Key Stage 3
National Strategy

Framework for teaching science:
Years 7, 8 and 9

Foreword

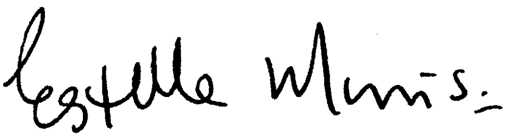
Science is diverse and exciting. It helps pupils to explore the world around them and understand so many things that have such relevance to daily life. Pupils must, therefore, have the best possible support for learning science at school.

Science is an integral part of our Key Stage 3 Strategy for strengthening standards in the early years of secondary education. We began this national strategy with English and mathematics, and the Frameworks we published for those subjects have been widely welcomed by teachers. The spotlight now moves – appropriately in Science Year – to the teaching and learning of science.

The *Framework for teaching science: Years 7, 8 and 9* will help teachers to teach engaging, challenging and inspiring lessons, and to establish high expectations for their pupils. It draws on the DfES/QCA scheme of work for science, and explains the ideas underlying the National Curriculum programme of study.

Like all our materials for the Key Stage 3 Strategy, teachers have played an important role in their development, and the science Framework is based on best practice and the experiences of pilot schools and other partners. We want schools to make a professional judgement about how to use it, depending on their own current ways of working and development needs.

I hope you will see the science Framework to be a valuable resource that supports good teaching and learning. Through the Key Stage 3 Strategy we have embarked on an ambitious programme for our 11- to 14-year-olds but, with teachers' continuing support and commitment, we are confident about its success.



The Rt Honourable Estelle Morris MP
Secretary of State for Education and Skills

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1 Introduction

The Government has set ambitious national targets for pupils' achievements in the National Curriculum tests for science at the end of Key Stage 3. By 2007, 80% of pupils are expected to reach level 5 and above, with a milestone target for 2004 of 70% at level 5 and above. To reach these goals will need effective teaching and raised expectations of all pupils.

The National Strategy for Key Stage 3 is part of the Government's support for schools as they strive to reach their targets. It began in schools in September 2001 with the introduction of two strands: English and mathematics. Three other strands – science, information and communication technology (ICT), and teaching and learning in the foundation subjects (TLF) – will be introduced in 2002–03.

The pilot of the science strand involved just over 200 schools across 17 LEAs from January 2001 to April 2002. Case studies illustrating how these schools have tackled aspects of the Strategy are on the DfES Standards website: www.standards.dfes.gov.uk/keystage3.

What the Strategy involves

As part of the Strategy schools are asked to:

- audit standards, teaching and learning;
- make effective use of the Strategy's Frameworks for teaching and the QCA schemes of work, either directly or to customise their own schemes of work;
- take part in selected units of continuing professional development and undertake follow-up work in school;
- take part in whole-school initiatives on cross-curricular issues, such as literacy and numeracy across the curriculum;
- support transition from Key Stage 2: for example, by offering a summer school, and by providing catch-up classes for Year 7 pupils who did not previously achieve level 4 in English and mathematics;
- provide mentoring for Year 8 pupils who are falling behind and becoming disaffected;
- provide booster support for Year 9 pupils before the national tests for Key Stage 3.

The starting point for science in relation to the Strategy is an audit of standards, teaching and learning in Key Stage 3 science, including some sampling of pupils' work and observation of lessons.

About this Framework

This *Framework for teaching science: Years 7, 8 and 9* is similar to the Frameworks for teaching English and mathematics. It provides practical suggestions and advice on meeting the National Curriculum requirements for science. It should be read alongside the exemplar DfES/QCA publication, *Science: a scheme of work for Key Stage 3*, referred to here as the QCA scheme of work for science.

The purposes of the science Framework are:

- to bring together in one place the experience of the pilot and best practice in secondary schools, much of which will already be familiar to teachers;
- to ensure that scientific enquiry is integrated with and taught alongside knowledge and understanding in a range of contexts;
- to identify the key scientific ideas that underpin science at Key Stage 3;
- to set out yearly teaching objectives for Years 7, 8 and 9 that build on science in Key Stage 2 and develop pupils' understanding of the key scientific ideas in Key Stage 3;
- to give advice on how teachers and trainee teachers can use the yearly teaching objectives to plan and teach appropriately challenging and engaging work to their pupils;
- to provide a basis for target setting;
- to enable headteachers and curriculum managers to set high and consistent expectations for pupils' achievement.

The science Framework is written mainly for heads of science departments, science teachers and trainee teachers. It will also be of some interest to:

- senior managers in secondary schools and LEA inspectors and advisers who support and monitor science teaching and standards;
- lecturers and independent consultants who advise science teachers or lead professional development programmes for them;
- inspectors who undertake inspections on behalf of Ofsted.

The contents of the science Framework

The expected development of pupils' knowledge and skills in science, and their understanding of key scientific ideas, is outlined by yearly teaching objectives for Years 7, 8 and 9. These objectives are based closely on the Key Stage 3 programme of study for science but do not cover it all. They are the essential objectives which identify for each year the core of what pupils should know and understand about scientific enquiry and key scientific ideas. They should determine the focus of teaching plans and formative assessments.

The rest of the document gives advice on planning, teaching, learning and assessing the science curriculum in Key Stage 3. Some sections are relatively brief, such as those on planning, on differentiation, or on teaching in special schools. Health and safety issues are not discussed. These topics are dealt with in greater detail in the Strategy's associated training and in the publications listed in section 8 (pages 65–66).

Three appendices supplement the main document.

Appendix 1 describes what most pupils should have learned in science by the end of Year 6.

Appendix 2 shows how the yearly teaching objectives relate to the strands of scientific enquiry (Sc1) in the Key Stage 3 programme of study.

Appendix 3 is a checklist of the key scientific vocabulary used in the yearly teaching objectives and the QCA scheme of work for science.

Using the science Framework

The Government believes that science teachers will find the Framework a helpful tool for reviewing and adjusting their practice. Many will wish to use it for planning their lessons. There is, after all, no point in individual teachers re-inventing solutions to problems and challenges that are common to all. Schools should make a professional judgement about how to implement the advice in this Framework, once they have studied it, evaluated their current practice and considered their professional development needs.

The factors below should influence the degree to which a science department adjusts its current practice:

- pupils' past, current and expected attainment in science and the extent to which the department is likely to meet its target for raising standards;
- the extent to which teaching objectives and expectations of pupils in science compare with the detail, challenge and rigour of those in this Framework;
- the curriculum leadership in the department and the department's effectiveness in evaluating its strengths and weaknesses, and in planning action to achieve higher standards;
- the quality of the planning, teaching and assessment of science and how these compare with the criteria identified in this Framework;
- the extent to which the department is staffed by teachers, including those qualified in physics, chemistry, biology and other science qualifications such as geology or biochemistry, who may need support with their planning and teaching across the whole of science, especially when they are teaching beyond their specialism;
- whether the department is already involved in an initiative to raise standards in science in Key Stage 3, through a properly supported programme that incorporates practices similar to those described in this Framework, making it possible to continue its own project development alongside the Strategy.

2 Science at Key Stage 3

The science curriculum

Science at Key Stage 3 builds on the knowledge, understanding and skills that pupils have developed in Key Stage 2. Most pupils have reached at least level 4 of the National Curriculum for science by the end of Year 6. Year 7 teachers need to be familiar with the Key Stage 2 programme of study and should assume that incoming pupils have already made progress. Appendix 1 (pages 67–69) outlines what most Year 6 pupils should have learned.

This Framework sets out **yearly teaching objectives** for Years 7, 8 and 9 (see pages 24–30). These lie at the heart of what pupils should understand, know and be able to do, so teaching plans and formative assessments should centre on them. The yearly objectives cover both scientific enquiry and the key scientific ideas that underpin the programme of study at Key Stage 3.

The approach to teaching science

Science demands versatile teachers and imaginative approaches to bring it to life for pupils and give them thorough understanding of the subject.

Pupils need to recognise, describe, use and apply key scientific ideas to explain abstract phenomena even when they appear in unfamiliar contexts. Delving into key ideas can stimulate pupils' curiosity and help them to make connections between different areas of science.

Scientific enquiry generally links direct practical experience with key scientific ideas. In the most effective practice, the principles of scientific enquiry are not left to special 'investigative science' lessons. They are integrated into most lessons, even those that involve little or no practical work. Teachers capitalise on chances in any lesson to encourage pupils to reflect, however briefly, on the evidence that supports scientific interpretations. For example, they ask pupils: 'How do you think they might have measured that?' or: 'How could you check those figures?'

Scientific enquiry

Why is scientific enquiry important?

Scientific enquiry has a central place in science because it helps pupils to understand how scientific ideas are developed and because the skills and processes of scientific enquiry are useful in many everyday applications. Scientific enquiry provides opportunities for pupils to consider the benefits and drawbacks of applications of science in technological developments, and in the environment, health care and quality of life.

Pupils need and enjoy the experience of scientific investigation. Good teaching ensures that it is taught through contexts taken from the whole programme of study and includes a range of domestic, industrial and environmental contexts. Pupils can:

- test out ideas experimentally;
- develop practical skills;

- carry out investigative fieldwork;
- use collaborative approaches to solving problems; and
- appreciate the importance of experimental evidence.

Their knowledge can be extended by asking them to draw on reference materials – from books or ICT sources – to help evaluate and reflect on their work. Through work like this, you can teach pupils how scientists worked in the past and how they work together today, using creative and critical thought to develop scientific ideas.

There are many different types of scientific enquiry such as:

- pattern seeking – for example, in surveys or correlations;
- using first-hand and secondary sources of information;
- identification and classification;
- using and evaluating a technique or technological application;
- fair tests involving the control of variables;
- using experimental models and analogies to explore an explanation, hypothesis or a theory.

Whenever possible, try to relate experimental work to scientific enquiry. Make explicit to pupils the skills that they will use or learn and how they might apply these later in an extended enquiry. Give them opportunities to combine their developing skills through tackling a whole investigation or enquiry at intervals throughout the key stage.

When choosing activities for scientific enquiry, plan for the different types of enquiry and draw on the full range of contexts in the programme of study. Consider different kinds of demands: both the procedural (the challenge of carrying out the task) and the conceptual (the challenge of the underlying scientific ideas). Plan activities that build progression in these two demands through the key stage. The yearly objectives on pages 24–30 will support these types of decision.

Pupils' experience of scientific enquiry

By the end of Year 6 pupils can carry out systematic investigations working on their own and with others. They can use knowledge and understanding to plan how to carry out a fair test and can read accurately the data presented in simple tables and graphs. They use a wide range of reference sources in their work including simple keys.

Pupils can talk with confidence about their work and its significance, and communicate ideas using scientific language, conventional diagrams, charts and graphs. They can identify simple patterns in results and point out results that do not appear to fit the pattern.

Pupils draw conclusions which match the data they have collected and begin to use this evidence to support further predictions. They know that scientists have combined evidence from observation and measurement with creative thinking to suggest new ideas and explanations for phenomena.

