of Study relating to common Levels of Attainment. It was anticipated that children would be assessed against these and their progress would be charted as a continuously developing record of achievement that would pass from school to school. Such arrangements addressed two key problems identified in the pre-1988 literature as major impediments to the promotion of primary–secondary continuity. First, children's primary experiences and achievements were often unknown by their secondary teachers. Second, even when known, typically they were so diverse as to make an appropriate response difficult (Jarman 1990).

At their instigation, then, there was widespread consensus that these national or regional curricular frameworks, whether statutory or non-statutory, could facilitate the promotion of primary–secondary continuity in mathematics and science. Research has shown, however, that this promise was rarely realised.

In the decade following their introduction, a number of studies of the new curricula were undertaken which had cross-phase continuity either as a significant or as their sole focus. In England and Wales, the National Foundation for Educational Research carried out three major surveys (Weston *et al.* 1992; Lee *et al.* 1995; Schagen & Kerr 1999). In Scotland, the implementation of the 5–14 Development Programme was evaluated (Harlen 1996; Malcolm & Simpson 1997). In Northern Ireland, an investigation of continuity issues was conducted (Sutherland *et al.* 1996). Evidence on the health of arrangements for primary–secondary transfer was also presented in inspection reports (eg Ofsted 1998). In addition, a few studies focused specifically on science (Russell *et al.* 1994; Jarman 1995, 1997; Peacock 1997).

These reports reveal a remarkable level of agreement as to the impact, across subjects and regions, of these centrally devised curricular frameworks on teachers' planning for primary–secondary continuity. The consensus was that they had prompted some, but not substantial, improvement in practice. Thus Schagen & Kerr (1999, p. 92) could write:

'… the National Curriculum has not had the anticipated positive impact on curriculum continuity and individual progression. [There is] a stark contrast between the rhetoric of the NC and the reality of the Year 7 classroom, where the 'fresh start' approach tends to predominate.'

This indicates that the impediments to the promotion of primary–secondary curricular continuity lie even deeper than earlier analyses admit. For example, the Northern Ireland research, involving in-depth interviews with 50 heads of science before and after the introduction of the statutory curriculum, exposed problems at the level of the 'what, why, and how' of curricular continuity itself (Jarman 2000). The study revealed that among those teachers who held a view of what cross-phase continuity meant in the context of their subject (and not all did) there was no real congruence. Therefore exhortations to promote primary–secondary continuity conveyed different messages to different people, and to some, no real message at all.

Establishing primary–secondary contacts and continuity require considerable investments of time and effort. It is important, then, that benefits are perceived to balance costs. However, in the Northern Ireland study it emerged that the reasons for pursuing primary–secondary continuity were not always evident to teachers. This has parallels with other research. In one survey of transfer it was noted that

60% of the secondary science teachers questioned said that they had never seen the Key Stage 2 Programme of Study. Of this group, nearly half did not see this as a serious weakness (Galton 2002). In this connection, the evidence discussed in the following section for post-transfer repetition and dips in pupils' performance is particularly significant.

The Northern Ireland study suggests the 'how' of continuity is also problematic. When asked how primary–secondary continuity in science could be improved the great majority of participants proposed what were essentially means rather than means and ends. Hence, perhaps, many local initiatives had floundered. Though contact was made, continuity was not pursued. By the same token, some teachers deliberately set out to discover what their pupils knew about particular topics but were then uncertain how to act on the information. This is not surprising. Such guidance as existed at the time was typically too general to support those who wished to translate contacts into continuity, or information into action. Beyond the exhortation to 'build on' earlier experiences, there was relatively little to indicate or illustrate what primary–secondary curricular continuity might actually look like in their subject. Section 7.6 reviews some current developments which begin to address this issue.

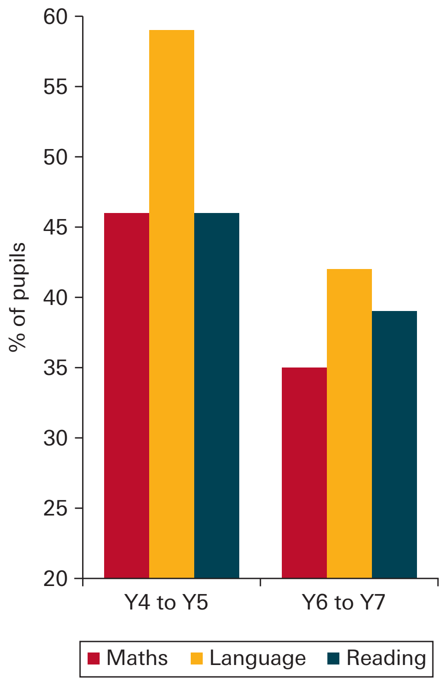
7.5 Problems at transfer: repetition and regression

In a successful primary–secondary transfer, children sustain or enhance their interest and their progress in learning. However, if they perceive their learning experiences to be merely a repetition of what has gone before and/or if they are not challenged in the way they expect or are entitled, then they may lose interest and/or fail to make progress. There are a number of recent, influential research studies and official surveys which shed light on these concerns and these will be reviewed briefly.

7.5.1 The ORACLE replication study

One of the most frequently quoted investigations of the impact of transfer on pupils' experiences, achievements and attitudes is the ORACLE (Observational Research and Classroom Learning Evaluation) replication study (Hargreaves & Galton 2002). In this, the progress of about 300 children was assessed as they transferred to one of six middle or secondary/high schools. Figure 7.1 shows the percentage of children who failed to make progress in absolute terms against standardised tests of language, mathematics and reading comprehension. The researchers estimated that 'transfer under present conditions results in up to two out of every five pupils failing to make expected progress during the year immediately following the change of school' (Galton *et al.* 1999, p. 10). For most, the differences were small. However, the researchers indicate that 12% of pupils transferring into Year 5 and 7% of those transferring into Year 7 made significant losses.

Figure 7.1. Percentage of pupils in cohort doing less well in same test one year after transfer.[a]



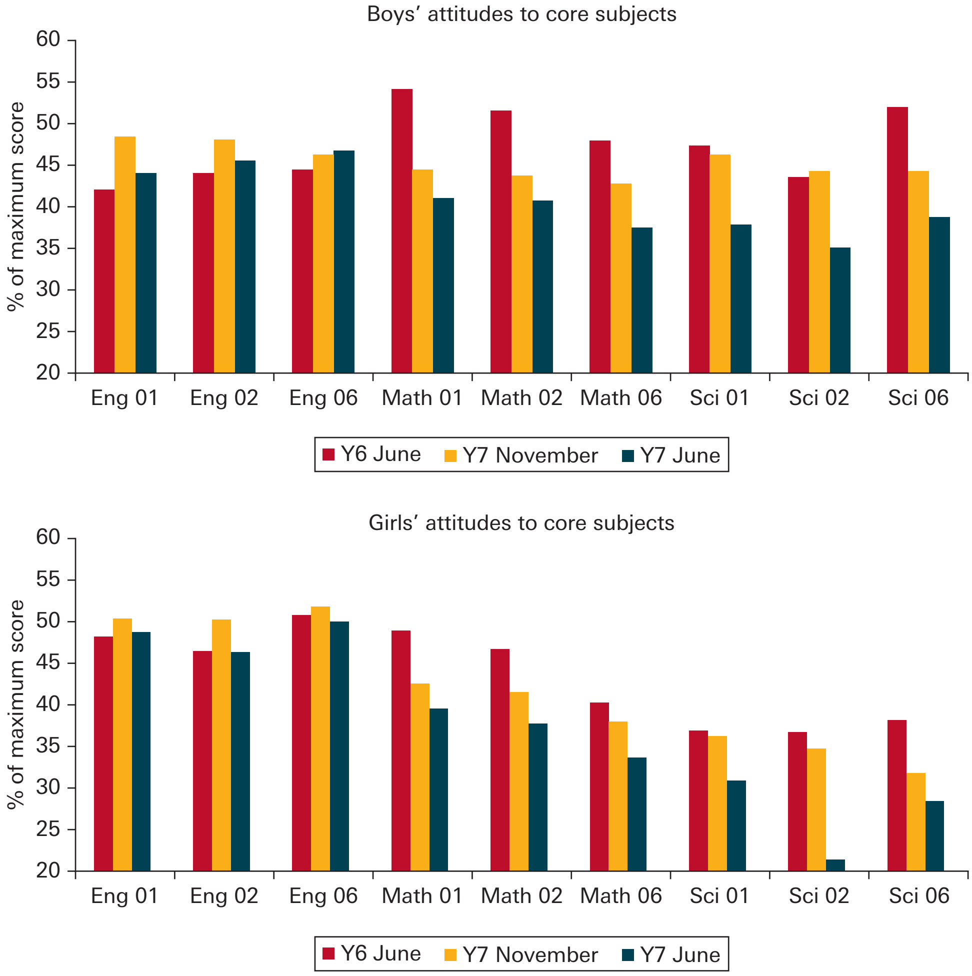
Source: Galton *et al.* (1999).

(a) This figure has been recreated, with permission from M. Galton and J. Gray, using data that appear in Hargreaves & Galton (2002), table 5.9, p. 147.

In the ORACLE replication study, pupils' classroom experience of English, mathematics and science was observed in both their primary and secondary schools. In the former, for both English and mathematics the amount of time spent on whole class teaching was about 35%, but for science it was 50%. In the latter, it increased for English and mathematics while for science it remained at about 50%. Both mathematics and science showed a reduction in pupils' engagement (time on task), with science notably so. For mathematics, the patterns of questioning and statement-making were broadly similar pre-transfer and post-transfer. For science, there was, post-transfer, a reduction in the incidence of open-ended questioning. In Galton (2009, p. 14) the observational data for science is re-presented but with some of the original categories omitted. Here it is reported that, pre-transfer, teacher-questions accounted for 16.2% and teacher-statements for 59.2% of the observations and, post-transfer, teacher questions accounted for 18.5% and teacher statements for 57.3% of the observations. Significantly, Galton notes 'over half of these lessons involved teachers talking at rather than with their pupils'.

Galton and his colleagues have also researched changes in pupils' attitudes toward school English, mathematics and science over the transfer period (Galton *et al.* 2003a; Galton 2009). The results shown in Figure 7.2 represent the findings of two studies. The 2001/02 data were collected from pupils drawn mainly from four local authorities. For

Figure 7.2. Changes in boys' and girls' attitudes to school English, mathematics and science from Year 6 to 7.



Source: Galton (2009), reproduced courtesy of the Wellcome Trust.

Note: Vertical axis is % of maximum possible score on a one to five scale; horizontal axis is subject by year cohort.

each subject, the maximum number of pupils tested on any one occasion was well over 1,000; the minimum number, however, was substantially lower. The second study involved six primary schools feeding into three secondary schools in one LA and 600 pupils participated. The data, collected on a scale of one to five, is presented by the researchers as percentages of the maximum possible score. In mathematics and science, the overall pattern is for attitudes to decline as pupils move from Year 6 through Year 7. In science, Galton (2009, p. 11) notes that most researchers attribute attitude dips at transfer to the failure of the actual lessons to meet the high expectations of pupils, many of whom had been eagerly looking forward to science in their new school:

'Viewing the purpose-built laboratories and beguiled by the exciting demonstrations on induction day, pupils assume that secondary school science will largely consist of doing experiments, only to discover very quickly that many of these activities … have already been done at primary school, don't occupy much lesson time, and require extensive writing up. …'

7.5.2 Suffolk transfer and transition initiatives

Suffolk Education Department has conducted a number of reviews of transfer as pupils move to their next school. In addition, the authority administers standardised reading tests to all its pupils at ages 7, 9, 11 and 13. In 1996 members of its advisory team visited the schools, watched the work and judged the standards of some 360 children, with a focus on English, mathematics and science. Their report (Suffolk Education Department 1997) recorded a dip in progress at transfer, as indicated by reading test data. Though there was evidence of good practice across subjects and across schools, nonetheless in some, failure to build on previous attainment in mathematics meant that pupils' progress was impeded. Teachers, unaware of their previous experiences and achievements, underestimated what they could do and children who had achieved Level 5 in their primary schools were working on tasks at Level 4, 3 and even 2. In science, the situation was similar with most schools being only partially successful in building on pupils' previous attainment. The more able pupils were most disadvantaged. In terms of the preparation and use of transfer documentation, practice was better in English than in mathematics or science. Overall, though, the picture in most schools was not good, mirroring that across the nation as a whole (Ofsted 2007). Encouragingly, in a follow-up review (Suffolk Education Department 2002) there was evidence that, particularly where transfer projects focused on pupils' work, children were being more appropriately challenged.