In Year 7, scientific enquiry should introduce pupils to:

- historical examples of the early work of scientists, including how collected evidence and creative thinking were used to draw conclusions and develop scientific ideas;
- the use of scientific knowledge to plan, obtain and present evidence during a scientific enquiry;
- the safety procedures and precautions that are needed when handling hazardous substances which they are likely to encounter in practical situations;
- the selection and appropriate use of equipment to observe and measure;
- describing and explaining what their results show when drawing conclusions;
- evaluating the strength of evidence.

Once these aspects have been established challenge pupils to apply their developing skills in different types of scientific enquiry. This will include increasingly complex investigative work. Teach pupils how to:

- consider how early scientific ideas do not match present-day evidence and how they have changed over time;
- consider some of the positive and negative effects of scientific and technological developments;
- identify different strategies for solving problems;
- use first-hand experience, secondary sources of information and ICT to help refine predictions;
- collect evidence in situations where variables can and cannot be readily controlled or where a suitable control is not obvious;
- use qualitative and quantitative approaches where appropriate;
- interpret data from tables and graphs using scientific knowledge and understanding;
- make predictions of additional readings from data they have collected;
- provide explanations and justifications when they describe patterns and relationships in data from their own and others' investigations;
- improve a scientific enquiry by obtaining more accurate, consistent and reliable evidence to support conclusions;
- identify limitations of data in conclusions.

Links with key scientific ideas

The use of different types of scientific enquiry should ensure that it is taught through contexts taken from across the Key Stage 3 programme of study.

The five key scientific ideas

The five key scientific ideas that underpin the Key Stage 3 programme of study are:

- **cells**
- **interdependence**
- **particles**
- **forces**
- **energy**

It is important to introduce all five key scientific ideas early in Key Stage 3. Pupils need to develop their understanding steadily so that they can recognise, use and then apply each of the ideas in different contexts. Once each idea has been introduced in Year 7, there is some flexibility about the sequencing of subsequent related units of work. For example:

- units on solutions or on atoms and elements can follow the introduction of particles;
- units on gravity and space can follow the introduction of forces;
- units on sound or light can follow the introduction of energy;
- units on food and digestion or microbes and disease can follow the introduction of cells;
- units on geological processes can follow the introduction of particles, forces and energy in Years 7 and 8.

The teaching sequence offers opportunities to reinforce and develop each key scientific idea. In Years 8 and 9, in particular, more sophisticated aspects of the key scientific ideas can be used and applied more widely. Draw pupils' attention to these wider applications and help them to recognise that a key idea used in one context may be applied in another. Draw on contexts from across the scientific disciplines and examples of science in past and present everyday life.

Different classes in the same school can follow different sequences of teaching units, provided that progression in key scientific ideas and in the yearly teaching objectives is maintained through Years 7, 8 and 9. The flexibility allows efficient use of equipment and other resources.

Misconceptions

Some scientific ideas are difficult because they involve the learner in abandoning previous beliefs – for example, a belief that heavy objects fall faster than light ones. Pupils will not necessarily be convinced by a demonstration. They are likely to see what they want or expect to see – that the heaviest object lands first – or they will try hard to find fault with the test in order to hang on to their belief. Although pupils' ideas can be challenged by physical evidence, it is often the evidence, not the idea, which they doubt.

Teachers have to challenge pupils' thinking and give them new perspectives from which to view the evidence through a range of activities and frequent reinforcement. Pupils often need to articulate the conflicts that exist in their minds. Drawing out their thinking and talking about their difficulties in abandoning their beliefs is a key role for an adult in the room, such as the teacher, a technician or a teaching assistant attached to the science department.

One of the most common misconceptions among 11-year-olds is that they believe incorrectly that energy can be ‘used up’, saying, for example, that a runner has lots of energy at the start of a race but this has all been ‘used up’ or ‘lost’ by the end. The QCA scheme of work describes the most common of pupils’ misconceptions connected with each unit of work. The Strategy’s programme of professional development includes discussion of these common misconceptions and approaches to teaching and learning that help to identify and address them.

Models and analogies

During Key Stage 3, pupils should use scientific ideas and models to explain scientific phenomena and events, and to understand a range of familiar applications of science. Models and analogies are powerful tools for representing and illustrating abstract ideas, particularly in the areas that cause pupils most difficulty. In primary science the models are often obvious; few children imagine that the Sun is a torch or that the Moon is an orange in spite of the common use of these representations of the solar system.

Examples of the models and analogies that are useful in Key Stage 3 science are:

- three-dimensional models of typical plant and animal cells;
- the analogy of scissors to explain the action of enzymes in digestion;
- computer animations, or movements of pupils themselves, to simulate the movement of particles during a change of state;
- commercially produced models to illustrate elements, compounds and chemical change;
- the use of marbles, ball-bearings or beads to illustrate physical properties such as density or Brownian motion.

Once pupils are familiar with the model you should encourage them to apply that model to explain new phenomena.

At times simple models do not suffice and more sophisticated models are needed to develop pupils’ understanding. For example, a simple model can represent what is happening as a reaction takes place in a test tube. But to develop their understanding pupils need to learn to represent compounds by formulae and to summarise chemical reactions by word equations.

Encourage pupils to consider critically the advantages and disadvantages of the different models and analogies that they meet in Key Stage 3 science – for example, the limitations of the three-dimensional kinetic theory model or those of the analogy of the nucleus as ‘the brain of a cell’. Help pupils to appreciate that different models and analogies can be used to explain different phenomena, properties or events.

Cells

Why is the cell a key idea?

'Cells are the building blocks of life' is a common phrase that is not always appreciated or fully understood. Some pupils may have encountered this idea in primary school or through the media, although it does not form part of the programme of study for Key Stage 2. Pupils know that living organisms feed and grow, and that plants photosynthesise, and should learn about the role of cells in these processes.

Understanding what cells do, their requirements, and their specialisation into tissues and organs, helps pupils to understand why complex living organisms are the way they are. It enables them to make greater sense of the organ systems and life processes that they study in some detail at Key Stage 3.

Pupils' experience of cells

By the end of Year 6 pupils will have some understanding of life processes, such as growth and reproduction, nutrition and movement. They will also have been taught about micro-organisms and should have some idea that these are too small to be seen easily. Their understanding of just how small that might be is likely to be limited.

In Year 7, early work on cells should develop pupils' knowledge and understanding that:

- cells are relatively very small;
- 'typical' animal and plant cells have similarities and differences;
- all living organisms are made up of one or more cells, with the exception of viruses;
- visible everyday living organisms are multi-cellular.

Once these aspects have been established teach pupils how an understanding of 'cells as building blocks of life' can be used to explain these phenomena.

- Multi-cellularity allows for specialisation of cells, tissues and organs; the function of specialised cells depends on their structure.
- Life processes such as respiration and photosynthesis occur in cells.
- Complex, multi-celled organisms, such as humans and green plants, need time to grow and develop, and they have specialised organ systems. For example, reproductive systems ensure that offspring are similar to their parents; other systems, such as the digestive, circulation, and breathing systems, increase the efficiency and effectiveness of the whole organism to supply its cells with nutrients and to remove wastes.
- The survival of whole organisms depends on the successful working of all their parts.
- Single-celled living organisms take advantage of a wide range of food supplies, including other living organisms. Some are harmful to humans and some are beneficial. Viruses are smaller than cells and can reproduce only inside living cells.

- Complex, multi-celled organisms have developed systems that help them fight infections, often caused by single-celled organisms and viruses.

Links with other key ideas

Respiration and photosynthesis are processes that involve energy transfer. Pupils in Key Stage 3 do not need to know the detail of the energy transfer in these processes. But they do need to understand that energy can be transferred from the Sun through light to carbohydrates. This enables cells, and therefore whole organisms, to gain and make use of energy to live.

Processes such as gas exchange and absorption of nutrients in plants and animals, and digestion and circulation in animals, are more easily understood if pupils have some understanding of particles.

Interdependence

Why is interdependence a key idea?

As pupils learn about other parts of the world, they begin to understand that the Earth is not a group of discrete parts but a continuous environment where activities in one place may produce effects far away. They start to appreciate how this continuum exists over time as well as place. The idea of interdependence in and between biological and physical environments is fundamental. Although links are sometimes slender, humans depend on and affect living organisms and their physical environment.

Pupils' experience of interdependence

By the end of Year 6 most pupils have some understanding of the links between life processes in animals and plants and the environments in which they are found. They know that the wide variety of animals, plants and materials can be grouped according to their similarities and differences. Pupils know that animals feed on plants or other animals, and that the feeding relationships can be described with simple food chains. They have been taught that animals and plants are often adapted to their environment through differences in their structure. They are aware of the need to care for other animals and plants, and for the whole environment and its sustainability. They have considered the cycling of materials in the context of the water cycle.

In Year 7, early work on interdependence should develop pupils' knowledge and understanding that:

- organisms that belong to the same species share many characteristics;
- living things are adapted to the environment in a variety of ways;
- variation is fundamental and inevitable;
- food chains are interconnected and feeding relationships can be more accurately described using food webs.

Once these aspects have been established teach pupils how interdependence can be used to explain:

- simple ideas about how communities of organisms live together and develop, and how numbers of some species may change over time, for example, because of competition or changes in the habitat;
- how natural and artificial selection can affect an organism's success in living and growing in its environment;
- why photosynthesis is important to all life;
- how the human need to maximise food production affects other living organisms and influences the balance in the environment;
- how natural systems recycle materials through food chains and webs and through particular physical and chemical processes that may take from seconds to millions of years.

Links with other key ideas

The most useful link to make is with energy. On Earth, energy is transferred to the system of living organisms as light from the Sun and eventually is transferred from the system as heat. All living organisms need energy to complete their life processes and every organism 'loses' some energy through heat transfer to its surroundings. This explains why food chains and webs are limited to a sequence of four or occasionally five organisms. The energy dissipation at each step in the food chain or web means that the top of the food chain is reached when the energy used in seeking food exceeds the useful energy gained from it.

Knowledge of particles and conservation of materials is also needed to comprehend the cycling of materials through feeding relationships, and physical cycles such as the rock cycle.

Particles

Why is the particle theory of matter a key idea?

The particle theory of matter is the abstract idea that helps pupils to develop their understanding of why materials behave as they do. It gives pupils a new insight into how the nature and behaviour of materials can be explained in a range of contexts. Some pupils may have encountered this idea in primary school or through the media, although it does not form part of the programme of study in Key Stage 2.

Pupils' experience of particles

By the end of Year 6 pupils know that materials can be grouped into solids, liquids or gases, and what causes simple substances such as water to change their physical state. They have been introduced to terms such as *evaporation* and *condensation* to describe these changes. They have sorted materials into groups according to simple physical properties and begun to explore chemical changes by observing and classifying some reversible and irreversible changes.

In Year 7, early work on particles should introduce pupils to:

- a simple model of matter made up of particles;
- how that model can be used to explain physical phenomena such as diffusion and gas pressure, and changes of state such as melting and solidifying.

Once these aspects have been established challenge pupils to apply their developing understanding of particles to explain other physical phenomena, such as expansion. As they meet a wider range of physical and chemical phenomena, they should develop a more sophisticated view of atoms as fundamental building blocks of matter, and use this new understanding to:

- recognise that the atoms of some elements can become more permanently joined to each other as the elements combine to form simple compounds, and that mixtures are composed of constituents that are not chemically combined;
- represent compounds by formulae, and understand how the formulae are derived;
- summarise and explain chemical reactions using word equations;
- predict the names and simple formulae of substances formed in chemical reactions.

At the same time, teach them to recognise the limitations of the simple model of matter.

Links with other key ideas

Pupils will use particles to explain a wide range of physical, biological and geological phenomena, such as the movement of substances through cell membranes, photosynthesis, digestion, and the formation of crystals in rocks. They will also consider how energy is transferred by the movement of particles in conduction, convection and evaporation.

Forces

Why is force a key idea?

In Key Stage 3, pupils need to extend their thinking from concrete examples of forces to a more abstract view. For example, they need to understand that the state of motion of an object depends upon the sum of the forces acting upon it; where the forces balance out, the object will be stationary or moving at constant speed. They should be able to identify the forces acting on an object in simple cases – for example, with a book resting on a table, the upward force of the table on the book, and the downward pull of the Earth's gravity on the book – and to recognise that in this example the forces balance. If pupils associate forces with physical activity and muscular strength, the idea of the table 'pushing up' is a difficult one – they often argue that 'the book is just sitting on the table'.

In Key Stage 3, pupils need to decide whether forces are balanced or not. They do not need to identify pairs of forces as in Newton's third law. In the example of the book on the table these are: (a) the pull of the Earth on the book and the pull of the book on the Earth, and (b) the force of the book on the table and the force of the table on the book. Identifying pairs of forces is something that they will do in Key Stage 4.

Pupils' experience of forces

In their early years and Key Stage 1 pupils have experimented with and can describe the effects of pushes and pulls on the state or motion of objects. They have met everyday meanings of the word ‘force’, probably in association with physical activity and muscular strength. **In Key Stage 2** they have started to develop the idea of frictional force and weight, and to use the convention of arrows to illustrate the forces acting on familiar objects.

In Year 7, early work on forces should help pupils to develop understanding that:

- forces have both magnitude and direction;
- friction and weight are forces;
- when the forces acting on an object are balanced, the object remains stationary or continues to move at constant speed;
- unbalanced forces acting on a moving object will cause it to speed up, slow down or change direction.

Once these aspects have been established teach pupils how to use the key scientific idea of force to explain:

- properties of magnetic materials;
- friction in liquids and gases;
- the turning effect of forces;
- the relationship between force and pressure;
- the movement and position of the planets in the solar system.

Links with other key ideas

Any explanation of moving objects is linked to knowledge and application of force as a key scientific idea. This includes extremely large objects in planetary motion, and molecular-sized particles in liquids and gases. Other examples of links are:

- force is generated by energy transfers in physical and biological systems;
- movement of the human body can be explained by the forces developed in pairs of muscles;
- physical weathering of rocks arises from forces generated by expansion and contraction and the freezing and thawing of water.

Later in the key stage the quantitative relationships between force, area and pressure can be used to explain adaptation in animals – to explain, for example, why polar bears and camels have large feet for walking on snow and sand.

Energy

Why is energy a key idea?

Energy is a powerful and unifying abstract idea which is difficult to define. It allows pupils to explain a range of physical phenomena, to account for what happens in biological, chemical, geological and physical processes, and to make predictions.

Pupils need to understand that energy allows us to keep track of change. Early in the key stage, teach pupils about energy resources, the use of fuels and the need to conserve them, and about how energy can be transferred from one place to another. A simple model for energy transfer can help pupils to appreciate the idea of energy conservation.

Pupils' experience of energy

Energy is not introduced in the National Curriculum until Key Stage 3 but pupils' ideas about energy have developed gradually from early pre-school experiences. By Year 6 they have a range of ideas about energy in everyday contexts. Many 11-year-olds associate energy with activity and use the term *energy* in speech, although they often state incorrectly that energy can be 'used up' or 'lost'. The challenge in Key Stage 3 is to establish energy as a key scientific idea with a meaning that may be different from pupils' everyday use of the word.

In Year 7, early work on energy should:

- make pupils aware of the differences between the meaning of the word *energy* in everyday use and its scientific meaning.

11-year-olds readily make a connection between what they eat and physical activity. For example, they may say: 'I need to go for a run to work off those chips!' Comments like this draw upon several aspects of energy:

- the chips are a *source* of energy;
- the human body can *store* energy;
- human activity *transfers* this stored energy to somewhere else;
- the energy is *dissipated* during the run – it transfers mostly as heat to the air, where it spreads out and becomes less useful.

Once pupils have developed some understanding of energy as a key scientific idea, you can introduce them to energy conservation as an 'accounting system'. This allows scientists to keep track of how much energy is transferred as phenomena occur. At this stage, pupils can begin to use a quantitative approach to the conservation of energy and energy transfers. The aim is for pupils to be able to use their understanding of energy to explain changes that occur, for example, when objects are lifted or in food webs.

In Key Stage 3, many teachers will explain energy conservation by referring to its *transfer*, although some prefer to refer to its *transformation*.

When teachers explain *energy transfer*, they describe how stored energy is *transferred* from one place to another. For example:

> *When a person uses a pulley to lift an object at the end of a rope, energy from the person's muscles is transferred to the object during the lifting process.*

When teachers explain *energy transformation*, they use words such as *changed* or *converted*. For example:

> *Energy from the person's muscles is changed first into kinetic energy, as the object moves upward, and then into potential energy, stored in the raised object*.

Neither of these approaches is right or wrong. The two points of substance are that:

- pupils need to be aware that either *energy transfer* or *energy transformation* might be used in different Key Stage 3 textbooks, tests or examination papers;
- teachers in a science department need to adopt a consistent approach to teaching energy across the science curriculum.

Once these aspects have been established pupils should learn to use the idea of energy to explain, for example:

- that temperature difference leads to the transfer of energy;
- how energy is transferred by the movement of particles in conduction, convection and evaporation;
- how energy is transferred in Earth cycles such as the rock cycle or water cycle;
- how energy can dissipate, reducing its availability as a resource, although it is always conserved;
- what potential difference is and how electricity can be generated.

Links with other key ideas

By the end of Year 7, most pupils will be expected to use the idea of energy transfer and energy conservation to explain their observations and findings – for example, to explain the difference in the brightness of two bulbs in series and in parallel. By the end of Key Stage 3, pupils need to be confident in linking energy with the other key ideas to provide more complex explanations – for example, to link the motion of particles with energy to explain a change in the temperature of a material or the expansion of a solid, or to explain how electrical current carries energy around a circuit.

Progression in Key Stage 3 science

In this Framework, **continuity** refers to consistency in expectations and teaching approaches between and within key stages. Good continuity extends pupils' experiences without unhelpful repetition. **Progression** refers to the step-wise development of scientific concepts and techniques, though the steps are not necessarily equal in size or taken at regular intervals. **Transition** occurs when pupils move from one year group to another, usually at the start of a new school year. The move between key stages is of particular importance, as this can mean a change of schools. It needs special consideration.

Pupils' progress from early knowledge of scientific ideas to a deeper and broader understanding needs to be planned and sequenced carefully. Good planning ensures that initial tasks are achievable and helps to build pupils' confidence. Sequence tasks so that they are increasingly demanding or are carried out with less support. Some pupils may find new ideas difficult, so adjust and adapt plans to suit particular circumstances and requirements.

87% of pupils achieved level 4 and above in the Key Stage 2 tests in 2001. The science that you teach to Year 7 pupils sometimes builds on what they already know, understand and can do, and sometimes introduces new ideas. Some of these are outlined in the table below.

Areas of Year 7 science that are closely related to the Key Stage 2 programme of study	Investigative science Environment Feeding relationships Solutions Separating mixtures Forces Electrical circuits Earth and beyond
Areas of Year 7 science that are not closely related to the Key Stage 2 programme of study	Cells Particles Chemical reactions Energy

You should expect pupils to make good progress with units of work that build on the Key Stage 2 programme of study. By the end of these units, many Year 7 pupils should be working at level 5 on the Key Stage 3 programme of study for science, some will be working at level 6 and almost all should be working at level 4 at least.

With new topics that are not related closely to the Key Stage 2 programme of study, you should expect most Year 7 pupils to be working at level 4 or 5 at the end of the relevant units.

Differential attainment between units of work that are related or not closely related to the Key Stage 2 programme of study should even out by the end of Year 7. Progress in units of work in Years 8 and 9 should be more consistent. When they are taught units in Year 8 most pupils should attain level 5, and in Year 9 most pupils should attain level 6 at the end of each unit. Expectations such as these should guarantee that, by 2007, 80% of pupils will achieve level 5 or above in the Key Stage 3 national tests.

The science Framework will help teachers to challenge and raise expectations. It is designed so that the expected attainment of most pupils who started Year 7 at level 4 or 5 is level 6 by the end of Year 9. This expectation is a little above the expectation of the National Curriculum for the end of Key Stage 3, which is pitched at levels 5 to 6. The purpose is to help you to set and achieve challenging targets for pupils, while recognising that not all pupils may reach this standard.

In each year of Key Stage 3, and taking account of the differential curriculum attainment outlined above in Year 7, the vast majority of pupils in mainstream schools will have reached these levels:

End of Year	Expected attainment		
	Pupils who make slower progress	Most pupils	Pupils who make faster progress
7	level 3/4	level 4/5	level 6
8	level 4	level 5	level 6/7
9	level 4/5	level 6	level 7/8 or level 7/7*

All pupils should be expected to communicate their understanding of science and make connections to related topics across the full breadth of the programme of study and beyond. Able pupils will confidently make such connections and will show that they can tackle more complex scientific enquiries and questions at higher levels.

Yearly teaching objectives in Key Stage 3 science

The yearly teaching objectives for Years 7, 8 and 9 are central to pupils' achievement in science. They identify for each year the core of what pupils should know and understand about scientific enquiry and the key scientific ideas. The yearly teaching objectives have been arranged carefully to support pupils' learning as they enter Key Stage 3 from Key Stage 2, and as they make progress from Year 7 to Year 9. They help pupils to make connections across the range of knowledge, understanding and skills that they meet in science lessons.

Objectives for Years 7, 8 and 9 are set out alongside each other to help you to identify progression. There are separate pages for scientific enquiry and the key scientific ideas of cells, interdependence, particles, forces and energy.