7.5.3 Leverhulme Numeracy Research Programme

In the longitudinal survey forming part of the Leverhulme Numeracy Research Programme, sets of numeracy questions with a uniform range of difficulty for that age group were posed to over 1,500 primary children in each of the year groups from Year 2 to Year 6 in at least 35 schools, chosen to form a varied sample of English schools. In the June of the following year the same children were tested on the same set of questions. In Year 7 the sample, although reasonably representative, was very much smaller ($n = 188$, from 10 different schools) because of the problem of tracking children into secondary schools. Between each of Years 2 to 5 and the following year, there was an average increase in success rate for a question of between 12% and 16%. However this changed radically between Years 6 and 7 where, on the set of 71 questions, there was a drop of around 2% in average success rate (Brown *et al.* 2008).

It was not clear why this fall occurred but contributory factors seemed likely to be the lessening of pressure for high numeracy attainment between Year 6 and Year 7 due to the high-stakes national testing in the May of Year 6, and the wider mathematical curriculum but lesser time and emphasis given to mathematics against other subjects in Key Stage 3.

Williams *et al.* (2007), working across the whole range of Key Stages 1, 2 and 3 with cross-sectional samples of over 1,000 students in each year group, and using Rasch techniques, suggest that there are identifiable above-average rises, presumably due to national testing, in both Year 2 and Year 6. While they confirm a steady increase in attainment over Key Stage 2, they also note only a very slow growth, almost a plateauing, in mathematical attainment, over Key Stage 3. This slow rate of growth across Year 7, 8 and 9 is confirmed in the different areas of ratio, decimals and algebra by Hodgen *et al.* (2009).

7.5.4 The evidence for repetition

All transfer studies designed to identify it, show evidence that pupils, in their new school, repeat work they have already done. Such repetition may involve a focus on facts they have already learned, on ideas they have already internalised, on skills they have already mastered or on activities they have already undertaken. Where this is planned to reinforce conceptual or procedural understanding prior to moving on, it is entirely reasonable. However, research suggests this is seldom so. Repetition is found to occur most frequently when teachers are unaware of what has gone before or, if aware, are unprepared to take account of it. This is an issue in mathematics teaching where, as the Suffolk study shows, teachers may substantially underestimate the earlier achievements of their pupils, and, so the pitch of subsequent work is inappropriate and unchallenging.

Repetition is a particularly pressing issue in science teaching. Here the spiral structure of the science curriculum means that children and young people revisit content and often context on a number of occasions during the period of their schooling. On transfer, many teachers lack awareness of their pupils' previous experience and/or confidence in their learning. Jarman (1997) has shown, for example, that at the time of her Northern Ireland study, secondary teachers' knowledge of primary science derived most often not from formal attempts to learn about their pupils' earlier work but from informal discussion with the children. Thus they were relying on the children's ability to describe their understandings and on their ability to draw out these understandings. Both processes are problematic. Children may fail to see connections between the contextualised science encountered in primary school and the more decontextualised science encountered in secondary school or they may find it difficult to describe in teacherly terms what they nonetheless know. Teachers have large classes and little time and they may find it difficult to promote the sort of dialogue necessary to elicit such information. It is significant that a number of parent-teachers in the study noted that they recognised a high level of science learning in their own children but failed to recognise the same in those they taught! As a consequence of these difficulties, there was a substantial underestimation of what pupils' knew, understood and could do.

7.5.5 The evidence for post-transfer dips in performance

The studies reviewed above provide evidence for a 'dip' in pupils' performance in mathematics associated with transfer. This has variously been referred to as post-transfer regression, the regression gap or the transfer hiatus. As Galton (2009) has noted there is less reliable information about changes in pupils' performance in science when moving from primary to secondary schools. Technically, this is more challenging to measure than for aspects of English and mathematics. Braund (2008, 2009) presents a comparison of the percentage of Key Stage 2 pupils at or above target Level in Key Stage 2 tests with the percentage of the same pupils, at Key Stage 3, who are at or above target Level in the Key Stage 3 tests (Table 7.1). He argues that, while there are signs that the 'regression gap' is closing in English and mathematics, in science the gap, larger to begin with, remains substantial. It must be recognised, however (and the author does) that there are considerable problems comparing robustly the Key Stage 2 science tests with the Key Stage 3 tests, and at best, this comparison

Table 7.1. Pupils achieving target Levels in National Curriculum tests (in England) at the end of Key Stage 2 and Key Stage 3.

	Percentage of pupils at or above target level in end of Key Stage 2 tests				Percentage of pupils at or above target level in end of Key Stage 3 tests		
	English	Mathematics	Science		English	Mathematics	Science
2000	75	72	85	2003	68	70	68
2001	75	71	87	2004	68	70	68
2002	75	71	86	2005	74	74	70
2003	75	73	87	2006	73	77	72
2004	78	74	86	2007	74	76	73

Source: Braund (2008), reproduced courtesy of the Well come Trust.

Note: These data vary from those in Tables A3.3 and A3.5, eg due to the selection of data used.

can only be regarded as indicative. Stronger confirmation, Braund suggests, comes from retests administered in secondary schools using questions from pupils' Key Stage 2 tests which have shown similar or greater regression (Bunyan 1998; Nicholls & Gardner 1999). This approach, however, is open to revision/coaching effects.

There is evidence, then, that, for a significant number of pupils, transfer from school to school is associated with a 'dip' in progress as measured by their performance in standardised or national tests. Research suggests that the phenomenon occurs in mathematics and science, but that it is not unique to these subjects. It is apparent across the regions of the UK, but it is not unique to the UK. International data from many Western countries show a similar dip in attainment following children's transfer to secondary school.

The issue of whether these transfer effects are cumulative, that is whether, in terms of pupils' progress, two-tier systems are preferable to three-tier (middle school) systems has also been researched. Galton (2009) reports that studies are either inconclusive or provide some limited evidence that they may be. An investigation of pupils' progress in all-through schools would be interesting in this regard.

Though not the focus of this chapter it should be noted that research has shown year-on-year transitions can also be problematic. Young people negotiate and renegotiate their identities in response to changing circumstances as they move through school (Measor & Woods 1984; Rudduck *et al*. 1996; West *et al.* 2010). Thus, for example, some pupils suffer a loss of momentum in their second year in secondary school and a few schools focus on Year 8 to re-engage young people who are beginning to lose their enthusiasm for learning (Galton *et al.* 1999).

To summarise and to conclude this section, there is evidence that, on transfer from primary school to secondary school, children often repeat work they have already done and/or engage in work without additional challenge. It is widely accepted that these happenings can have a negative impact on both their interest and their progress in learning. Many educationists consider repetition and/or under-expectation to be contributory factors in pupils' diminishing interest as they move into and through secondary school. In addition, repetition and under-expectation inevitably represent lost opportunities to advance learning. This alone could be a contributory factor in post-transfer dips in performance. Coupled with diminished interest, the effect could be compounded.

7.6 Strategies for promoting successful primary–secondary transfer

In view of evidence such as that presented in the previous section, the promotion of successful primary–secondary transfer, and indeed year-on-year transition, is presently perceived as a high priority. Until recently, consideration was being given to including 'partnership working' as an aspect of the School Report Card planned to supersede the Achievement and Attainment Tables (DCSF/Ofsted 2009). In England, cross-phase transfer is a focus of the National Strategies, but it is unclear what will happen after the Strategies have been abolished in 2011. In Wales there is now a statutory requirement that primary and secondary schools cooperate in the drawing up of 'Transition plans' which address the action that will be taken in respect of managing and coordinating transfer, joint curriculum planning, achieving continuity in teaching and learning methods, achieving consistency in assessment and monitoring of pupils' progress and, importantly, evaluating the impact of the policy and initiatives. In Scotland, the Curriculum for Excellence has, as one of seven planning principles, the expectation that children and young people should experience continuous progression in their learning from ages 3–18. Improving primary–secondary transfer is also the theme of a number of recent or current research and development projects. Together these initiatives are providing subject-specific, action-explicit advice for teachers, which has long been wanting in this field.

The next section presents a brief overview of the measures that can be taken to promote successful primary–secondary transfer. Some general principles, common to all curricular areas, are noted; practices currently adopted by schools are listed and the desirability of taking account of the growing evidence base in relation to effective transfer is discussed.

7.6.1 General principles

Under the umbrella of the National Strategies, a number of initiatives with the potential to promote successful primary–secondary transfer have been undertaken. The 'Strengthening Transfers and Transitions' action research project was established to identify and develop specific actions that address these issues. The seven participating local authorities selected school families to be involved, each of which chose its own approach. Some explored general matters such as promoting shared understandings of effective teaching, learning and assessment; others targeted particular subjects including mathematics and science. In addition to presenting case studies, the project report (DCSF 2008) identifies significant elements of successful practice and their implications for local authorities and schools. Importantly it distinguishes seven principles found to underpin effective transfers (Figure 7.3), stressing, crucially, that productive partnerships are built on mutual professional regard and trust.

7.6.2 Action to address transfer issues

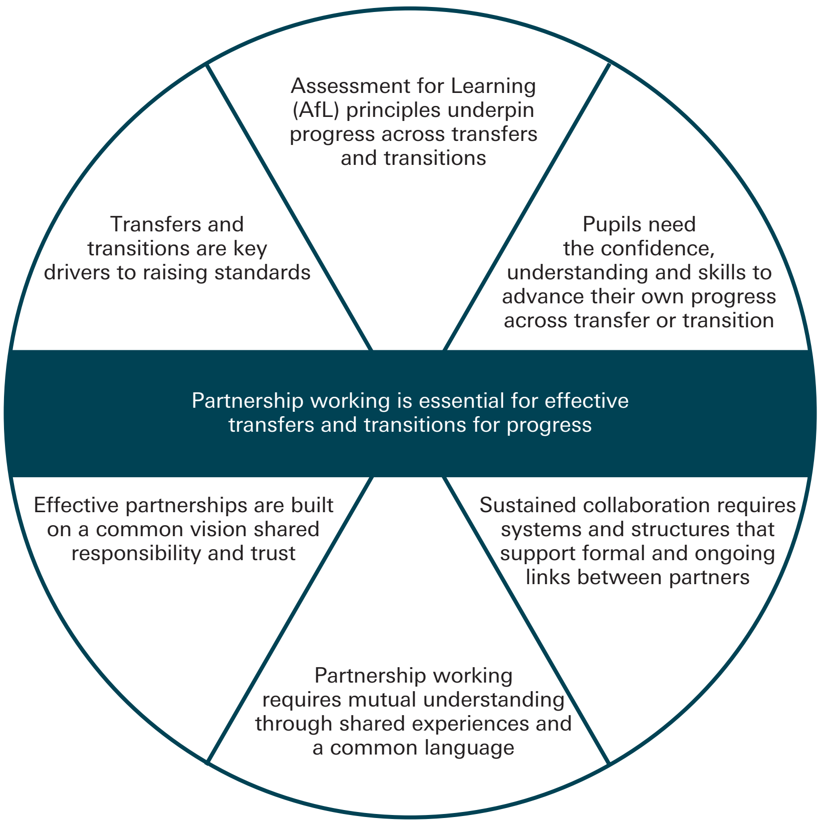
Galton and his colleagues have collected details from schools of their current transfer activities and classified schools' actions to address the 'pastoral' and 'academic' issues at the primary–secondary interface as administrative, social, curricular, pedagogical and management-of-learning (eg Galton *et al.* 2003b, p. 13). Table 7.2 provides an important list of strategies that can contribute to successful primary–secondary transfer. Significantly, over a four year period, a substantial shift in emphasis was noted; in 1999 transfer initiatives were predominantly concerned with the pastoral; by 2003, more were concerned with the academic, that is, with promoting continuity of learning.

An important family of strategies is those emerging under the designation 'management-of-learning'. These include extended induction programmes and the teaching of thinking and study skills. They stress the growing role of the young person as a 'professional learner' taking increasing responsibility for his or her own progress.