You should give priority to the yearly teaching objectives when you are planning work, assessing pupils' progress and setting curriculum targets for individuals and groups of pupils. For some pupils a target may need to be broken down into smaller steps. For other pupils, it may be appropriate to choose a target linked to the yearly teaching objectives for the year group below or above. Whatever the targets, assessment of pupils' progress against the yearly teaching objectives provides the next starting points for building pupils' understanding.

Scientific enquiry

Yearly teaching objectives

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Consider early scientific ideas, including how experimental evidence and creative thinking have been combined to provide scientific explanations. • Use scientific knowledge to decide how ideas and questions can be tested; make predictions of possible outcomes. • Identify and control the key factors that are relevant to a particular situation. • Select and use appropriate equipment, including ICT, to make observations and measurements correctly, e.g. 1 °C or 1 newton. • Use repeat measurements to reduce error and check reliability. • Present and interpret experimental results through the routine use of tables, bar charts and simple graphs, including line graphs. • Describe and explain what their results show when drawing conclusions; begin to relate conclusions to scientific knowledge and understanding. • Evaluate the strength of evidence, e.g. in bar charts and graphs; indicate whether increasing the sample would have strengthened the conclusions.	• Consider how some early scientific ideas do not match present-day evidence, and describe how new creative thinking has been used to provide a scientific explanation. • Identify more than one strategy for investigating questions and recognise that one enquiry might yield stronger evidence than another. • Recognise that a range of sources of information or data is required. • Use a range of first-hand experience, secondary sources of information and ICT to collect, store and present information in a variety of ways, including the generation of graphs. • Use appropriate range, precision and sampling when collecting data during a scientific enquiry, and explain why these and controlled experiments are important. • Draw conclusions from their own data and describe how their conclusions are consistent with the evidence obtained, using scientific knowledge and understanding to explain them. • Consider whether an enquiry could have been improved to yield stronger evidence (e.g. improving the accuracy or sufficiency of measurements or observations); explain any anomalous results.	• Explain how scientific ideas have changed over time; describe some of the positive and negative effects of scientific and technological developments. • Select and use a suitable strategy for solving a problem; identify strategies appropriate to different questions, including those in which variables cannot be easily controlled. • Carry out preliminary work such as trial runs to help refine predictions and to suggest improvements to the method. • Make sufficient systematic and repeated observations and measurements with precision, using an appropriate technique. • Select and use appropriate methods for communicating qualitative and quantitative data. • Describe patterns in data; use scientific knowledge and understanding to interpret the patterns, make predictions and check reliability. • Describe how evidence or the quality of the product supports or does not support a conclusion in their own and others' enquiries; identify the limitations of data in conclusions.

Cells

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Describe a simple model for cells that recognises those features all cells have in common and the differences between animal and plant cells. • Explain that some living organisms are only one cell but that others are multi-celled. • Explain that growth means an increase in the size and number of cells. • Explain that in multi-celled organisms certain cells may become specialised, e.g. sperm and egg cells. • Explain that similar specialised cells can be grouped together to form tissues, that tissues can form organs, and that these do not all develop and grow at the same time; use this to explain why and how some organisms care for and protect their offspring. • Describe fertilisation as the joining of the nucleus of a male sex cell (e.g. sperm) to the nucleus of a female sex cell (e.g. egg) and use this knowledge to explain that the resulting offspring are always similar to their parents but never identical.	• Describe the role of the main nutrients in the body; explain why all cells need them and the importance of a balanced diet. • Explain why some nutrients have to be broken down before the body can use them, and use models and analogies to describe how enzymes break down large molecules during digestion. • Describe the digestive system using knowledge of enzymes to explain how it works, and the role of the circulation system in transporting the products of digestion to cells. • Explain that cells obtain energy through respiration, which often requires oxygen (aerobic respiration); use this to explain why tissues need a good blood supply; identify similarities in aerobic respiration in animals and plants. • Classify bacteria and fungi as cellular micro-organisms and viruses as micro-organisms that are smaller than a cell; explain that some micro-organisms are useful to humans and some are harmful. • Describe some of the systems in the human body for fighting infecting micro-organisms and immunisation as a way of improving immunity; use knowledge of cells, tissues and organs to explain how these systems work.	• Use a word and/or symbol equation to describe respiration and explain similarities with burning of fuels. • Explain that multi-celled organisms survive well only if all their parts work well together; use this to explain how smoking, alcohol, some drugs and exercise affect parts of the human body. • Explain that the nucleus in a cell contains genes that control all the characteristics of the organism; use this to explain: – fertilisation, where genes from one parent join with genes from the other to produce a new set of genes; – how selective breeding, either by nature or by humans, can increase the chance of certain genes passing from parent to offspring. • Describe photosynthesis and the requirement of chlorophyll, light, carbon dioxide and water; know that plant nutrition involves photosynthesis and other nutrients obtained from the soil; use this to explain: – photosynthesis as a source of biomass; – that these other nutrients, used to produce proteins and other substances, can be supplied by fertilisers; – how leaves and roots are adapted to their functions; – conditions in which plants grow well. • Distinguish between photosynthesis and respiration in plants, including the use of word equations.

Interdependence

Yearly teaching objectives

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Explain that organisms can be grouped by their similarities and differences, and that a species is a group of very similar organisms; identify some of the main taxonomic groups of animals, describing some common features. • Explain how food chains within a habitat can be combined into food webs. • Describe ways in which organisms are adapted to daily or seasonal changes in their environment and to their mode of feeding; use this idea to explain why some organisms can live more successfully than others in different habitats.	• Identify some of the main taxonomic groups of plants and describe some common features. *Interdependence and energy* • Explain that energy is transferred between organisms in food chains and webs; use this to: – relate the abundance and distribution of organisms to the resources available within a habitat; – begin representation of this using pyramids of numbers.	• Describe relationships of organisms in a food web and use this to explain: – why photosynthesis is important to humans; – why maximising human food production can significantly affect other animals and plants; – how the abundance and distribution of organisms may be affected by pesticides, weedkillers and the accumulation of toxins; – how pyramids of numbers represent feeding relationships in a habitat. • Explain that habitats change in response to changes in physical, chemical and biological factors. • Begin to describe a model for the whole environment that recognises how the materials that make up all living organisms are recycled, and that energy from sunlight flows through the system; use this to explain the need for sustainable development.

Particles

Yearly teaching objectives

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Describe a simple particle model for matter, recognising: – the size, arrangement, proximity, attractions and motion of particles in solids, liquids and gases; – the relationship between heating and movement of the particles. • Use the simple particle model to explain: – why solids and liquids are much less compressible than gases; – why heating causes expansion in solids, liquids and gases; – why diffusion occurs in liquids and gases; – why air exerts a pressure; – why changes of state occur; – why mass is conserved when substances dissolve to form solutions; – why temperature increases are likely to result in substances dissolving more quickly; – the formation of a saturated solution.	• Use the simple particle model to explain: – movement of substances through cell membranes by assuming particles are of different sizes; – how crystals form and that slow cooling results in the formation of larger crystals from molten material and solutions. • Describe a more sophisticated particle model for matter, recognising: – the atom is the basic building block of matter; – there is a relatively small number of different atoms; – elements consist of only one type of atom; – compounds consist of fixed combinations of different types of atoms that cannot be easily separated; – atoms and combinations of atoms can be represented by symbols and formulae. • Use the more sophisticated particle model to explain how chemical reactions take place.	• Identify evidence which indicates that a chemical reaction has taken place, such as the association of energy transfer with chemical change. • Recognise that chemical reactions can be modelled by assuming that atoms can rearrange themselves, and that this can happen in only a limited number of ways, for example, $A + B \rightarrow AB$, $AB + CD \rightarrow AD + CB$. • Use the particle rearrangement model to: – predict the names and formulae for products that might be formed from given reactants; – write word and symbol equations for some simple reactions; – explain why mass is conserved in chemical reactions; – explain how acids react with bases and neutralisation occurs. • Describe how metals react with: – oxygen, water, acids and oxides; – solutions of salts of other metals. • Identify differences in reactivity of metals to construct a reactivity series; use this to explain uses of metals and make predictions about the reactions of metals.

Forces

Yearly teaching objectives

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Recognise that a force has both magnitude and direction and use this to: – identify the directions in which forces act; – describe situations in which forces are balanced. • Describe situations in which forces are unbalanced and use this idea to explain a change in: – the shape of an object; – the direction of a moving object; – the speed of a moving object. • Explore the forces acting on stationary objects. • Describe the forces acting on objects moving at constant speed. • Distinguish between mass and weight, giving examples. • Describe some ways of reducing friction between an object and a solid surface and some situations in which friction is useful.	• Identify magnetic materials and their properties, including forces of attraction and repulsion. • Use the idea of force to describe the patterns of magnetic fields produced by permanent magnets and electromagnets. • Predict how the magnetic field pattern changes when the strength of an electromagnet increases.	• Use friction in liquids and gases to explore how resistance to an object moving through changes with the object's speed and shape; explain how streamlining reduces an object's resistance to air and water. • Recognise how the turning effect of a force (moment) is related to the size of the force and the distance the force is from the pivot; use moments to explain how a simple object can be balanced. • Recognise how the effect of a force depends upon the area to which it is applied and that the force acting per unit area is called pressure; use the relationship to explain: – the pressure exerted by solids; – pressure within liquids and gases. • Recognise that gravity is a force of attraction between objects, that this force is greater for large objects like the Earth but gets less the further an object moves away from the Earth's surface; use these ideas to explain: – how weight is different on different planets; – how stars, planets, and natural and artificial satellites are kept in position in relation to one another.

Energy

Year 7 pupils should be taught to:	Year 8 pupils should be taught to:	Year 9 pupils should be taught to:
• Identify a range of fuels and explain: – the uses of fuels (food) by living and non-living ‘systems’; – their use as valuable resources; – why conservation of fuels is important in the light of the Earth’s diminishing energy resources. • Use a simple model of energy transfer to explain: – that the Sun is the ultimate source of energy; – how non-living things can change or move and describe these events; – the transfer stages in a range of living and non-living systems; – the purpose of cells in an electric circuit; – that electric current carries energy to components in an electric circuit; – that energy is transferred to components in both series and parallel circuits.	• Describe energy transfer as the result of temperature difference and use this to explain that: – heating is a process where energy is transferred; – temperature change is the response of the material to the energy transfer; – radiation is a means of energy transfer which does not directly depend on the movement of particles. • Recognise that when light travels from a source it is transferring energy; use this idea to: – describe the nature and propagation of light; – explain the behaviour of light, including reflection and absorption. • Recognise that when sound travels by vibrations from the source it is transferring energy; use this idea to: – describe amplitude and frequency; – explain the transmission, production and reception of sound. *Energy and particles* • Use the particle model of solids, liquids and gases and energy transfer to explain: – the processes of conduction, convection and evaporation; – what happens when substances change state; – the performance of thermal conductors and insulators.	• Recognise the idea of energy conservation as a useful scientific accounting system when energy is transferred; use this to explain energy transfers in familiar situations, energy efficiency and energy dissipation. • Develop, from a simple model of energy transfer in electrical circuits, the idea of potential difference in electrical circuits. • Use the model of energy conservation to explain how: – the potential difference measured across cells or components shows how much energy is transferred from the cells to the current and from the current to the components; – electrical energy can be generated using fuels, including the energy transfers involved; recognise possible environmental effects of this.