7.6.3 Evidence-based development work

Though progress has been slow, our knowledge of the factors associated with effective transfer arrangements is growing. This is an important resource which should be drawn upon when planning initiatives. The work of Martin Braund and his colleagues on the development of science

Figure 7.3. Seven key principles that underpin effective transfers and transitions.



Source: DCSF (2008), reproduced with permission.

Table 7.2. Examples of school transfer activities.

Type of initiative	Percentage	Example
Administrative (designed to smooth transfer process)	6.1	Meetings between senior staff, Heads of Year, subject coordinators, SENCOS etc, **Electronic data transfer, Target setting**, communication with parents
Social (aimed at reducing pupils' anxieties about the move to the new school)	32.1	Induction day + Open evenings, Use of secondary school facilities by Y6 pupils (ICT, drama, sports). **Increased support for pupils 'at risk', Buddy/mentoring schemes, Joint celebration events, Extended pre-transfer induction activity**
Curriculum (maintaining continuity and progression)	45.8	Secondary staff observing and teaching in feader schools, Joint training days. **Foundation programme taught by single teacher in Y7, Bridging units, Summer schools for gifted and low achievers**
Pedagogic (helping Y7 teachers to build on effective primary practice)	8.6	**Y6 and Y7 teacher exchanges, Peer observation, Use of Advanced Skills Teachers**, booklets on good practice, **Citizenship, thinking skills and cognitive acceleration teaching programmes, joint marking exercises**
Management of Learning (helping Y7 students become 'professional pupils')	7.4	**Extended post-transfer induction programmes mainly in PSE and Humanities including acquisition of study skills, thinking strategies etc. Identifying preferred learning styles. Improving motivation of disaffected learners, peer tutoring**

Source: Galton *et al.* (2003b).

Initiatives that were rare at the time of the (1999) Phase I review have been highlighted in bold.

'bridging units' is exemplary in this regard, being substantially informed by relevant research evidence built up over recent years (Braund & Hames 2005; Braund 2007, 2008, 2009).

Bridging units were provided for English and mathematics within the National Strategies, but not for science. In this project primary and secondary teachers came together, with support, to collaborate on work that their pupils would start at the end of primary school and complete in secondary school.

Following implementation, the units were evaluated. Results showed an overwhelmingly positive response from the children. The primary teachers were also very positive, their only concern being that the work might not be continued in or sufficiently valued by their receiving school. The secondary teachers, though more moderate in their response, still considered the units valuable, reporting that their pupils had enjoyed the programme. Further, in a limited-scale pilot study, it was found that reassessing the children on selected questions from their Key Stage 2 tests showed positive, albeit small, gains for those who had participated in the project compared with those who had not, though, as expected, both exhibited some regression.

Others have criticised bridging units (eg Galton 2002; Galton *et al.* 2003a) pointing to a lack of success when they are 'off the shelf' rather than prepared by the users, when their purpose is unclear, when they do not sit easily with primary teachers' intentions for the final term, when they are not followed through effectively by secondary teachers and, importantly, when they fail to present children with fresh experiences and new challenges.

Braund's work, however, illustrates the value of applying the outcomes of previous research in the design of new initiatives. In the case of bridging units, it shows that, thoughtfully planned and presented, such programmes can have positive outcomes for pupils and also, in terms of their professional development, for teachers, a conclusion independently supported by developments in Suffolk. There are, of course, constraints on this approach, not least the limited number of subjects that could be simultaneously served and the problems encountered in areas where there are no well-defined 'school families'.

Braund (2008) stresses, quite properly, that no one strategy is sufficient to provide successful primary–secondary transfer. Further developments have been undertaken where primary and secondary teachers are involved in co-planning, co-observation and co-teaching in science. In an interesting project, topics taught at both Key Stages 2 and 3 are indentified and approaches are devised so that the work continues to engage and challenge the pupils after transfer and teachers in both phases can make explicit the links between the earlier and later learning experiences.

In many of the most successful interventions primary teachers and secondary teachers worked together, in an atmosphere of professional trust and esteem, to progress their pupils' learning. It should be noted that the support of local authority and or university-based personnel was often also a factor in securing a favourable outcome. Whatever measures are adopted, however, means for embedding them into school planning documents and schemes of work are essential—research has shown inter-school links to be very vulnerable to staff changes and interventions can easily evaporate with time (Jarman 2000). It is important, too, to evaluate their effectiveness on an ongoing basis.

7.7 Conclusions

Schools deal well with the pastoral aspects of primary–secondary transfer and the majority of pupils settle quickly into their new schools. Typically, the academic aspects of transfer are addressed less effectively and the limited provision for cross-phase curricular continuity has been described as a 'longstanding weakness' within our education system (Ofsted 2002, p. 2). Though there are examples of good practice and it is gratifying to be able to report that their incidence is increasing, many schools fail to take account and advantage of pupils' prior learning in mathematics and science. Where partner primary and secondary schools have little knowledge of their respective practices, children may suffer low teacher expectation and/or excessive repetition of previous work. It is widely accepted that these can have a negative impact on both their interest and their progress. These are serious matters at an impressionable time in a child's life and an important time in his or her learning journey. This case has been stated most starkly in a Scottish report advocating primary–secondary cooperation (SCCC 1986, p. 19):

'We are persuaded that the period between ten and fourteen is the time when young people are won or lost from schooling; that is the time when they recognise its point and purpose, or when they reject it.'

It is acknowledged that fostering continuity and progression across the primary–secondary interface represents one of the more complex and challenging issues facing our schools. However, through the experiences of those who are actively researching and developing strategies to promote pupils' interest and progress in learning at transfer, important information is being gained about how successful practice in this regard might be furthered. Where individuals and institutions see definite benefits associated with transfer activities, they are more likely to commit time and effort thereto. To this end, the case for attending to cross-phase continuity in learning, as an important aspect of a school's overall responsibility to ensure its pupils achieve their full potential, may need to be made more effectively than at present.

Planning for continuity and progression in mathematics and science should include a consideration of curriculum, pedagogy, assessment and attainment. It is particularly important that teachers in the secondary school be familiar with the standards of work achieved by pupils in their primary schools. The promotion of continuity in learning in mathematics and science can and should be enhanced by programmes which aim, more generally, to sustain children's interest in and motivation to learn and to develop their role as 'professional learners'.

There is a need for the more efficient transfer and effective use of pupil records across the primary–secondary interface. This requires the design of record systems that are sufficiently detailed to be useful and sufficiently concise to be usable. Further advantage could be taken of the new technologies to facilitate the exchange of actionable information. To enhance their sustainability, successful primary–secondary transfer practices need to be embedded into schools' policies and key planning and improvement documentation. They should be the subject of review and revision on a regular basis. The promotion of successful cross-phase transfer should be recognised as the shared responsibility of central and local government working together with primary and secondary schools. Government and its agencies will need to give more consistent attention to the issue of primary–secondary transfer, maintaining the matter as a high priority and recognising that work in this regard is demanding of time and resource. Approaches involving primary and secondary teachers working together, and especially those which involve them observing in each others' classrooms, have proved particularly profitable and should be encouraged where practicable.

Finally, some interesting and exciting work is taking place in mathematics and science in relation to primary–secondary transfer. The challenge that remains—and it is a substantial one—is how best to disseminate these ideas, to encourage other schools to address these issues, and to support them effectively as they do so. The Society's aspiration is that children, right across the UK, may maintain and indeed develop their energy and enthusiasm for learning in these important areas of the curriculum.

Recommendation 14

National regulators and developers of curricula and assessment should carefully review the impact of new and revised curricula and assessment arrangements on primary-secondary transfer in science and mathematics.

Recommendation 15

While longitudinal studies of children's developing mathematical abilities across the primary-secondary interface already take place, there is a need for the Economic and Social Research Council and other education research funders to encourage similar, high-quality studies of children's developing scientific knowledge, understanding and skills and how these are applied to the world around them. This should include, using a range of methods, research on boys' and girls' attitudes towards science and mathematics and how these change during primary and early secondary education.

8 Conclusions

8.1 Initial reflections

The Royal Society first announced its intention to survey primary and early secondary science and mathematics education in 2007 (Royal Society 2007, p. 1). The publication of this report reflects a burgeoning of evidence recognising the tremendous significance that children's early educational experiences of science and mathematics may have in determining their attitudes towards, enthusiasm for and desire to study further or pursue a career in these or related STEM subjects. It also reflects the Society's concern that, despite entries to mainstream science and mathematics A-levels generally rising across the UK in recent years, participation in later secondary and tertiary education has consistently, and for too long, been at too low a level to meet the needs of the economy, indicating that a fresh approach is needed to tackle this ingrained problem.

The approach to this study has been similar to that undertaken in compiling previous 'state of the nation' reports (Royal Society 2007, 2008), and similar difficulties have arisen. It has been challenging, for instance, to ensure that coverage of each of the Home Nations is balanced. The visible imbalances reflect genuine difficulties in unearthing comparable information, or the fact that such information is simply unavailable (an example being the lack of any disaggregated data on attainment by different ethnic populations in Northern Ireland). Equally, the report's authors have been acutely conscious of the danger of making generalisations about shared patterns of attainment, the cause(s) of which may actually be very different.

The Society has purposefully not attempted to investigate in detail differences in the UK curricula: these would merit a separate report. However, rather like the Earth's tectonic plates, their structure and content are constantly shifting, with there being a noticeable increase in curriculum development activity during the first decade of the 21st century, and as was noted in the second 'state of the nation' report, an accelerating divergence of the UK's education systems that makes fair comparisons, let alone generalisations, increasingly difficult.

Nonetheless, while the education systems of England, Northern Ireland, Scotland and Wales continue to move apart from one another, it is clear that each must in its own way tackle a largely common set of challenges. This report therefore has set out to establish what these challenges are.

8.2 The status of 5–11 science and mathematics curricula and assessment in primary schools

Ideological notions of what primary education should be about have been subjugated to the constraints of the curricula and their associated assessment systems. Finally, however, the inability of written tests at Key Stage 2 to assess science attainment in necessary depth, together with their impact on the curriculum and on pupils' enjoyment of science, has been recognised, resulting in the abandonment of national testing in science at Key Stages 2 and 3 in England (as well as, at an early juncture, in Northern Ireland and Wales).

However, some commentators have perceived the ending of testing as indicative of a reduction in the status of science in the primary curriculum. This view gains some support from the manner in which science is now included in the curricula of Northern Ireland and Wales within broad areas of study rather than as a subject in its own right. Similarly, had the proposed new primary curriculum for England been ratified in April 2010, science would have been contained within an area of 'scientific and technological understanding'. Only in the proposed Curriculum for Excellence in Scotland is science retained as a standalone subject.

The reduced degree of prescription in the curricula will allow teachers more flexibility to choose content of relevance to their pupils, but there is a danger of a return to broad 'topics' in which science features in the plans but is given a surface treatment in practice. The danger is likely to be increased if there continue to be shortages of science specialists in the primary workforce. Should this transpire, then it will be considerably out of line with trends across the world of raising the status of science in pre-secondary education.

Although the National Strategies are to be dissolved in 2011, the Government has consistently indicated that mathematics should continue to be regarded as a 'core' subject in the English primary curriculum. But it is disappointing that national tests in Key Stage 2 mathematics in England have yet to be abolished. The arguments for ending these are similar to those that were successful in persuading policy-makers to abandon Key Stage 2 tests in science. It is to be hoped that these tests will be removed in due course in favour of teacher-led assessment and national sampling. Persistence with high-stakes tests will continue to discourage innovative approaches to teaching mathematics. Mathematics is treated as a separate subject in Scotland at primary level, but it is concerning to see that future Scottish Surveys of Achievement will focus purely on literacy and numeracy.[95]

8.3 Judging and then improving the effectiveness of 5–14 science and mathematics in the UK

8.3.1 Pupil attainment

There are genuine difficulties in providing data that are of sufficient and consistent quality and reliability for

95 See http://www.ltscotland.org.uk/assess/of/ssa/index/2009.asp, accessed 7 April 2010.

policy-makers to judge the effectiveness of each of the UK's education systems and to be able to determine in an informed way where and precisely what change is needed.

Chapter 3 analysed currently available data on pupil attainment in science and mathematics, these being the official and, therefore, the most obvious measures of education system performance. Throughout, the Levels of attainment reported have included data both from assessment by teachers and from national tests, where available. These two methods of assessment were built into the national assessment arrangements from the start, acknowledging that tests would not be capable of reflecting as wide a range of performance as could be encompassed by teachers using a variety of methods.