3 Raising standards in science

Factors that promote higher standards in schools have been documented by Ofsted and in school improvement research. Where the **leadership, management and planning** of science in secondary schools is concerned, better standards occur when:

- the head of department is well informed, provides strong leadership and sets high expectations for what can be achieved by staff and pupils;
- a desire to secure high standards through effective teaching and learning pervades the whole department;
- there is sufficient timetabled teaching time for science, with lesson time extended through regular homework and other out-of-class activities;
- a science scheme of work, based on identified teaching objectives, ensures high expectations, consistent approaches and good progression;
- science teachers observe each other teach, and meet regularly to discuss and develop common understanding of the Key Stage 3 science curriculum;
- there is systematic monitoring and an annual review, led by the head of department, of teachers' planning, teaching and assessment, followed up by discussion and feedback;
- evidence from the review is used to set targets and identify action points for incorporation into departmental and school improvement plans;
- there is regular monitoring of:
  - the accommodation and resources used for science;
  - health and safety requirements; and
  - levels of technical support in science.

Where the **teaching** of science is concerned, better standards occur when:

- lessons have high expectations and clear objectives that pupils know;
- well-paced lessons offer challenging tasks that engage both girls and boys, including:
  - practical work, coupled with interventions by teachers, to develop the investigative skills of scientific enquiry;
  - oral and mental work to develop pupils' knowledge and understanding;
  - study of interesting examples of key scientific ideas in everyday life and other subjects, to show how the ideas are often dependent on each other;
  - posing of non-routine problems to encourage pupils to think for themselves;
- manageable differentiation is based on work common to all pupils in a class, with targeted support to help those who have difficulties;
- teachers introduce pupils to difficult scientific concepts in well-planned stages, using a combination of exposition, demonstration, modelling, instruction and dialogue;

- teachers use well-judged and appropriately pitched explanations to inspire confidence in pupils;
- teachers question pupils effectively, giving them time to think, and expecting them to explain their reasoning using evidence to support their arguments;
- written activities for different scientific purposes consolidate the teaching and are supported by judicious use of ICT, textbooks and other resources;
- pupils are given guidance and examples to illustrate the expected forms of writing;
- pupils are taught and learn about the uncertainty of scientific evidence;
- lessons make links between scientific theory and experiment, so that pupils learn how the practical applications of science are changing the nature of society and the economy;
- teachers take account of cultural and religious sensitivities when teaching topics such as human reproduction, inherited diseases and diet;
- teachers give appropriate attention to health and safety and show pupils how to take responsibility for safe working.

Where the **assessment** of science is concerned, better standards occur when:

- pupils understand and take part in the assessment of their work and progress;
- teachers use pupils' contributions to assess their strengths and difficulties, to set group and individual targets for pupils to achieve, and to plan the next stage of work;
- assessments include informal observations, oral questioning and occasional tests or special activities designed to judge progress;
- recording systems give teachers the information that they need to plan and report successfully, but are not too time-consuming to maintain.

The role of the subject leader

The head of science and any Key Stage 3 science coordinator have a crucial role to play in implementing the National Strategy for Key Stage 3. Positive and sustained leadership of the science department will ensure that it operates as effectively as possible. Although some tasks may be delegated, the head of a secondary science department is generally responsible for:

- inspiring science staff and supporting their professional development;
- reviewing standards, teaching and learning in science, setting annual targets for the subject and producing an annual improvement or development plan outlining the actions needed to achieve the targets;
- encouraging science staff to discuss and debate the teaching and learning of key scientific ideas;
- reviewing and updating the science scheme of work and teaching resources;
- organising science teaching groups and allocating staff to teach them;

- monitoring and evaluating teachers' planning and teaching of science and the assessment of pupils' learning, work and progress;
- ensuring that the department takes part in cross-curricular activities, such as literacy and numeracy across the curriculum;
- liaising with staff who support particular groups of pupils;
- liaising with partner primary schools;
- keeping the senior leadership team informed about the department's plans and progress.

In the context of the Strategy, subject leaders have two main responsibilities. These are:

1 **To identify strengths and areas for development** in the subject through:

- leading an audit to evaluate standards and the quality of teaching in the subject;
- identifying targets to be achieved and action points for achieving them; and
- working with staff in the department to identify their professional development needs in relation to the Strategy.

The audit of standards and the quality of teaching and learning can be based on the Strategy's audit guide and criteria in this science Framework. For science, a supplement links the identified priorities to opportunities provided by the Strategy for continuing professional development. The purpose of the audit is to identify for the school's senior leadership team and for the department:

- what (if any) changes are needed to the department's work in order to raise standards;
- which teachers could benefit most from the training and school-based consultancy offered through the Strategy.

The action points should ensure that the identified changes are tackled in order of priority, at a pace that is manageable for the department with the resources available to it, and in a way that ensures that the changes can be sustained.

2 **To lead improvements and support implementation of the Strategy** by:

- offering curriculum leadership;
- leading and disseminating Strategy training;
- monitoring implementation.

A major responsibility of the subject leader is to inspire colleagues by offering curriculum leadership so that all staff teaching science regularly discuss and develop a common understanding of how to teach certain scientific topics or particular groups of pupils. Such discussions help to develop teamwork and consistent approaches. At times they will be for the purpose of disseminating ideas learned on training. They can lead to refinements of a scheme of work and the preparation of teaching materials that all teachers of science can use. From time to time the discussions can be extended to other departments so that science staff consider with other teachers:

- how science can support the teaching and learning of other subjects and what other subjects can contribute to science;

- how science will be involved in the initiatives on literacy and numeracy across the curriculum;
- the use of ICT resources for scientific activities, particularly the use of data logging, spreadsheets and databases (see pages 46–47).

A vital part of implementation is the subject leader's monitoring role. Part of the work of a subject leader is to be aware of the quality of teaching among staff in the department and the teaching styles and methods they are using, and to advise and support teachers accordingly. In a thriving department, the subject leader will from time to time observe science lessons taught by other members of staff. In turn, they will be given an opportunity to observe the subject leader teaching and to see each other at work.

The subject leader also reviews regularly with departmental staff the written work of pupils in different classes in order to monitor the progress of each class and to check that marking and other assessments are being carried out satisfactorily. These observations are best when they are followed up with feedback and collective discussion, and can be of particular help to newly qualified and non-specialist teachers of science.

A separate Key Stage 3 Strategy booklet, *Securing improvement*, is available for subject leaders about their role. The booklet helps to identify strengths and areas for professional development, and links to the publication *Leading from the middle*, from the National College for School Leadership (see section 8, page 65).

4

Planning

The time involved in careful planning is a worthwhile investment. It reduces the demands of paperwork in the long term. Plans that are well constructed and informative do not have to be written in full prose or elegantly word-processed, though they do need to be accessible to others. Their prime purpose is to specify coverage, ensure good progression and so improve teaching and learning.

It is helpful to consider three levels of planning: long-term, medium-term and short-term.

Long-term and medium-term plans

The QCA exemplar scheme of work for science

The programmes of study for Key Stage 3 science form a long-term plan. The QCA scheme of work illustrates how the programmes of study can be:

- arranged into coherent teaching units; and
- distributed across the three years of the key stage in a sequence that provides continuity and progression in pupils' learning.

The scheme, with the associated teacher's guide, is published on the DfES Standards website: www.standards.dfes.gov.uk.

The scheme of work:

- groups topics in units of work throughout each term and over the year;
- shows how to sequence units of work across Key Stage 3 so that they build on preceding work, link with other units and prepare pupils for Key Stage 4;
- describes what different groups of pupils might be expected to achieve in particular units;
- integrates scientific enquiry into the teaching of other sections of the programme of study;
- refers to the contexts in which science and technology are developed and used, and their impact at a personal, local and global level;
- incorporates literacy, numeracy, ICT and key skills in science lessons and illustrates how to encourage pupils to think about the science they are doing;
- shows how out-of-school activities can enhance learning in school.

Each unit of work in the scheme provides a detailed medium-term plan. Related units can be linked together to form a main topic that pupils can be taught over a half-term or a term. They reflect the progression in the teaching and learning of scientific enquiry and the key scientific ideas in and across years, as outlined in the yearly teaching objectives. The units also provide opportunities to revisit topics and to make connections between different aspects of science.

A suggested number of hours of teaching is given for each unit, including time for assessment of previous learning, checking pupils' progress during the unit and reviewing pupils' progress at the end of a unit. Each unit contains:

- **Expectations**
  These are broad descriptions of what most pupils will be able to do and know at the end of the unit, with modifications for those attaining above or below the standard expected for the year group. The expectations are based on judgements about pupils' performance at the end of Key Stage 3 outlined in the National Curriculum as level descriptions.

- **Learning objectives**
  These outline the small steps involved in building up the knowledge, skills and understanding that are the focus of the unit.

- **Possible teaching activities**
  These help pupils to develop the knowledge and skills outlined in the objectives. Activities are grouped under headings in the form of a general question that indicates the focus. Some activities take longer than others and some are more demanding. Use the differentiated expectations and learning outcomes to judge which activities to stress for a particular group of pupils. Over time, the suggested activities can be added to or replaced, using existing school resources, and cross-referenced to other resources, including textbooks and ICT.

- **Learning outcomes**
  These can be used to assess the extent to which pupils have met the learning objectives and if they are ready to move on to the next activity. There is no need to keep detailed records of each pupil's progress in relation to the learning outcomes.

- **Points to note**
  These include teaching points, references to ICT, common misunderstandings and suggestions for extension activities, some of which are suitable for homework. They highlight links with other units in the scheme, with the QCA scheme for Key Stage 2, and with other subjects where similar ideas might be taught. They also give safety points.

- **Language for learning**
  This lists key scientific terms and technical language for the unit (see also appendix 3 of this Framework, pages 73–76).

- **Out-of-school learning**
  This suggests optional opportunities for out-of-school learning, for pupils on their own or with friends or families. The activities are not homework suggestions. They provide examples of contemporary science relevant to pupils' lives and enhancement activities that could take place in a science club.

Reviewing the school's scheme of work

Schools should make a professional judgement about how they will review or customise their own scheme of work for science, once they have studied this Framework and the QCA scheme of work, reflected on their Key Stage 3 Strategy training, and evaluated their current practice. They can use as little or as much of the QCA scheme as they find helpful, adapting any ideas from it to meet pupils' needs and the science department's priorities.

Whatever the decision, the work should involve all staff, including technicians and teaching assistants attached to the science department.

Short-term or lesson plans

Short-term plans or lesson plans are based on the units in a scheme of work. Lesson plans are teaching notes for a block of lessons or individual lessons, showing how a unit of work will unfold to achieve the intended objectives.