However, it is not possible to provide an overall statement that summarises the trends and latest Levels of attainment across the UK. This is because of differences in the organisation of assessment methods used in the four nations and changes to them during the period covered by this report. It is possible to summarise the major trends in each nation, but even here inconsistencies over the years in the manner in which attainment data have been reported (most especially in England) prove confounding.

Across England, Northern Ireland and Wales, which share a similar Key Stage structure and system of assessment, Levels of attainment at or above the expected Level in science and mathematics generally levelled off across Key Stages 1–3 at some point during the mid-2000s. However, some very marked—and indeed very concerning—differences are evident in the attainment of pupils of different ethnicity and socioeconomic status. That these differences have knock-on effects higher in the education system in terms of attainment and progression in science and mathematics should send a clear message both to Government and the science and mathematics communities concerning where interventions particularly need to be focused.

As it is measured differently, attainment in Scotland is not comparable with that elsewhere in the UK, and is complicated by the fact that since 2005 there has been no central collection and reporting of individual pupil results. Since that time, data on pupils' attainment in science are only available from the 2007 Scottish Survey of Achievement.

Notwithstanding the changes to the curricula and assessment systems across England, Northern Ireland and Wales, questions remain concerning what the recorded Key Stage attainment data truly signify. Crucially, do they accurately reflect children's understanding of the subject, as opposed to their ability to deal with written test items? With respect to science, there is considerable doubt about this. Key Stage assessments in science are too dependent on how much knowledge a pupil has managed to cram in the weeks of 'drilling' to the test. Their structure prevents any real sense being gained of the extent of pupils' understanding of scientific concepts and this could lead to overestimation of pupils' knowledge/understanding of the subject at the start of secondary schooling, making successful transfer more difficult.

8.3.2 The teaching workforce

As was reported in the first 'state of the nation' report, subject specific data on the teaching workforce are sorely lacking. Attempts to uncover basic information about the numbers of science/mathematics subject specialists teaching in the primary and early secondary maintained workforce were hampered particularly by the fact that:

- there is no consistency in the way that subject specialists are counted by the UK Governments and their agencies, and indeed some (such as the GTCNI and GTCW) do not normally record this sort of information;
- following initial teacher training, details of either subject specialism or teaching phase specialism are not retained in official records, making it very hard to monitor the numbers and distribution of practising science and mathematics specialists;
- in England, reliance on provision of data on subject specialists and specialist teachers at primary/early secondary levels rests, for the time being, with the GTCE, whose estimates of the numbers of subject specialists in England vary according to the type and level of qualification(s) included in counts;
- self-reporting in Scotland by teachers of their subject specialism cannot be trusted because it is not known whether teachers are reflecting their actual deployment or the nature of their qualifications or, conceivably, both of these.

Despite these difficulties, this report has been able to establish that, in England at least, the numbers of teachers with specialist subject degrees and teaching qualifications in science and mathematics currently working in maintained primary schools are small, and indeed insufficient to cover the needs of all primary schools in England. Given the breadth of the curriculum, the current expectations for primary teachers to teach all subjects, and the variable size and geographical isolation of primary schools, it would be unrealistic to expect every school to have a specialist teacher in all subjects. Yet the string of studies showing a general lack of confidence among teachers in teaching science,[96] and the negative knock-on effects this may have in terms of switching pupils off the subject, plainly show that there is a clear, urgent need for all primary schools to be able to access practitioners with expertise in science.

While there is no doubt that the quality of teacher records needs to be improved, this should not hide the fact that guidance and clarity are urgently needed concerning how specialism should be recognised and precisely what level

96 For a review, see Harlen (2008b).

of science specialism is required by practitioners in primary and early secondary schooling.

Science needs to be enquiry-based at all levels of education, but as seen in Chapters 3 and 6, teaching to the test together with its associated fact-based approach to learning misrepresents how science works, and conflicts with children's natural curiosity and exploratory instincts. Further, the oft-reported under-confidence among teachers in teaching science is undoubtedly related to lack of science knowledge (Murphy & Beggs 2005), which seems to go hand in hand with an unwillingness to engage in practical work (NESTA 2005; Science Learning Centres 2010). Confidence comes from learning by doing (SCORE 2008), but the ability to teach science really well generally requires a genuine enjoyment of the subject. It is probable that teachers who have chosen to study science and gained bespoke qualifications in it will be more confident in undertaking practical science teaching.

A better appreciation is needed of whether the subject-based demands of teacher training courses in science are appropriate to the design and content of the curricula.

8.3.3 Initial and continuing teacher education

Across all four Home Nations pupils' attainment as measured by percentages reaching expected Levels at different times has been found to decline with increasing age. The growing demand on teachers' own subject knowledge in teaching the older age group in primary schools could be a central factor in this trend. In relation to science, teachers' own knowledge has long been a matter of concern. Research in the early 1990s (Bennett *et al.* 1992; Summers & Kruger 1992) 'revealed that many teachers not only lacked confidence and perceived competence to teach science but indeed retained many misconceptions found in school pupils' (Harlen & Holroyd 1997). The raised science requirements for entry to teacher training since that time were intended to alleviate this problem, but Chapter 4 has shown that few teachers in primary schools have more than the minimum qualifications in science and mathematics. Data provided by the GTCE showed that many registered teachers with science backgrounds gained their initial teacher training qualifications some years ago, with one count showing that 36% of these were aged 40 or more.[97] Further, there is no reliable information about how those with such qualifications are deployed. As long as all primary teachers are regarded as generalists and teach all subjects, there is a massive task of upgrading the subject knowledge and related pedagogical skills of all who teach pupils at Key Stage 2 and equivalent.

The main options for action appear to be: to raise the entry requirements for all primary teachers, as discussed in Chapter 5; to tailor initial education to prepare some teachers with suitable qualifications in science or mathematics to be subject leaders of these subjects, and possibly to teach them in the final year or two of primary school; to provide continuing professional development (CPD) opportunities for all teachers to respond to individual needs and to changing curricula and assessment requirements. The first of these risks a reduction in recruitment, which would undoubtedly set back the gains made in overall staffing levels in primary schools. The second would limit the flexible deployment of staff, which is essential to accommodate inevitable changes in curricula and pedagogy, unless teachers are to be limited in choice of where they work. The third could, in theory, benefit all teachers and provide for flexible deployment of staff provided that obstacles to the uptake of CPD are removed.

One of these obstacles is the cost to schools not only of the courses but of providing cover during teachers' absence. Another is the availability of cover, even if the cost is not a problem. A third results from usage of high stakes assessment and test results, which have been found to deter those teaching at the top of the primary school—who may most need to improve their subject knowledge—from leaving their class to attend courses.

The CPD provided by the national network of Science Learning Centres and the NCETM, together with the additional opportunities afforded by the Primary School Quality Mark, the Chartered Teacher status (CSciTeach and CMathTeach) and the Masters in Teaching and Learning all have potential to help raise levels of subject knowledge and pedagogical skills among teachers with a specialist background in these disciplines, to raise thereby the profile of science and mathematics and contribute more generally to increasing the reputation of the teaching profession. However, if they are to help solve the problems outlined in this report, it is essential that their criteria/content, uptake and impact are carefully monitored and for research to be conducted into how teachers and their schools benefit, including at what stages of teachers' careers these have the greatest effect. In addition, it is essential that CPD be sustainably funded in the long-term.

Furthermore, the need for primary schools to be able to access teachers with specialist subject knowledge and skills in teaching science and mathematics suggests a requirement for a model of local CPD delivery, based on an informed understanding of where and how such specialists are deployed.

While much attention has been given to initial and continuing education aiming to improve teachers' subject knowledge, the points made earlier about assessment lend considerable weight to a strong focus on developing teachers' ability in assessment. Currently little time is given to this in initial education courses, and in CPD science courses provided by the network of Science Learning Centres fewer than 2.5% of courses for primary teachers deal with teaching, learning and assessment combined (see Table 5.3). At a time when new curricula across the

97 Alison Vale (Data Governance Team Leader, GTCE), personal communication, 29 October 2009.

UK are emphasising key skills and problem-solving, it is essential that these are included in reliable assessment if they are to be taken seriously. This is of particular concern at the present time when teachers' assessment is under the spotlight as a dependable replacement for tests.

8.4 Improving attainment and engagement in science and mathematics education 5–14

Chapter 6 reviewed some of the key factors within and outside the classroom that affect pupils' learning. With this knowledge, from research and experience, it ought to be possible to improve not just pupils' attainment but also their enjoyment and interest in studying science and mathematics. Yet much classroom practice appears to neglect what has been shown to be effective. For instance, while the advantages of discussion, working in groups and using an enquiry-based approach are known, research still reports that pupils find science boring and uninteresting because they mostly experience whole-class teaching (Pell & Jarvis 2001) and generally inadequate stimulation from practical work (HMI/Ofsted 2004). This calls for research into factors that are inhibiting teachers from using the most effective approaches, whether due to lack of knowledge or lack of necessary skills in implementing them. Transfer of the findings of practice-based educational research into pedagogical practice during initial teacher training and post-qualification continuing professional development needs to be improved.

Fortunately not all research has been ignored and Chapter 6 also points to pre-school provision and home support, including opportunities for free provision of computers and Internet access in low-income families through the Home Access Programme. The strong influence of home learning background on children's cognitive development means that much can be done outside the classroom to help children's learning. Science is particularly well served by museums, interactive science centres, zoos, etc, most of which have provision for organised programmes as well as for informal learning. There is much to be found out about how to make best use of such opportunities and ongoing research is to be welcomed.

One of the benefits of learning outside the classroom is reported to be more positive attitudes towards science, but exactly what this may mean is in need of further clarification. Current methods of measuring attitudes are of questionable validity, often comprising a varied mixture of self-concept, self-confidence, liking and valuing the subject. Using these measures, the overall trend shows a decline as pupils pass through the primary school and the secondary school. Taking attitude as meaning willingness to undertake particular activities, this decline is a matter of concern in the face of the need both for more participation in STEM subjects in the upper years of secondary education and the need for improved scientific literacy in the whole population. Research is needed in this area to clarify what aspects of affective response are important in determining pupils' decisions about continuing to study science and mathematics post-16, what it is that influences these responses and what, if anything, can be done to promote more positive responses.

8.4.1 Primary–secondary transfer

An important influence on pupils' performance and attitudes in early secondary education is the process of transfer from primary school. Attitudes to science and mathematics have been reported to fall from pre-transfer to post-transfer and to continue to decline in secondary school. It is relevant to note that some changes also occur in attitudes to English, but to a smaller degree and less consistently. There is evidence, also, from studies of national test results in England of a decline in Levels of attainment in science but not in mathematics and English.

Reasons for these trends include the need to adjust to the different scale and structure of life in secondary schools and to the more academic content and ways of study pupils encounter. Schools generally have attended well to the first of these, eg, through visits and buddying arrangements. Ways of dealing with the second, including the use of 'bridging units' to provide some continuity in learning, have been developed. However, research indicates that teaching methods show less continuity and pupils often encounter repetition of previous work and reduced expectation of what they can achieve just at a time when they are eager for new challenges.

That this repetition is more likely to arise from secondary teachers' lack of knowledge of primary science and mathematics than from planned reinforcement raises several questions about how the curricula are developed and communicated.

When the national curricula in science and mathematics were created in 1989, they covered the whole of primary and secondary education, ages 5–16. The new curricula in Northern Ireland, Scotland and Wales, introduced from 2007 onwards, now extend from reception/foundation to the end of secondary education. But in England the revised primary curriculum resulting from the Rose Review, which has recently been abandoned by the new Government,[98] was produced after the implementation of the Foundation Stage curriculum and the new Key Stage 3 and Key Stage 4 curricula. The impression gained is of continuity across boundaries to and from primary school being an after-thought. Secondary teachers, concerned with the implementation of a new Key Stage 3 curriculum have understandably given less attention to continuity with what primary pupils currently learn in Year 6 under the 'old' curriculum and to whether this would change in the revised curriculum.