It is important not to have too many objectives in a particular lesson or block of lessons, so that the teacher and pupils can remember them. Lessons may have subsidiary objectives that do not need to be written down but the yearly teaching objectives are key. They should be used to focus lesson plans on the needs of pupils and available resources. The main requirement of lesson plans is that they make clear how the yearly teaching objectives for the relevant unit will be taught and met.

Lesson plans should:

- indicate the yearly teaching objectives for each block of lessons or individual lessons that form part of the unit;
- stress the relevant scientific terms and technical language;
- outline starter activities, including initial questions;
- show how work will be developed in the main part of the lessons through teaching input, key questions and pupil activities, with suggestions for differentiation where appropriate;
- indicate how lessons will be rounded off;
- suggest what homework will be set;
- identify links with other areas of science;
- refer to relevant resources, such as textbooks and ICT applications;
- refer where relevant to risk assessments and specific health and safety procedures.

Each unit of work will consist of several lessons: for example, an 8-hour unit may be planned in a sequence of 3, 2 and 3 lessons. In the units in the QCA scheme of work, activities are grouped under headings in the form of general questions, but these are not intended to represent single lessons. General questions may need to be answered in more than one lesson and you will need to judge for a particular group of pupils which activities to stress. For example, you might plan an introductory lesson based on a problem, or a lesson focusing on an open-ended investigation suitable for pupils with a wide range of attainment.

There could be up to three versions of a particular unit of work for a specific year group, differentiated for higher, average and lower attainers, but with some overlap.

A sample lesson

The lesson below (adapted from one in the *Year 9 booster kit: science*) contains enough detail to describe the lesson to a reader. An individual teacher's personal lesson plans would be much briefer and would probably refer to particular pupils or resources by name. There is no expectation that all teachers produce lesson notes like this, but a bank of lessons with this degree of detail can be useful for supply teachers, newly qualified teachers and non-specialists.

What are reactions? Year 9 — 1 hour

Objective

To revise identification of evidence which indicates that a chemical reaction has taken place

Vocabulary

antacid, carbonate, characteristic, exothermic, flammable, hydrogen, indigestion, metal, neutralisation, pH, product, reactant, reaction, reactive, salt

Resources

A range of cards for sorting (include reactions from other areas of science, such as iodine added to starch as an indicator for photosynthesis, and from more simple to more complex chemical changes)

Text on acids and alkalis

OHT with graph of results of previous experiment and sets of related questions

Display of practical equipment or demonstration reactions (see QCA scheme of work, unit 7F)

Starter activity — 10 minutes

Introduce the objective. Ask pupils in pairs to sort statements on cards into reversible or irreversible chemical changes. The statements should provoke discussion about whether or not a change is permanent or is easily reversed. Listen to pupils as they make decisions about each statement. After 5 or 6 minutes get pairs into fours to compare decisions and widen the discussion. Go through the accepted answers, allowing time for pupils' comments.

Main activity — 40 minutes

Characteristics of reactions — 10 minutes

Ask pupils for ideas on what they are likely to 'see' when reactions take place. They can scan the 'irreversible' statements in the first activity to find these. Widen the definition of 'see' to mean 'anything that you could observe or measure' and establish a list on the board.

Using statements about the characteristics of reactions, ask pupils to match reaction characteristics to the reactions they identified in the first activity. Pupils should recognise that some of the reactions have more than one measurable characteristic. Direct less confident pupils to two or three pre-selected statements. Distinguish the making of new products from energy transfer. Ask pupils to group reactions according to common characteristics and encourage them to make as many groupings as they can. Circulate around groups and challenge more able pupils to describe the types of energy transfer taking place in one or more of the reactions.

Summarise this activity by explaining that it shows that we need to know what to observe or measure if we are to follow reactions in a scientific or investigative way.

Reactions of acids 20 minutes

Ask pupils to read a short text on reactions of acids and highlight whenever an energy transfer takes place. If necessary, use different levels of text for different groups of pupils. Pupils can read alone or in pairs or in any way that will help them understand the passage.

Now ask pupils in pairs to:

- consider a number of groups of statements about common acid–alkali reactions;
- justify which of the groups they agree with by writing ‘I agree with … because …’;
- consider what they have just read along with other ideas they may have;
- discuss ideas before making a decision about each group.

Provide a prepared writing frame for any pupils who would benefit from this. Circulate and listen to the ideas of different groups.

Discussing results and choosing equipment 10 minutes

Explain how the production of a gas can be useful in tracking reactions. Show an OHT of a graph of results of pupils’ experiments on two types of limestone rock where volume of carbon dioxide was measured over time. Give out questions about the graph and ask pupils to work in small groups to allow for more viewpoints in the discussions. Take feedback by considering each question in turn and moving from group to group to get a range of answers. Discuss any misconceptions that are apparent and question pupils about the equipment needed to produce the most reliable results for these experiments.

Plenary 10 minutes

Ask pupils in pairs to write down three facts they have learned about characteristics of reversible and irreversible reactions. Monitor pupils to assess informally their grasp of the facts. Get pairs into fours to share their three facts. Take brief feedback to summarise the lesson, drawing on groups that have considered biological reactions as well as physical reactions.

Homework

Ask pupils to produce a concept map showing links between a couple of chemical reactions and their characteristics.

5

Teaching and learning strategies

The Key Stage 3 Strategy promotes these principles:

- sufficient regular teaching time for the teaching and learning of scientific knowledge, and of the understanding and skills of scientific enquiry;
- direct, interactive teaching, through whole-class and small-group work, including the demonstration of essential practical and technical skills;
- engagement by all pupils in tasks and activities that, even when differentiated, relate to a common topic for the whole class;
- extra support for pupils who need it to keep in step with the majority of their year group;
- regular opportunities to develop scientific language and mental and visualisation skills through oral work and modelling;
- opportunities for pupils to use and apply their understanding of key scientific ideas, either on their own or with others, with varying degrees of support;
- opportunities to carry out extended investigative work;
- time for pupils to reflect on their learning.

Teaching time

In Key Stage 3, the typical amount of teaching time given to science is about 3 hours a week, approximately 12% of the teaching week. Heads of science, when they discuss Key Stage 3 with school timetablers, should aim to ensure that science lessons in each year group are frequent and spread across the week, not bunched together.

Organisational models such as four lessons of 50 minutes are useful. They satisfy the principle of frequency, ensuring that pupils maintain and sharpen their scientific knowledge, understanding and skills through near daily contact. Other models, such as three 70-minute science lessons, or six 35-minute lessons made up of double and single periods, need to be organised carefully, particularly where fortnightly timetables operate. Seventy-minute lessons are useful for laboratory practical work, but for lessons without practical work, 70 minutes can be too long for pupils to maintain their concentration if the teaching is to be intensive and direct. On the other hand, a single 35-minute period offers too little time for key scientific ideas to be developed and consolidated in the main part of the lesson.

The focus on direct, interactive teaching

It is vital that pupils engage actively with their learning. This is the basis of scientific mastery, particularly when dealing with abstract phenomena. Without it, learning is superficial and soon lost.

Aim to spend a proportion of each lesson in leading interactive tasks that involve all pupils. Organising pupils as a ‘whole class’ helps to maximise their contact with you so that every pupil benefits from direct teaching for sustained periods in each phase of the lesson. But intervention, direct teaching and interaction are as crucial during individual, paired and group work as they are in whole-class sessions, whether they be practical work or other activities.

High quality direct, interactive teaching is oral, collaborative and lively. It is not achieved by lecturing the class, or by expecting pupils to teach themselves indirectly during practical work or from books. It is a two-way process in which pupils are expected to play an active part by answering questions, working together collaboratively during scientific enquiry, contributing points to discussions, and explaining and demonstrating their methods, conclusions and solutions to others in the class.

Good direct, interactive teaching is achieved by balancing different teaching and learning approaches:

- **Directing and telling:** sharing your teaching objectives with the class, ensuring that pupils know what to do, and drawing attention to points over which they should take particular care, such as how to ensure that one step follows from another in a scientific argument, the degree of accuracy to adopt when making a measurement, how to communicate findings, how to label axes correctly or plot a smooth curve …
- **Demonstrating:** giving clear, well-structured demonstrations using appropriate resources and visual displays: for example, showing a particular technique or a scientific method for a practical activity, showing how to interpret a graph or develop a rigorous scientific argument, interpreting a view through a microscope using photographic slides, or electronic views from a mini-camera or CD-ROM using a data projector or whiteboard …
- **Explaining and illustrating:** giving accurate, well-paced explanations, and referring to previous work or methods: for example, using models and analogies to assist understanding, giving the meaning of a scientific term, symbol or form of notation, explaining how evidence leads to an acceptable conclusion …
- **Questioning and discussing:** questioning in ways which match the direction and pace of the lesson to ensure that all pupils take part (supported where necessary by apparatus, a calculator or a communication aid, or by an adult who translates, signs or uses symbols); using open and closed questions, skilfully framed, adjusted and targeted to make sure that equal numbers of girls and boys, and pupils of all abilities, are involved and contribute to discussions; asking for explanations; giving time for pupils to think before inviting an answer and deciding when it is apt to have a ‘no hands up’ approach; listening carefully to pupils’ responses and responding constructively in order to take forward their learning; challenging their assumptions and making them think …
- **Exploring and investigating:** asking pupils to pose problems, suggest a line of enquiry or design a fair test, to investigate for themselves or identify anomalous results; equipping pupils with the skills required to plan and carry out investigations, including opportunities to extend the range of equipment they can use successfully in their work …
- **Consolidating and embedding:** providing varied opportunities to practise and develop newly learned skills, through a variety of activities in class and well-focused homework; asking pupils either with a partner or as a group

to reflect on and talk through a process; inviting them to expand their ideas and reasoning, or to compare and then refine their methods and ways of recording their work; encouraging them to use and apply their scientific skills to solve scientific problems across the curriculum …

- **Reflecting and evaluating:** identifying pupils' errors, using them as positive teaching points by talking about them and any misconceptions that led to them; discussing pupils' justifications of the methods or resources they have chosen; evaluating pupils' presentations of their work to the class; giving them oral feedback on their written work …
- **Summarising and reminding:** reviewing during and towards the end of a lesson the science that has been taught and what pupils have learned; identifying and correcting misunderstandings; inviting pupils to present their work and picking out key points and ideas; making links to other work in science and other subjects; giving pupils an insight into the next stage of their learning …

Effective science lessons

Effective science lessons have tight structures and clear objectives. Science lessons are effective when pupils are clear about what is expected of them. Good lessons are the result of careful planning and include:

- high expectations and clear objectives, conveyed to pupils in simple language: 'What I am looking for is pupils who can …';
- time for a brief review of previous work at the start of the lesson and a plenary including a summary of the lesson at the end;
- appropriate exposition, demonstration, class practical work and other activities that interest pupils and capture their imagination;
- questions used throughout to challenge thinking;
- time to assess informally the extent to which pupils develop their understanding of key scientific ideas;
- references to relevant contemporary science applications or issues, including topical local examples or those in the national media;
- extended discussion so that pupils have opportunities to air views, articulate ideas and hear the views of others;
- the use of models and analogies to aid pupils' understanding.