Aside from curricula reform, the schooling infrastructure has been changing. The Plowden Report (1967) initially prompted the creation of middle schools in England, but

98 *Op. cit.*, note 60.

their numbers fell during the 1980s, and particularly thereafter in response to the introduction of the National Curriculum with its division of the curriculum at Key Stage 2 and Key Stage 3 favouring the old primary/secondary school division, and have continued to fall since. However, since 2000, new concept academies have been introduced, a number of which are all-through schools catering for learners throughout primary and secondary education (up to age 16 and sometimes beyond). Since September 2007, 13 such all-through schools have been created.[99] It is too early to see whether these schools successfully bridge the traditional divide between primary and secondary, but it will be important to monitor whether the traditionally recorded dips in attitude and attainment are as marked in these schools.

8.5 Looking to the future

As this report has shown, the UK's educational systems have been in a state of constant flux, with changes to the curriculum and/or assessment system at various times during the period covered. It is certainly the case in England that these changes have been happening without any obvious attention being paid to the numbers and distribution of subject specialists or to the more general training and development needs of the workforce.[100]

The rushed introduction of a new primary curriculum for England—which may be compared with the considerably longer and more considered equivalent processes undertaken in Northern Ireland, Scotland and Wales—was thwarted by the dissolution of Parliament prior to the May General Election. It is to be hoped that the new Government will take a more constructive and holistic approach to the curriculum and assessment planning process that involves establishment of a parallel programme of evaluation.

Of course, the responsibility for driving up the quality of primary science is a shared one. In England, the STEM directories, created and supported by a partnership between Government and leading organisations within the UK STEM Community, provide details of 142 schemes across the UK that are geared to enriching or enhancing the primary curriculum. In addition to the monitoring of current schemes and new ones being encouraged, there is an independent need for the business community and key learned and professional STEM bodies to invest more of their resources in fostering high quality primary science education. This investment needs to be sustained and will particularly be required for as long as science specialists are underrepresented in the workforce. Increased funding of science at the grass roots will, in time, reap dividends in terms of producing the scientists, engineers and mathematicians needed to help secure our future prosperity in the new scientific century (Royal Society 2010b).

99 See http://www.standards.dfes.gov.uk/academies/, accessed 6 April 2010.

100 We note that during the early 1990s, 20 day courses in primary science were funded and a certain amount of time in them had to be devoted to subject knowledge.

8.6 Final thoughts

The increasing divergence across the nations of the UK in policies and provision for education in science and mathematics for pupils aged 5–14 can be an important source of information to aid understanding of what works best in certain circumstances. However, there are many aspects of this provision where this report has been unable to obtain relevant data about pupil performance, teacher qualifications, participation in continuing professional development and the deployment of staff. A key overarching requirement is a need for improved records in a form that enable comparisons of key statistics across time and among the four nations.

This report reinforces how important education in the primary and early secondary years is. But it has also revealed many areas of practice that are in need of urgent attention to inform decisions about how best to provide education in science and mathematics for pupils in these formative years. Among the most pressing are: (i) how to develop and disseminate pedagogy that meets the aspirations of new curricula to promote skills of thinking and enquiry and of problem solving; (ii) how to improve the provision and of uptake of continuing professional development of teachers; (iii) how to support teachers in dependable assessment practice if assessment by teachers is to replace tests; (iv) what are the pros and cons of specialist teaching in the final years of primary education; (v) how to make best use of new technologies and (vi) how can transition between primary and secondary education be made smoother.

Recommendation 16

A co-ordinated programme of evidence-based quantitative and qualitative research into primary science and mathematics education in the UK is required to inform future policy decisions. This should be developed from the Economic and Social Research Council's Targeted Initiative on Science and Mathematics Education which focuses on the secondary and later phases, and should reference the Alexander Review of Primary Education. Other funders of educational research within this area, including the Wellcome Trust, the Gatsby Foundation and the Nuffield Foundation, should be involved in determining a suitable framework.

However, above all, there is a need for all the key players and stakeholders, including Government and industry, to collaborate and coordinate policies, strategies and activities to ensure that all children receive the best possible science and mathematics education and are able to access and make the most of the available opportunities to study these and related subjects to all levels, both inside and outside the classroom.

9 Glossary

AAP	Assessment of Achievement Programme
ACES	Advisory Council on Education in Scotland
ACME	Advisory Committee on Mathematics Education
AfL	Assessment for Learning
APU	Assessment of Performance Unit
ASE	Association for Science Education
AST	Advanced skills teacher
BEd	Bachelor of Education
CCEA	Council for the Curriculum Examinations and Assessment (Northern Ireland)
CLEAPSS	Consortium of Local Education Authorities for the Provision of Science Services
CMathTeach	Chartered Mathematics Teacher status
CPD	Continuing professional development
CSciTeach	Chartered Science Teacher status
DBIS	Department for Business, Innovation and Skills
DCELLS	Department for Children, Education, Lifelong Learning and Skills
DCSF	Department for Children, Schools and Families
DENI	Department for Education, Northern Ireland
DES	Department for Education and Science
DfEE	Department for Education and Employment
DfES	Department for Education and Skills
EAL	English as an additional language
EPPE	Effective Provision of Pre-school Education project
FE	Further education
FSM	Free school meal
GCSE	General Certificate of Secondary Education
GTC	General Teaching Council
GTCE	General Teaching Council for England
GTCNI	General Teaching Council for Northern Ireland
GTCS	General Teaching Council for Scotland
GTCW	General Teaching Council for Wales
GTTR	Graduate Teacher Training Registry
HLTA	Higher Level Teaching Assistant
HMI(E)	Her Majesty's Inspectorate (of Education)
HMSO	Her Majesty's Stationery Office
ICT	Information and communications technology
IDACI	Income Deprivation Affecting Children Index
INSET	In-service education and training
ITT	Initial teacher training

KS	Key Stage
MaST	Mathematics Specialist Teacher
MTL	Masters in Teaching and Learning
NCETM	National Centre for Excellence in the Teaching of Mathematics
NFER	National Foundation for Educational Research
NQT	Newly Qualified Teacher
NSLC	National Science Learning Centre
NT	National Test(s)
NUT	National Union of Teachers
OECD	Organisation for Economic Co-operation and Development
Ofsted	Office for Standards in Education
PGCE	Postgraduate Certificate in Education or Professional Graduate Certificate in Education
PGDE	Postgraduate Diploma in Education
PIPS	Performance in Primary Schools
PRS	Primary Specialised Subjects (3/5–11 years, KS1+2)
QCA	Qualifications and Curriculum Authority
QTS	Qualified Teacher Status
SATs	Standard Assessment Tasks or Standard Attainment Tests
SCORE	Science Community Representing Education
SFR	Statistical first release
SLC	Science Learning Centre
SSA	Scottish Survey of Achievement
SSERC	Scottish Schools Equipment Research Centre
STEM	Science, technology, engineering and mathematics
TA	Teacher assessment(s)
TDA	Training and Development Agency for Schools
TIMSS	Third International Mathematics and Science Study
UCAS	Universities and Colleges Admissions Service
WAG	Welsh Assembly Government

10 References

ACCAC (2004). Review of the school curriculum and assessment arrangements 5–16. A report to the Welsh Assembly Government. Awdurdod Cymwysterau, Cwricwlwm & Asesu Cymru: Cardiff.

ACES (Advisory Council on Education in Scotland) (1946). *Primary education*. Edinburgh: HMSO.

ACME (Advisory Committee on Mathematics Education) (2009). *The mathematics education landscape in 2009. An overview of the latest issues facing the 5–19 mathematics landscape produced for the DCSF/DIUS STEM Higher Level Strategy Group*. ACME: London, UK. See http://www.acme-uk.org/downloaddoc.asp?id=139, accessed 28 March 2010.

Albone S & Tymms P (2004). *The impact of the National Numeracy Strategy on children's attitudes to mathematics*. British Educational Research Association Annual Conference, UMIST: Manchester, UK.

Alexander R (ed.) (2010). *Children, their world, their education. Final report and recommendations of the Cambridge Primary Review*. Routledge: Abingdon, Oxon.

Alexander, R & Hargreaves, L (2007). Community soundings: the Primary Review witness sessions. Faculty of Education: Cambridge, UK.

Askew M, Brown M, Rhodes V, Wiliam D & Johnson D (1997). *Effective teachers of numeracy.* Report for the Teacher Training Agency. King's College London: London, UK.

Askew M, Hodgen J, Hosssain S & Bretscher N (2010). *Values and variables. Mathematics education in high-performing countries*. Nuffield Foundation: London, UK.

Baines E, Blatchford P, Kutnick P, Chowne A, Ota C & Berdondini L (2008). *Promoting effective group work in primary schools: developing relationships to enhance learning and inclusion. A guide for teachers*. Routledge: London, UK.

Balls E (2009). *Primary schools*. Written Ministerial Statement, 19 November 2009. See http://www.dcsf.gov.uk/newprimarycurriculum/

Bangs J (2010). Maintaining an outstanding workforce. In *The future of the teaching workforce: licences, recruitment and development*, p. 44. Uncorrected transcript from a conference held on 20 January 2010. Westminster Education Forum: London, UK.

Becker BJ (1989). *Gender and science achievement: a re-analysis of studies from two meta-analyses*. J. Res. Sci. Teach. **26**, 141–169.

Belot M & James J (2009). *Healthy meals and educational outcomes*. Institute for Social & Economic Research: Colchester, Essex.

Bennett J & Hogarth S (2005). *Would YOU want to talk to a scientist at a party? Students' attitudes to school science and science*. Research Paper 2005/8. University of York Department of Educational Studies: York.

Bennett SN, Wragg EC, Carre CG & Carter DSG (1992). *A longitudinal study of primary teachers' perceived competence in, and concerns about, National Curriculum implementation.* Res. Papers Educ. **7**, 53–78.

Birmingham Educational Development Centre (1975). *Continuity in education (junior to secondary). EDC Project Five: Final Report.* City of Birmingham Education Department: Birmingham.

Black P, Harrison C, Lee C, Marshall B & Wiliam D (2003). *Assessment for learning: putting it into practice.* Open University Press: Buckingham.

Blatchford, P, Bassett, P, Brown, P, Koutsoubou, M, Martin, C, Russell, A & Webster, R (with Rubie-Davies, C) (2009). *Deployment and impact of support staff in schools: the impact of support staff in schools (results from Strand 2, Wave 2)*. DCSF Research Report RR148. Institute of Education: London, UK.

Board of Education (1926). *The education of the adolescent. Report of the Consultative Committee (Hadow Report).* HMSO: London, UK.

Board of Education (1931). *The primary school.* Report of the Consultative Committee (Hadow Report). HMSO: London, UK.

Braund M (2007). *'Bridging work' and its role in improving progression and continuity: an example for science education*. Br. Educ. Res. J. **33**, 905–926.

Braund M (2008). *Starting science . . . again? Making progress in science learning*. Sage: London, UK.

Braund M (2009). Progression and continuity in learning science at transfer from primary to secondary school. In *Perspectives on Education 2 (Primary–secondary transfer in science)*, pp. 22–38. The Wellcome Trust: London, UK.

Braund M & Hames V (2005). *Improving progression and continuity from primary to secondary science: pupils' reactions to bridging work*. Int. J. Sci. Educ. **27**, 781–801.

Breakwell GM & Beardsell S (1992). *Gender, parental and peer influences upon science attitudes and activities.* Public Understanding Sci. **1**, 183–197.

Brown M (2007). *The story and the effects of national testing in English schools*. See http://www.docstoc.com/docs/18679162/the-story-and-the-effects-of-national, accessed 21 February 2010.

Brown M, Askew M, Millett A & Rhodes V (2003). *The key role of educational research in the development and* *evaluation of the National Numeracy Strategy*. Br. Educ.Res. J. 25, 655–672.

Brown M, Askew M, Hodgen J, Rhodes V, Millett A, Denvir H & Wiliam D (2008). Progression in numeracy ages 5–11: results from the Leverhulme longitudinal study. In *Mathematical difficulties: psychology and intervention.* Dowker A (ed.), pp. 85–108. Academic Press/Elsevier: San Diego.

Bunyan P (1998). *Comparing pupil performance in Key Stage 2 and 3 science SATs*. School Sci. Rev. 79, 85–87.

CACE (1967a). *Children and their primary schools (Plowden Report)*. HMSO: London, UK.

CACE (1967b). *Primary education in Wales (Gittins Report)*. HMSO: London, UK.

Christie D, Donaldson C, Howe C, Jessiman E, Livingston K, Thurston A, Tolmie A & Topping K (2004). *The impact of enhanced group work in primary classrooms*. ESRC Teaching and Learning Research Programme Annual Conference, Cardiff.

Colley A, Comber C & Hargreaves D (1994). *School subject preference of pupils in single sex and co-educational secondary schools*. Educ. Stud. 20, 379–385.

Collins S, Reiss M & Stobart G (2008). *The effects of national testing in science at KS2 in England and Wales. Executive Summary*. Report commissioned by the Wellcome Trust in association with the ASE. Institute of Education: London, UK. See http://www.wellcome.ac.uk/stellent/groups/corporatesite/@msh_peda/documents/web_document/wtd039972.pdf

Comber LC & Keeves JP (1973). *Science in nineteen countries*. Wiley: New York.

Cowan R & Saxton M (2010). Understanding diversity in number development. In *Psychological aspects of education: current trends.* In *Number development and difficulty.* Cowan R, Saxton M & Tolmie A (eds). Br. J. Educ. Psychol. Monograph Series II, no. 7, pp. 1–14.

Cuban L (2002). *Oversold and under-used: computers in the classroom.* Harvard University Press: Cambridge, MA.

Davenport P & Howe C (1999). *Conceptual gain and successful problem-solving in primary school mathematics.* Educ. Stud. 25, 55–78.

de Abreu G (1995). *Understanding how children experience the relationship between home and school mathematics.* Mind, Culture and Activity 2, 119–142.

DBIS (2010). *Science and mathematics secondary education for the 21st century*. Report of the Science and Learning Expert Group. Department for Business, Innovation and Skills: London, UK.

DCSF (2008). *The National Strategies. Strengthening transfers and transitions. Partnerships for progress*. DCSF: London, UK.

DCSF (2009a). Your child, your schools, our future: building a 21st century schools system. TSO: London, UK.

DCSF (2009b). *Education and training statistics for the United Kingdom: 2009 (Internet only)*. See http://www.dcsf.gov.uk/rsgateway/DB/VOL/v000891/index.shtml, accessed 25 March 2010.

DCSF (2009c). *Key Stage 1 attainment by pupil characteristics in England, 2008/09.* See http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000899/index.shtml

DCSF (2009d). *National Curriculum assessments at Key Stage 2 in England, 2009. (Revised.)* See http://www.dcsf.gov.uk/rsgateway/DB/SFR/s000893/index.shtml

DCSF/NFER (2008). *Secondary School Curriculum and Staffing Survey 2007.* Research Report DCSF-RR026. DCSF: London, UK.

DCSF/Ofsted (2009). *A School Report Card: prospectus*. DCSF: Annesley, Nottingham.

Dearing R (1994). *The National Curriculum and its assessment.* Final report. School Curriculum and Assessment Authority: London, UK.

DENI (1981). *Primary education. Report of an Inspectorate survey in Northern Ireland*. Department of Education Northern Ireland: Belfast.

DENI (1988). *Education in Northern Ireland. Proposals for reform*. Department of Education Northern Ireland: Belfast.

DENI (1990). *Aspects of provision and responses in education in Northern Ireland 1987–1989. A report by the Department's Inspectorate*. Department of Education Northern Ireland: Belfast.

DENI (1996). *The quality of teaching and learning in English, mathematics and science in a sample of primary schools 1994–95*. Department of Education, Northern Ireland: Bangor.

DENI/DELNI (2009). *Report of the STEM review*. Department of Education Northern Ireland/Department for Employment and Learning: Belfast.

Department for Education and Employment (2001). *Schools building on success*. TSO: London, UK.

Department of Education and Science (1983). *9–13 middle schools: an illustrative survey*. HMSO: London, UK.

DES (1978a). *Primary education in England.* A report by HMI. HMSO: London, UK.

DES (1978b). *Primary education in England. A survey.* HMSO: London, UK.

DES (1982). *Mathematics counts (Cockcroft Report)*. HMSO: London, UK.

DES (1987). *The National Curriculum 5–16: a consultative document*. HMSO: London, UK.

DES/WO (1988). *Task Group on Assessment and Testing: a report*. Department of Education and Science and Welsh Office: London, UK.

DfES (2008). *Gender and education: the evidence on pupils in England*. DfES: London, UK.

Duckworth K (2007). *What role for the 3Rs? Progress and attainment during primary school. DCSF Research Brief no. DCSF-WBL-01-07*. See http://www.dcsf.gov.uk/research/data/uploadfiles/DCSF-WBL-01-07.pdf

Derricott R (1985). 'Establishing curricular continuity'. In *Curriculum continuity: primary to secondary.* Derricott R (ed.). NFER–Nelson: Windsor.

Dowker A & Sigley G (2010). Targeted interventions for children with arithmetical difficulties. In *Psychological aspects of education: current trends. Number development and difficulty.* Cowan R, Saxton M & Tolmie A (eds). Br. J. Educ. Psychology Monograph Series II, no. 7.

Ecsite-uk (2008). *Inspiration, engagement and learning: the value of science & discovery centres in the UK. Working towards a benchmarking framework.* See http://sciencecentres.org.uk/reports/downloads/inspiration-engagement-learning-the-value-of-science-discovery-centres-in-the-uk.pdf

EPPI (2003). *The impact of collaborative CPD on classroom teaching and learning.How does collaborative continuing professional development (CPD) for teachers of the 5–16 age range affect teaching and learning?* Evidence for Policy and Practice Information and Co-ordinating Centre, Institute of Education: London, UK.

Erickson G & Erickson L (1984). *Females and science achievement: evidence, explanations and implications.* Sci. Educ. 68, 63–89.

ETI (1999). *Children and their learning. Primary inspections (1992–98).* Education and Training Inspectorate, Department of Education: Bangor.

ETI (2001). *Survey of science and technology and design (1990–2000)*. Education and Training Inspectorate, Department of Education: Bangor.

Francis LJ & Greer JE (1999). *Measuring attitude towards science among secondary school students: The affective domain.* Res. Sci. Technol. Educ. 17, 219–226.

Fraser B (1982). *How strongly are attitude and achievement related?* School Sci. Rev. 63, 557–559.

Galton M (2002). *Continuity and progression in science teaching at Key Stages 2 and 3.* Cambridge J. Educ. 32, 250–265.

Galton M (2009). Moving to secondary school: initial encounters and their effects. In *Perspectives on Education 2 (Primary–secondary transfer in science)*, pp. 5–21. The Wellcome Trust: London, UK.

Galton M & MacBeath J (2002) *A life in teaching? The impact of changes on primary teachers' working lives.* A report for the National Union of Teachers (NUT). Faculty of Education, University of Cambridge.

Galton M, Gray J & Rudduck J (1999). *The impact of school transitions and transfers on pupil progress and attainment.* Research Report RR131. Department for Education and Employment: London, UK.

Galton M, Gray J, Rudduck J, Berry M, Demetriou H, Edwards J, Goalen P, Hargreaves L, Hussey S, Pell T, Schagen I & Charles M (2003a) *Transfer and transitions in the middle years of schooling (7–14): continuities and discontinuities in learning*.

Galton M, Hargreaves L & Pell T (2003b). *Progress in the middle years of schooling: continuities and discontinuities at transfer.* Education 3–13 31, 9–18.

Galton M, Edwards J, Hargreaves L & Pell T (2003c). *Transfer and transitions in the middle years of schooling (7–14): continuities and discontinuities in learning*. DfES Research Report 443, pp. 43–74. Annesley, Department of Education and Science.

Galton M, Gray J & Rudduck J (2003d). *Transfer and transition in the middle years of schooling (7–14*): *continuities and discontinuities in learning*. DfES Research Report 443. Department of Education and Science: Annesley.

Gorwood B (1986). *School transfer and curriculum continuity.* Croom Helm: Beckenham.

Gove M (2009). *A comprehensive programme for state education.* Speech, 6 November 2009. See http://www.conservatives.com/News/Speeches/2009/11/Michael_Gove_A_comprehensive_programme_for_state_education.aspx, accessed 28 February 2010.

Gray J (2009). *School experiences and adolescent well-being: the effects of transfer from primary to secondary school*. Nuffield Foundation seminar. Adolescent transitions: social and educational challenges. Nuffield Foundation: London, UK.

Green S & Oates T (2007). How to promote educational quality through national assessment systems. A paper presented at the International Association for Educational Assessment Annual Conference, Baku, Azerbaijan, September 2007.

Harding J (1983). *Switched off: the science education of firls.* Longman: New York.

Hargreaves L & Galton M (2002). *Transfer from the primary classroom: 20 years on*. Routledge & Falmer: London, UK.

Harland J, Kinder K, Ashworth M, Montgomery A, Moor H & Wilkin A (1999). *Real curriculum: at the end of Key Stage 2.* Report One from the Northern Ireland Curriculum Cohort Study. NFER: Slough.

Harland J, Moor H, Kinder K & Ashworth M (2002). *Is the curriculum working? The Key Stage 3 Phase of the Northern Ireland Curriculum Cohort Study.* NFER: Slough.

Harlen W (1983). *Basic concepts and the primary/secondary science interface*. European J. Sci. Educ. 5, 25–34.

Harlen W (1996). *Four years of change in education 5–16.* SCRE: Edinburgh.

Harlen, W (2007). *Assessment of learning.* Sage: London, UK.

Harlen W (2008a). *Assessment of learning*. Sage, London, UK.

Harlen W (2008b). Science as a key component of the primary curriculum: a rationale with policy implications. In *Perspectives on education. 1. Primary science*. Wellcome Trust: London, UK.

Harlen W & Holroyd C (1997). *Primary teachers' understanding of concepts of science: impact on confidence and teaching.* Int. J. Sci. Educ. 19, 93–105.

Hattie J (1999). *Influences on student learning. Inaugural Professorial Lecture.* University of Auckland: Auckland.

Henry J (2001). *Boy-friendly tests unfair, say heads. Times Educational Supplement*, *25 May 2001*. See http://www.tes.co.uk/article.aspx?storycode=347375, accessed 1 March 2010.

Hills J, Brewer M, Jenkins S, Lister R, Lupton R, Machin A, Mills C, Modood T, Rees T & Riddell S (2010). *An anatomy of economic inequality in the UK*. Report of the National Equality Panel. Government Equalities Office/ London School of Economics and Political Science: London, UK.

HMIE (2005). *Improving achievement in science in primary and secondary schools*. HM Inspectorate of Education: Livingston.

HM Inspectors of Schools (1980). *Learning and teaching in Primary 4 and Primary 7*. HMSO: Edinburgh.

HMI/Ofsted (2004). *Science in primary schools*. HMI/Ofsted: London, UK.

HMSO (2006). *Science and innovation investment framework 2004–2014: next steps*. HM Treasury: London, UK.

Hodgen J & Wiliam D (2006). *Mathematics inside the Black Box.* NFER–Nelson: London.

Hodgen J, Küchemann D, Brown M & Coe R (2009). *Secondary students' understanding of mathematics 30 years on.* Paper presented at the British Educational Research Association Annual Conference, Manchester, September 2009.

Holmlund H, McNally S & Viarengo M (2008). *Impact of school resources on attainment at Key Stage 2*. DCSF research report RR043. DCSF: London, UK.

House of Commons (2008). *Testing and assessment.* Third report of the Children, Schools and Families Committee, Session 2007–08, volume 1 (HC 169-I). TSO: London, UK.

House of Commons (2010). *Training of teachers.* Fourth report of the Children, Schools and Families Committee, Session 2009–10, volume 1 (HC 275-I). TSO: London, UK.

House of Lords (2006). *Science teaching in schools*. Report with evidence. Science and Technology Committee, Tenth Report of Session 2005–06 (HL Paper 257). TSO: London, UK.

Howe C (1998). *Conceptual structure in childhood and adolescence*. Routledge: London, UK.

Howe C & Tolmie A (1998). Productive interaction in the context of computer-supported collaborative learning in science. In *Learning with computers: analysing productive interaction.* Littleton K & Light P (eds), pp. 24–45. Routledge: London, UK.

Hoyles C & Lagrange J-B (eds) (2010). *Digital technologies and mathematics teaching and learning: rethinking the terrain.* Springer: Dordrecht.

ILEA (Inner London Education Authority) (1986). *The Secondary Transfer Project. Bulletin 7. The views of secondary school teachers.* ILEA: London, UK.