A typical science lesson can vary depending on the type of work that pupils are to do. A practical lesson, and particularly those that involve scientific enquiry of an extended nature, will require different planning and management from lessons that are focused on the reinforcement of knowledge and understanding.

A typical 50- to 60-minute lesson is likely to include one or more starter activities, a main activity and a concluding plenary.

Starter activities (about 5 to 10 minutes)

Each new lesson can begin with setting the scene and a short activity to help pupils to tune in, interest them and engage their attention.

Setting the scene involves clarifying the objectives and explaining the purpose of the lesson. You might want to look back, discuss homework and, when the main activity spans more than one lesson, consider how a lesson develops from the previous one. You might outline the sequence of the lesson so that pupils know what to expect, say why a certain experiment or investigation is to be done, and indicate where the lesson fits in with other lessons. All this helps pupils to understand why they are learning these new ideas and to make connections.

Short, stimulating starter activities, either before or after the scene setting, help to get the lesson off to a brisk start and prepare pupils for the main activity. For example:

- try a mental warm-up, an introduction to new phenomena, a thought experiment, or a 'What if…?' question to find out what pupils think and elicit their ideas;
- focus on key words through a loop card game, a word web or word dominoes;
- present and discuss some 'amazing facts';
- consider different types of text, such as explanations or questions that require pupils to provide alternative answers to interesting phenomena;
- present a problem, explore a challenging statement or opposing views;
- carry out short data handling activities, using an OHP to display a graph, chart or table and asking questions such as: 'What event or "story" could the graph illustrate?', 'What questions could this chart help to answer?', 'What do the data in the table show you?', 'What conclusion would you write if this graph represented your results?'

The main activity (about 25 to 40 minutes)

Building on the starter, the main activity is characterised by high levels of direct, interactive teaching and probing questioning, regardless of whether pupils are working as a whole class, in groups or individually, or whether the lesson consists of practical work, an extended investigation or written work. Organise the class so that you can interact with as many pupils as possible. Teach specific skills such as interpreting graphs and evaluating evidence in this part of the lesson. Match the tasks and activities for pupils to do to their previous attainment and your objectives for the lesson. You may want to allow some choice here. Examples of activities include focused practical work, or the use of scientific models to explain phenomena or elucidate conflicting ideas and evidence.

Effective science lessons can have several cycles of main activity and plenary; mini-plenaries during the main part of a lesson allow misconceptions to be identified and dealt with quickly. Throughout the main activity, encourage pupils to make predictions before any demonstrations, especially those that give unexpected outcomes. Look for gains in understanding, wrong science, misconceptions … Use opportunities to report back, clarify, model and review.

A concluding plenary (about 5 to 10 minutes)

Short plenaries may take place during the main activity, while the concluding plenary rounds off the lesson. It is far more than 'clearing up' after a practical session and should be just as dynamic as the starter. Help the pupils to reflect on the lesson, say what was important about it and consider the progress they have made. Draw out from them and highlight the key learning points, such as facts, ideas and vocabulary. Get them to think about how they might apply the new ideas, by showing how the ideas can be used and where they fit in.

The final plenary can also look forward to the next stage of learning. It should make pupils think and anticipate what the next steps might be. The homework you set should help pupils to consolidate or apply what they have learned, or prepare for the next lesson.

Effective science lessons and flexibility

Secondary schools work to different time constraints so the structure and timing of science lessons will differ. The outline structure of a three-part lesson described above is recommended since it can be adapted to different circumstances. It provides a beginning, a middle and an end in which you prepare pupils for what they are to learn, teach it to them, then help them to recognise what they have achieved. It allows a variety of patterns of teaching methodology and organisation, depending on a lesson's objectives and its position in a series of lessons.

The outline structure is not a mechanistic recipe to be followed. Use your professional judgement to determine the activities, timing and organisation of the beginning, middle and end of the lesson to suit its objectives. For example, with four 50-minute lessons each week, you might have a starter of 15 minutes on one day, with a brisk two or three minutes on the remaining days. In the longer starter, pupils might enter the room and start to work on a challenging problem posed on the board, with oral and mental work, based on their initial thoughts on the problem, taking place after five or ten minutes.

In the main part of the lesson, in particular, there is scope for considerable variety and creativity, with a different interplay of work with the whole class, groups, pairs and individuals on different days, although each lesson should include direct teaching and interaction with the pupils, and activities or exercises that pupils do. For example, at the start of a new unit of work you might need more time for demonstration, explanation and discussion with the whole class, interspersed with very short exercises for pupils; the plenary may be very short. On the other hand, when you have identified general errors or misunderstandings during the main part of a lesson, you may need several mini-plenaries during the lesson to sort them out, as well as a final summing-up. Later in a unit of work, pupils might start the main part of a lesson by continuing to work in pairs on a previous problem; once they have refocused on it, you might hold a mini-plenary with the whole class to share ideas, highlight important results and structure work from there on. At the end of a unit of work it can be useful to use the plenary to look back with the whole class over a number of lessons to draw together what has been learned and to identify key points and methods that you want pupils to remember and use in the future. For this kind of plenary, you may need a much longer time than usual.

Using ICT in Key Stage 3 science

The use of ICT in science lessons should promote better learning of science, not just contribute to the National Curriculum for ICT. Science at Key Stage 3 must be relevant to pupils and as much as possible reflect the current world of science. Industrial and research science relies heavily on ICT-controlled equipment and often involves the adaptation of traditional experiments to take advantage of new measuring techniques. Impressive achievements, such as the sequencing of the human genome, would not have been possible without ICT-controlled analytical tools. Pupils in Key Stage 3 need to appreciate that this is the direction of science in the 21st century.

Used well, ICT enables pupils to gain information that they could not otherwise obtain. For example, through data logging, pupils can capture data involving very fast or very slow changes, such as the time taken for a ball-bearing to drop from a height or changes in the air temperature of a greenhouse over 24 hours. Electronic measuring equipment removes the tedium of manual measuring and recording and frees up time for discussion of the underlying science.

ICT can be used in science to **enhance individual learning**: for example, individuals or pairs of pupils can use a simulation to model changes in populations of bacteria in different conditions. In individual or paired applications, pupils need clear directions before they start, otherwise you might spend too much time trouble-shooting. Structured tasks and activities should focus on the scientific ideas underpinning the model, not the ICT skills needed to manage the software.

ICT can also be used in science to **enhance the learning of a whole class**, if a large screen or data projector is available so that the whole class can see. For example, with a whole class you could use:

- an oxygen probe to measure the levels of oxygen in various samples of pond water to help explain why different habitats support different plants and animals;
- a data logger to collect, analyse and evaluate changes of pH during neutralisation reactions, or changes of mass when an acid reacts with carbonate salts;
- a microscope connected to a computer monitor to display close observations;
- a spreadsheet to complete calculations and plot graphs, and to show how changing the data alters the graphs;
- a simulation to explore toxic materials in food chains, or investigate circuits;
- a video or CD-ROM to observe a dangerous reaction, such as adding caesium to water;
- an Internet link to find up-to-date information, for example, on environmental issues.

The key to success in all these applications is the quality of the whole-class discussion of the observations and their implications. Encourage the class to:

- ask questions, predict and hypothesise;
- observe, measure and record, and manipulate variables;

- interpret results and evaluate scientific evidence;
- present and communicate their findings in a variety of ways.

The main applications of ICT in Key Stage 3 science are these.

- **Simulations and modelling** help pupils to understand phenomena that in a school laboratory may be too slow, too fast, too dangerous or too expensive. Simulations allow pupils to investigate the effects of changing variables (e.g. in an exploration of the factors that affect photosynthesis), and to consolidate and reinforce their conceptual understanding (e.g. about the particulate properties of materials).
- **Data logging** helps pupils to record, present and analyse results. For example, sensors can be used to record temperature, moisture, light and pressure, and experimental results can be displayed as a graph on an interactive whiteboard.
- **Databases, spreadsheets and graphical calculators** allow pupils to organise, search, sort and display information in order to explore relationships, look for patterns and test hypotheses. For example, they might extract data on the nutrient value of different foods or analyse and evaluate information about diets.
- **Information resources** allow pupils to find information to develop their knowledge and understanding of science. For example, CD-ROMs, data files and access to the Internet can supplement textbooks by providing an extensive source of information and illustration; selected pages on websites can be downloaded for further study offline. Video snippets allow pupils to see things that cannot be brought into school.
- **Publishing and presentation software** such as word-processors and desktop-publishing packages allow pupils to present their findings to others. Time can sometimes be saved by dividing tasks between groups and getting them to report back; the use of PowerPoint presentations for this purpose can increase pupils' motivation and enthusiasm.

In addition, ICT can offer significant support to science teachers by assisting with the preparation of teaching materials.

ICT resources are not a panacea for all eventualities. In some situations they will be the best way to convey or consolidate a new idea or concept, but not always. ICT needs to be planned carefully into the departmental scheme of work so that pupils make good progress. Check whether the use of ICT is appropriate by asking these questions.

- Will pupils be able to see patterns or behaviours more clearly?
- Will the use of ICT add reliability or accuracy to measurements?
- Will time be saved by reducing the time spent on measurement and recording?
- Will pupils have access to information not otherwise readily available?
- Will pupils be engaged in the selection and interpretation of information?
- Will the use of ICT help pupils to think through scientific ideas?

6 Assessment and target setting

Many pupils now leave Year 6 with personal targets, records and a history of intervention. This body of information can help secondary teachers to make a quick start on work that is well matched to pupils' capabilities. The clean-sheet approach is too slow, and allows pupils to coast or to fall back when they need to be challenged. As a minimum, teachers of Year 7 classes should know about pupils' science attainment from Year 6 and, on the basis of their average points score from Key Stage 2, their projected likely level of attainment in Year 9. Reviewing other performance data, teacher assessments and early work in Year 7 will alert you to unexpected changes in performance which need to be resolved and enable you to adjust your teaching expectations accordingly.

Priorities for each new cohort can be derived from Key Stage 2 levels and raw scores and the qualitative information provided by work sampling and other monitoring in the early part of Year 7. This helps the department to translate wider ambitions such as 'improve knowledge and understanding of life processes and living things (Sc2)' first into numerical targets, such as 'increase by 10% the proportion of pupils achieving the Year 7 key objectives for cells by the end of Year 7', then into specific curricular targets, such as 'all pupils will recognise that all cells have a nucleus, cell membrane and cytoplasm'.