ILEA (Inner London Education Authority) (1988). *The Secondary Transfer Project – final report. Bulletin 17. Improving secondary transfer.* ILEA: London, UK.

Institute of Electrical Engineers (1994). Views of science among students, teachers and parents.

Iuculano T, Tang J, Hall C & Butterworth B (2008). *Core information processing deficits in developmental dyscalculia and low numeracy.* Dev. Sci. 11, 669–680.

Jarman R (1990). *Primary science – secondary science continuity: a new ERA?* School Sci. Rev. 71, 19–29.

Jarman R (1995). *Science is a green field site: a study of primary science/secondary science continuity in Northern Ireland.* Educ. Res. 37, 141–157.

Jarman R (1997). *Fine in Theory: a study of primary-secondary continuity in science, prior and subsequent to the introduction of the Northern Ireland Curriculum.* Educ. Res. 39, 291–310.

Jarman R (2000). Between the idea and the reality falls the shadow: a review of provision for primary science–secondary science curricular continuity in the United Kingdom. In *Issues in science education.* Sears J & Sorensen P (ed.), pp. 133–142. Routledge: London, UK.

Jarvis T & Pell A (2005). *Factors influencing elementary school children's attitudes to science before, during and following a visit to the UK National Space Centre.* J. Res. Sci. Teach. 42, 53–83.

Joffe L & Foxman D (1984). *Assessing mathematics 5. Attitudes and sex differences.* Mathematics in School 13, 22–26.

Johnson S (1987). *Gender differences in science: parallels in interest, experience and performance.* Int. J. Sci. Educ. 9, 467–481.

Jones DV (2002). *National numeracy initiatives in England and Wales: a comparative study of policy.* Curriculum J. 13, 5–23.

Jones G, Howe A & Rua M (2000). *Gender differences in students' experiences, interests, and attitudes towards science and scientists.* Sci. Educ. 84, 180–192.

Jones M, Harland J, Mitchell H, Springate I & Straw S (2008). *Evaluation of the Chemistry for Non-Specialists training programme*. Final report. NFER: Slough.

Jones P & Elias P (2005). *Science, engineering and technology and the UK's ethnic minority population.* A report for the Royal Society. Warwick Institute for Employment Research: Coventry.

Kahle JB & Lakes MK (1983). *The myth of equality in science classrooms.* J. Res. Sci. Teach. 20, 131–140.

Kelly A, Whyte J & Smail B (1984). *Girls into Science and Technology*. Final report. Department of Sociology: Manchester.

Knuver AWM & Brandsma HP (1993). *Cognitive and affective outcomes in school effectiveness.* School Effectiveness and School Improvement 4, 189–204.

Kuhn D & Udell W (2003). *The development of argument skills*. Child Dev. 74, 1245–1260.

Lee B, Harris S & Dickson P (1995). *Continuity and progression 5–16: developments in schools.* NFER: Slough.

Levačić R, Jenkins A, Vignoles A, Steele F & Allen R (2005). *Estimating the relationship between school resources and pupil attainment at Key Stage 3.* DCSF research report RR679. DCSF: London, UK.

Ma X & Kishor N (1997). *Assessing the relationship between attitude toward mathematics and achievement in mathematics: a meta-analysis.* J. Res. Math. Educ. 28, 26–47.

McFarlane A & Sakellariou S (2002). *The role of ICT in science education.* Cambridge J. Educ. 32, 219–232.

McGregor D (2008). *The influence of task structure on students' learning processes: observations from case studies in secondary school science.* J. Curriculum Stud. 40, 509–540.

McGuiness C (1999). *From thinking skills to thinking classrooms: a review and evaluation of approaches for developing pupils' thinking.* DfEE: Nottingham.

McKinsey & Co. (2007). *How the world's best-performing school systems come out on top.* See http://www.mckinsey.com/App_Media/Reports/SSO/Worlds_School_Systems_Final.pdf, accessed 13 April 2010.

Malcolm H & Simpson M (1997). *Implementing 5–14 in primary and secondary schools: steady development? Interchange 49.* SOEID: Edinburgh.

Mareschal D, Quinn PC & Lea SEG (2009). *The making of human concepts*. Oxford University Press.

Martin A (2010). *Building classroom success: eliminating academic fear and failure*. Continuum Books: London, UK.

Massey A, Green S, Dexter T & Hammet L (2003). *Comparability of national tests over time: KS1, KS2 and KS3 standards between 1996 and 2001*. Final report to QCA of the Comparability Over Time Project (Research and Evaluation Division of the University of Cambridge Local Examinations Syndicate).

Measor L & Woods P (1984). *Changing schools. Pupils perspectives on transfer to a comprehensive.* Open University Press: Milton Keynes.

Melhuish E, Romaniuk H, Sammons P, Sylva K, Siraj-Blatchford I & Taggart B (2006a). *The Effective Pre-School and Primary Education 3–11 Project (EPPE 3–11): the effectiveness of primary schools in England in Key Stage 2 for 2002, 2003 and 2004*. DfES/Institute of Education, University of London: London, UK.

Melhuish E, Quinn L, Hanna K, Sylva K, Sammons P, Siraj-Blatchford I & Taggart B (2006b). *Effective pre-school provision in Northern Ireland (EPPNI).* Summary report 1998–2004.

Melhuish E, Sylva K, Sammons P, Siraj-Blatchford I, Taggart B, Phan M & Malin A (2008). *Preschool influences on mathematics achievement.* Science 321, 1161.

Merrell C, Jones P, Bolden D, Jones K, Defty N & Ndaji F (2010). *A review of children's and young people's attitudes to mathematics and science.* Centre for Evaluation and Monitoring: Durham. (Unpublished paper.)

MLA (2008). *Inspiring learning. Improvement toolkit for museums, libraries and archives.*

Moor H, Jones M, Johnson F, Martin K & Cowell E (2006). *Mathematics and science in secondary schools. The deployment of teachers and support staff to deliver the curriculum.* DfES Research Report no. 708. DfES: Annesley, Nottingham.

Mortimore P, Sammons P, Stoll L, Lewis D & Ecob R (1988). *School matters*. Open Books: Wells, Somerset.

Moss G, Jewitt C, Levačić R, Armstrong V, Cardidi A & Castle F (2007). *The interactive whiteboards, pedagogy and pupil performance evaluation: an evaluation of the Schools Whiteboard Expansion (SWE) project*. London Challenge (Vol. RR 816). Department for Education and Skills: London, UK.

Mullis IVS, Martin MO & Foy P (with Olson JF, Preuschoff C, Erberber E, Arora A & Galia J) (2008). *TIMSS 2007 international science report: findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades*. TIMSS & PIRLS International Study Center, Boston College: Chestnut Hill, MA.

Murphy C & Beggs J (2001). *Pupils' attitudes, perceptions and understanding of primary science: comparisons between Northern Irish and English schools.* Annual Conference of the British Educational Research Association (Leeds).

Murphy C & Beggs J (2003). *Children's attitudes towards school science.* School Sci. Rev. 84, 109–116.

Murphy C & Beggs J (2005). *Primary science in the UK: a scoping study.* Final report to the Wellcome Trust. Queen's University Belfast and St Mary's University College: Belfast.

Murphy C, Beggs J, Carlisle K & Greenwood J (2004) *Students as 'catalysts' in the classroom: the impact of co-teaching between science student teachers and primary classroom teachers on children's enjoyment and learning of science.* Int. J. Sci. Ed. 26, 1023–1035.

Murphy C, Neil P & Beggs J (2007). *Primary science teacher confidence revisited: ten years on.* Educ. Res. 49, 415–430.

Nardi E & Steward S (2003). *Is mathematics T.I.R.E.D.? A profile of quiet disaffection in the secondary mathematics classroom.* Br. Educ. Res. J. 29, 345–367.

NCETM (2009). *Researching effective CPD in mathematics education (RECME)*. Final report.

NESTA (2005). *Real science. Encouraging experimentation and investigation in school science learning*. NESTA: London, UK.

NET/Sutton Trust (2009). *Teach primary. Improving the status and quality of primary school teaching*. NET/Sutton Trust: London, UK.

NICC (1990). *Science: guidance materials*. Northern Ireland Curriculum Council: Belfast.

NICED (1986). *Guidelines for primary schools: science.* Northern Ireland Council for Educational Development: Belfast.

Nicholls G & Gardner J (1999). *Pupils in transition moving between Key Stages.* Routledge: London, UK.

Noble-Rogers J (2010). Maintaining an outstanding workforce. In *The future of the teaching workforce: licences, recruitment and development*, p. 46. Uncorrected transcript from a conference held on 20 January 2010. Westminster Education Forum: London, UK.

Nunes T, Bryant P & Watson A (2010). *Key understandings in mathematics learning.* Nuffield Foundation: London, UK. Available to download from www.nuffieldfoundation.org (In the press).

Ofsted (1998). *Secondary education 1993–97. A review of secondary schools in England.* HMSO: London, UK.

Ofsted (2002). *Changing schools: evaluation of the effectiveness of transfer arrangements at age 11*. See www.ofsted.gov.uk, accessed 19 February 2010.

Ofsted (2003). *The National Literacy and Numeracy Strategies and the primary curriculum. (HMI 1973.)* Ofsted: London, UK.

Ofsted (2007). *The Annual Report of Her Majesty's Chief Inspector of Education, Children's Services and Skills 2006/07*. The Stationery Office: Norwich.

Ofsted (2008). *Mathematics: understanding the score. Messages from inspection evidence. (Ref. 070063.)* Ofsted: London, UK.

Ofsted (2010). *The National Strategies: a review of impact.* Report 080270. Ofsted: London, UK.

Osborne J & Dillon J (2008). *Science education in Europe: critical reflections*. King's College: London, UK.

Osborne J & Hennessy S (2003). *Literature review of science education and the role of ICT: premise, problems and future directions.* Futurelab Report 6. See http://www.futurelab.org.uk/resources/documents/lit_reviews/Secondary_Science_Review.pdf

Osborne J, Driver R & Simon S (1998). *Attitudes to science: issues and concerns.* School Sci. Rev. 79, 27–33.

Osborne J, Simon S & Collins S (2003). *Attitudes towards science: a review of the literature and its implications.* Int. J. Sc. Educ. 25, 1049–1079.

Peacock A (1997). *Opportunities for science in the primary school.* Trentham Books: Stoke on Trent.

Pell A & Jarvis T (2001). *Developing attitude to science scales for use with children of ages from five to eleven years.* Int. J. Sci. Educ. 23, 847–862.

Philips S (2008) *Children's performance on and understanding of the Balance Scale problem: the effects of adult support.* PhD thesis. University of Strathclyde.

Philips S & Tolmie A (2007). *Children's performance on and understanding of the Balance Scale problem: the effects of parental support.* Infant and Child Dev. 16, 95–117.

Piaget J (1974). *The principles of genetic epistemology*. Routledge: London, UK.

Plewis I & Goldstein H (1998). *The 1997 Education White Paper—a failure of standards*. See http://www.cmm.bristol.ac.uk/team/HG_Personal/critique-of-1997-white-paper.pdf, accessed 19 February 2010.

Pines AL & West LHT (1986). *Conceptual understanding and science learning: an interpretation of research within a sources-of-knowledge framework.* Sci. Educ. 70, 583–604.

Politeia (2007). *Teaching matters: the recruitment, employment and retention of teachers.* The report of the Politeia Education Commission. Politeia: London, UK.

Politeia (2009). *Teaching matters: recruitment, employment and retention at home and abroad*. The report of the Politeia Education Commission. Politeia: London, UK.

Price GR, Holloway I, Räsänen P, Vesterinen M & Ansari D (2007). *Impaired parietal magnitude processing in developmental dyscalculia.* Current Biol. 1, R1042–R1043.

QCA (2007). *The national curriculum at Key Stages 3 and 4*. QCA: London, UK.

QCA (2008). *The gender gap in attainment. A brief international comparative review. (QCA/08/3565.)* QCA: London, UK.

QCDA (2009). *Primary curriculum review. Curriculum reform consultation report to the DCSF. (QCDA/09/4355.)* QCDA: London, UK.

Reid N & Skryabina EA (2002). *Attitudes towards physics.* Res. Scii Technol. Educ. 20, 67–81.

Reid N & Skryabina EA (2003). *Gender and physics.* Int. J. Sci. Educ. 25, 509–536.

Reynolds Y (2010). *Children's concepts of measurement.* PhD thesis, Institute of Education, London.

Robertson IJ (1987). *Girls and boys and practical science.* Int. J. Sci. Educ. 9, 505–518.

Royal Society (2007). *The UK's science and mathematics teaching workforce. A 'state of the nation' report.* Report RS1018. Royal Society: London, UK.

Royal Society (2008). *Science and mathematics education, 14–19. A 'state of the nation' report on the participation and attainment of 14–19 year olds in science and mathematics in the UK, 1996–2007.* Report RS1290. Royal Society: London, UK.

Royal Society (2010a). *Primary science and mathematics education: getting the basics right. A summary of the key issues in 5–11 science and mathematics education from the Royal Society's 'state of the nation' report on 5–14 science and mathematics education in the United Kingdom.* Report DES 1819. Royal Society: London, UK.

Royal Society (2010b). *The scientific century: securing our future prosperity.* Report DES 1768. Royal Society: London, UK.

Rudduck, J, Chaplain, R & Wallace, G (1996). *School improvement: what can pupils tell us?* David Fulton: London, UK.

Russell T, Black P, Harlen W, Johnson S & Palacio D (1988). *Science at age 11. A review of APU survey findings 1980–84*. HMSO: London, UK.

Russell T, Qualter A & McGuigan L (1994). *Evaluation of the implementation of science in the National Curriculum at Key Stages 1, 2 and 3. Volumes 1, 2 and 3.* SCAA: London, UK.

Sammons P, Taggart B, Sylva K, Melhuish E, Siraj-Blatchford I, Barreau S & Manni L (2006). Variations in teacher and pupil behaviours in Year 5 classes. Institute of Education: London, UK.

Sammons P, Sylva K, Melhuish E, Siraj-Blatchford I, Taggart B, Grabbe Y, Barreau S (2007). *Effective Pre-School and Primary Education 3–11 Project (EPPE 3–11): Influences on children's attainment and progress in Key Stage 2. Cognitive outcomes in Year 5.* DfES/Institute of Education, University of London: London, UK.

Save the Children (2009). *Helping families support children's success at school*. See http://www.savethechildren.org.uk/en/docs/Helping_Families_Review_of_Research_Evidence_%285%29.pdf

Schagen S & Kerr D (1999). *Bridging the gap? The National Curriculum and progression from primary to secondary school.* NFER: Slough.

Schibeci RA (1984). *Attitudes to science: an update.* Stud. Sci. Educ. 11, 26–59.

Science Learning Centres (2010). *Practical work survey report. March 2010.* See https://content.sciencelearningcentres.org.uk/general/69197/PracticalWorkreportFINAL.pdf, accessed 8 April 2010.

Shayer M & Adey P (2002). *Learning Intelligence: Cognitive acceleration across the curriculum from 5 to 15 years.* Open University Press: Buckingham.

Shayer M & Ginsburg D (2009). *Thirty years on – a large anti-Flynn effect? (II): 13- and 14-year olds. Piagetian tests of formal operations norms 1976–2006/7.* Br. J. Educ. Psychol. 79, 409–418.

Shayer M, Ginsburg D & Coe R (2007). *Thirty years on – a large anti-Flynn effect? The Piagetian test. Volume and heaviness norms 1975–2003.* Br. J. Educ. Psychol. 77, 25–41.

SCORE (2008). *Practical work in science: a report and proposal for a strategic framework*. SCORE: London, UK. See http://www.score-education.org/downloads/practical_work/report.pdf, accessed 8 April 2010.

Scottish Consultative Committee on the Curriculum (SCCC) (1983). *Primary/secondary liaison in environmental studies/social subjects.* Report of Joint Scottish Committee on Environmental Studies/Scottish Central Committee on Social Subjects Group. SCCC: Dundee.

Scottish Consultative Committee on the Curriculum (SCCC) (1986). *Education 10–14 in Scotland.* Report of the Programme Directing Committee (PDC). SCCC: Dundee.

Scottish Executive (2002). *5–14 attainment in publicly funded schools 2000/01 (by June 2001).* News release. See http://www.scotland.gov.uk/stats/bulletins/00138-00.asp, accessed on 22 February 2010.

Scottish Executive (2003). *Assessment, testing and reporting 3–14.* Consultation on partnership commitment. Scottish Executive: Edinburgh.

Scottish Government (2008). Scottish Survey of Achievement, 2007. Science, science literacy and core skills—supporting evidence. Scottish Government: Edinburgh.

Scottish Government (2009). *Growing up in Scotland: the impact of children's early activities on cognitive development.* Scottish Government: Edinburgh.

SED (Scottish Education Department) (1965). *Primary education in Scotland. (The 'Primary Memorandum'.)* HMSO: Edinburgh.

SED (Scottish Education Department) (1987). *Curriculum and assessment in Scotland: a policy for the 90s.* SOED: Edinburgh.

Sibieta L, Chowdry H & Muriel A (2008). *Level playing field? The implications of school funding.* Research Paper. CfBT Education Trust: London, UK.

Sjoberg S. (2000). Interesting all children in 'science for all'. In *Improving science education.* Millar J, Leach J & Osborne JF (eds). Open University Press: Buckingham.

Slavin R, Hurley EA & Chamberlain A (2003). Cooperative learning and achievement: theory and research. In *Handbook of psychology: educational psychology.* Reynolds WM & Miller GM (eds), vol. 7, pp. 177–198. Wiley: New York.

Smail B & Kelly A (1984). *Sex differences in science and technology among 11 year old schoolchildren. II. Affective.* Res. Sci. Technol. Educ. 2, 87–106.

Statistics Commission (2005). *School education statistics: user perspectives. Report by the Statistics Commission incorporating Review of schools education statistics by National Foundation for Educational Research.* Report no. 26. Statistics Commission: London, UK.

Statistics Commission (2008). *Releasing official statistics. A review of statistical first releases.* Statistics Commission: London, UK.

Stillman A & Maychell K (1984). *School to school. LEA and teacher Involvement in educational continuity.* NFER–Nelson: Windsor.

Stobart G (2009). *Determining validity in national curriculum assessments.* Educ. Res. 51, 161–179.

Strand S (2007). *Minority ethnic pupils in the Longitudinal Study of Young People in England (LSYPE).* DCSF research report RR002. DCSF: London, UK.

Sturman L, Ruddock G, Burge B, Styles B, Lin Y & Vappula H (2008). *England's achievement in TIMSS 2007: national report for England*. NFER: Slough.

Suffolk Education Department Inspection and Advice Division (1997). *A report on an investigation into what happens when pupils transfer into their next schools at the age of 9, 11 and 13.* Suffolk LEA: Ipswich.

Suffolk Education Department Inspection and Advice Division (2002). *Transfer Review 2001.* Suffolk LEA: Ipswich.

Summers M & Kruger C (1992). *Research into English primary school teachers' understanding of the concept of energy.* Eval. Res. Educ. 6, 95–111.

Sutherland A, Johnston L & Gardner J (1996). *The transition between Key Stages 2 and Key Stage 3. A report for the Northern Ireland Council for Curriculum, Examinations and Assessment.* NICCEA: Belfast.

Sutton Trust (2010). *Cognitive gaps in the early years. A summary of findings from the report 'Low income and early cognitive development in the UK' by Elizabeth Washbrook and Jane Waldfogel.* Sutton Trust: London, UK.

Sylva K, Melhuish E, Sammons P, Siraj-Blatchford I & Taggart B (2004). *The Effective Provision of Pre-School Education (EPPE) Project. Findings from pre-school to end of Key Stage 1.* DfES: Annesley, Nottingham. See http://www.dcsf.gov.uk/research/data/uploadfiles/SSU_SF_2004_01.pdf

Sylva K, Melhuish E, Sammons P, Siraj-Blatchford I & Taggart B (2008). *Effective pre-school and primary education 3–11 project. Final report from the primary phase: pre-school, school and family influences on children's development during Key Stage 2 (ages 7–11).* DCSF research report RR061. DCSF: Annesley, Nottingham.

Thurston A, Topping KJ, Tolmie A, Christie D, Karagiannidou E & Murray P (2010). *Cooperative learning in science: follow-up from primary to high school.* Int. J. Sci. Educ. 32, 501–522.

Tolmie A, Tenenbaum H, Pino-Pasternak D, Sines J & Messenger A (2010). *Generalization in children's explanations of physical state changes*. Child Dev. (Submitted.)

Topping KJ & Trickey S (2007). *Collaborative philosophical enquiry for school children: cognitive effects at 10–12 years.* Br. J. Educ. Psychol. 77, 271–288.

Topping KJ, Thurston, Tolmie A, Christie D, Murray P & Karagiannidou E (2007). *Group work: transition into secondary.* Report to Scottish Executive Social Research Department. See http://www.scotland.gov.uk/Resource/Doc/211082/0055779.pdf

Torrance H (2002). *Can testing really raise educational standards?* Professorial Lecture delivered at the University of Sussex, 11 June 2002.

Tversky A & Kahneman D (1974). *Judgement under uncertainty: heuristics and biases.* Science 185, 1124–1131.

Tymms P (2004). *Are standards rising in English primary schools?* Br. Educ. Res. J. 30, 477–494.

Tymms P & Gallacher S (1995). *Primary Science: an exploration of differential classroom success.* Res. Sci. Technol. Educ. 13, 155–162.

Tymms P, Bolden D & Merrell C (2008). Science in English primary schools: trends in attainment, attitudes and approaches. In *Perspective on Education 1 (Primary science)*, pp. 19–42. Wellcome Trust: London, UK.

UNICEF (2007). *Child poverty in perspective: an overview of child well-being in rich countries*. Innocenti Research Centre Report Card 7. UNICEF Innocenti Research Centre: Florence.

Wallace, I (1994). *The Northern Ireland curriculum–solving actual problems*. The Curriculum J. 5, 31–41.

Watson S, Dodd J & Jones C (2007). *Engage, learn, achieve: the impact of museum visits on the attainment of secondary pupils in the East of England 2006–2007*. Research Centre for Museums and Galleries: Leicester.

Webb NM (2009). *The teacher's role in promoting collaborative dialogue in the classroom.* Br. J. Educ. Psychol. 79, 1–28.

Webb NM & Palincsar AS (1996). Group processes in the classroom. In *Handbook of educational psychology.* Berliner DC & Calfee RC (eds), pp. 841–873. Macmillan: New York.

Weinburgh M (1995). *Gender differences in student attitudes toward science: a meta-analysis of the literature from 1970 to 1991.* J. Res. Sci. Teach. 32, 387–398.

Wellcome Trust (2005). *Primary horizons.* Wellcome Trust: London, UK.

Wellington J & Osborne J (2001). *Language and literacy in science education*. Open University Press: Buckingham.

West P, Sweeting H & Young R (2010). *Transition matters: pupils' experiences of the primary–secondary school transition in the West of Scotland and consequences for well-being and attainment.* Res. Papers Educ. 25, 21–50.

Weston P, Barrett E & Jamison J (1992). *The quest for coherence. Managing the whole curriculum 5–16.* NFER: Slough.

Whetton C (2009). *A brief history of a testing time: national curriculum assessment in England 1989*–2008. Educ. Res. 51, 137–159.

Whetton C, Ruddock G & Twist L (2007). *Standards in English primary education: the international evidence.* Research survey 4/2. Primary Review interim reports. Cambridge, UK.

Whyte J (1986). *Girls into science and technology*. Routledge: London, UK.

Wiliam D (2009). *Assessment for learning: why, what and how?* Institute of Education: London, UK.

Williams J, Wo L & Lewis S (2007). Mathematics progression 5–14: plateau, curriculum/age and test year effects. In *Research in mathematics education.* Bills L, Hodgen J & Povey H (eds), Vol. 9, pp. 127–142. British Society for Research into Learning Mathematics: London, UK.

Williams P (2008). *Independent review of mathematics teaching in early years settings and primary schools.* Final report. DCSF: Annesley, Nottingham. See http://publications.teachernet.gov.uk/eOrderingDownload/WMR%20Final%20Report.pdf

Woodward C & Woodward N (1998) *Girls and science: does a core curriculum in primary school give cause for optimism?* Gender and Educ. 10, 387–400.

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