Assessment, recording and reporting are important elements of teaching but they have to be manageable if the information they yield is to be useful. The best assessment has an immediate impact on both teaching and learning. First, it alerts you to the needs of pupils who are either out of step or exceeding expectations. Second, it helps you to maintain the pace of learning for all pupils by informing teaching plans in a continuous cycle of planning, teaching and assessment. Third, the immediate feedback that you give to pupils, and the self-assessments that you encourage them to make, are crucial in helping them to identify how to improve their work.

It is useful to consider assessment at three connected levels: short-term, medium-term and long-term.

Short-term assessments

Short-term assessments are an informal part of every lesson. Their purposes are to:

- check that pupils are developing mental skills: for example, that they can recall scientific facts, and use visual imagery and models to explain scientific phenomena;
- check that pupils have grasped the main teaching points in a particular lesson or unit of work, whether they have any misunderstandings or misconceptions that you need to put right, and whether they are ready to move on;
- give you information which will help you to give pupils feedback, adjust day-to-day lesson plans and brief any support staff about which pupils to assist, and how to assist them.

Short-term assessments help you to judge the degree to which your short-term teaching objectives have been met. There are three main ways to make them:

- **During every lesson** you absorb and react to pupils' responses, see whether they are confident or hesitant with new work, decide whether they need extension work or more help, and offer immediate support. Where you notice any difficulties, misunderstandings or misconceptions, you can adjust your lesson and address them straight away, if necessary continuing in the next lesson or two. In this way, pupils can keep up with the pace of work and do not fall behind. In plenary sessions, you can acknowledge individual and class achievement and effort and remind pupils about their targets. Plenary sessions are also a good time to firm up short-term assessments by asking probing questions to judge how well pupils have understood new work and to check again for any misunderstanding or misconceptions.
- **At intervals** you can supplement your day-to-day observations. For example, a homework task or an occasional short informal test can give you useful information on who has learned what and who needs extra support. The ideas on 'checking progress' in each unit of the QCA scheme of work can be helpful here.
- **Marking of pupils' classwork and homework** helps you and them to judge their progress. It needs to be done together with pupils or followed immediately by discussion with the whole class and individuals to give them feedback on their performance and what they need to do to improve. For this purpose constructive written comments or questions are more helpful forms of marking than grades and ticks and crosses. At the same time you will probably want to ask pupils to correct any errors and to discuss with them the merits of their different methods or approaches. Marking, feedback, corrections and rectifications of difficulties are best done immediately after a piece of work so that pupils can still remember how they approached the task and so that you can modify your teaching plans if you need to. Some teachers focus their marking and feedback on a particular group in a particular week, using detailed marking to inform their discussion with that group; marking of the work of other groups is less detailed in that week but is sufficient to help pupils to keep on track with their work.

Short-term assessments do not need to be recorded, since they are for immediate action and attention. Some teachers note briefly when a pupil surprises them, perhaps with his or her knowledge or with the degree of success at something that is unexpectedly difficult. These informal, personal recordings can help to clarify patterns in performance over time or responses to specific teaching or support. Any recording needs to be manageable and determined by individual teachers; some prefer to make detailed notes while others prefer brief annotations in mark books or planners.

Medium-term assessments

Medium-term assessments should gather new information, not just confirm what you already know. They are mainly to:

- review pupils' progress over a particular unit of work or the previous half-term in relation to the yearly teaching objectives:
  - what they know and can do;
  - whether they can apply their knowledge, understanding and skills in a new context;
  - whether they still have any difficulties;
- identify pupils' progress against specific individual targets so you can give pupils feedback and set new targets;
- help you to plan work over the next half-term or so;
- give you information to feed into end-of-term or end-of-year assessments.

Most pupils should be living up to expectations for their class and you will be familiar with their progress and learning from your short-term assessments. Assessment of pupils' progress in the medium term should be made against the relevant yearly teaching objectives for each year for the unit of work, not against the level descriptions.

Medium-term assessments are best timed to influence planning. Towards the end of a unit of work, there is an obvious opportunity to assess how well pupils have done against the relevant yearly teaching objectives, and to set targets for the future. This may mean, for example, using a variety of assessment methods. The expectations outlined in each unit of the QCA scheme of work and the activities on 'reviewing progress' could both be helpful here.

Assessment tasks or activities can be designed so that pupils can tackle them independently. You can then concentrate on the pupils you are unsure about. The results need not be elaborate if the units of work have gone well. The purpose may just be a matter of identifying which pupils need extra feedback or consolidation, and setting new targets for the whole group or particular groups and individuals. The principle is to mobilise medium-term assessments quickly into the setting of relevant and realistic targets.

Recording pupils' progress

It is helpful if pupils' progress towards yearly teaching objectives is recorded but, of course, this is not a statutory requirement. Since there are relatively few yearly objectives, records are not too onerous to maintain, and updating them every six weeks or so is sufficient. The easiest system is a class record of progress against the relevant yearly objectives. Teachers need only note:

- any pupils who have struggled to meet the objective(s) and who will need extra support when the class revisits that topic;
- any pupils who coped quickly with the work, were taken further and who will need to be given more challenging work when they revisit that topic.

This record should be used to inform planning by current and future teachers, so should be passed on to subsequent teachers. A class record of this kind can be a useful aide-mémoire for parents' evenings or when you are writing annual reports.

Targets for individual pupils

A discussion with pupils during the course of each half-term to set them personal targets helps them to achieve the yearly teaching objectives over the medium term. You may want to arrange your discussion with some pupils on an individual basis – for example, pupils with special needs or pupils who would benefit from a degree of privacy – but for most of them you can organise the discussion in small groups as part of an ordinary science lesson. Ask pupils to suggest two or three improvements to work on over the next term. You could also offer pupils some practical advice on the steps they might take to achieve their targets, and give them an occasional opportunity to work on the targets as part of one or more homework tasks. It is helpful if some monitoring of progress towards individual pupils' science targets can take place in tutor-group time as part of a whole-school approach to target setting.

Individual targets will usually be linked to the yearly teaching objectives that you will focus your teaching on over the next few weeks, or to extracts from level descriptions. They may be very specific: for example, to become proficient at writing conclusions to practical work. For some pupils a target may need to be broken down into stages: for example, to record one thing they have discovered. For others, it may be appropriate to choose a target linked to the yearly teaching objectives for the year group below or above. Whatever the targets, they need to be straightforward and not too many at one time, so that pupils understand them. One way of keeping track of pupils' individual targets is to highlight a class record of objectives. Exceptionally, there may be some pupils with special needs whose personal targets need to be recorded in supplementary notes.

Long-term assessments

Long-term assessments are summative. They are made against the level descriptions on a 'best-fit' basis at the end of a key stage and, if schools wish, annually. Their purposes are to:

- assess individual pupils' work against the level descriptions;
- help to review pupils' overall progress and attainment against school, local and national targets for Key Stage 3;
- give supplementary information about individual pupils' attainment and progress for reporting to parents and, if appropriate, the next teacher.

Long-term assessments include end-of-year tests or examinations, and teacher assessments.

Teacher assessments at the end of the key stage

At the end of each key stage, teachers are required to give a level for each pupil for each attainment target: scientific enquiry (Sc1), life processes and living things (Sc2), materials and their properties (Sc3) and physical processes (Sc4). It can be helpful to study the pitch of the yearly teaching objectives against the level descriptions for each year group.

End of Year	Expected attainment		
	Pupils who make slower progress	Most pupils	Pupils who make faster progress
7	level 3/4	level 4/5 level	6
8	level 4	level 5	level 6/7
9	level 4/5	level 6	level 7/8 or level 7/7*

Pupils' attainment in science often shows characteristics of several different levels both within and across attainment targets. A pupil's understanding does not develop in a series of even steps but often as quite sudden leaps interspersed with plateaux and even sometimes slipping back.

The level descriptions are designed to be used as a best-fit model at the end of a key stage to encompass this variation in performance. You will need to decide if a pupil has broadly achieved a particular level or whether the level above (or the level below) is a better fit. This judgement should be relatively quick and easy to make for the great majority of pupils for each attainment target if you have assessed their medium-term progress against the yearly teaching objectives. Item analysis of test papers can also help you to judge pupils' performance against the level descriptions by providing a clear picture of curricular strengths and weaknesses.

Before assessments are made, it is helpful if all staff teaching science in Key Stage 3 examine together and 'level' a sample of pupils' work from each Year 9 class. This helps to make sure that judgements against the National Curriculum level descriptions are consistent throughout the department.

Using levels to track progress

Assigning levels can help in tracking pupils' progress as part of long-term assessment. It is not the intention that level descriptions, or subdivisions of them, are used weekly, half-termly or even termly.

Partitioning the levels into three subdivisions based on pupils' raw scores in tests – for example, 4a, 4b and 4c – has sometimes helped schools to target and improve the achievement of specific groups of pupils. These are broad categories that highlight noticeable differences in performance in a level. Partitioning levels more finely – for example, into ten subdivisions – is inappropriate since the categories become too fine: the number of test marks separating the subdivisions, for example, would not be great enough to measure real differences in attainment with confidence.

7 Inclusion and differentiation

Science has the potential to engage and inspire all pupils. Try to ensure that, as far as possible, pupils work together through the planned programme for their class so that all of them are included in each unit of work, take part fully in lessons, and benefit from the discussion and interaction with their teacher and their peers.

Although setting in Key Stage 3 science varies across schools, most organise Year 9 pupils in ability sets for their science lessons. Planning tends to be easier if the attainment spread in a class is not too wide, although even in an ability set there is still a range of attainment. More than half of all secondary schools organise Year 8 into ability sets and under half organise Year 7 into ability sets.

There are several ways of meeting the needs of classes with a spread of attainment, whether they are ability sets or mixed ability. The first step is to establish a classroom climate where all pupils feel that they can contribute and which secures their motivation and concentration. The next step is to adopt teaching and organisational strategies to keep all pupils involved and suitably challenged, while giving them maximum opportunity to interact with their teacher. This includes providing appropriate support, aids or interventions to give particular pupils access to the planned programme and to keep any who might fall behind in step with the rest of their class.

The success of setting depends on close teamwork, cooperative planning and careful monitoring by science staff to make sure that pupils can move from set to set as their progress demands and that expectations for all pupils are suitably high; lower expectations are not justified simply because pupils are in a lower set. Remember that pupils' performance can vary between science topics and that some pupils in lower attaining sets can perform better than expected with certain topics.

Teachers of lower sets can take account of the expectations in the QCA scheme of work for science for pupils who make less progress. Teachers of higher attaining sets, with a significant number of pupils who achieved level 5 at age 11, can draw on the expectations for pupils who make more progress, and on the yearly teaching objectives that will challenge the pupils most effectively. For example, during the autumn term, a Year 7 class in a selective school, or a Year 7 top set in a comprehensive school, is likely to follow a programme that draws extensively on the yearly teaching objectives for Year 8.

Differentiation in whole-class oral and mental work

In starter activities with the whole class, you could begin with some questions that all pupils can manage in order to get them involved and interested. When you direct questions to the whole class, maintain pace but build in enough wait time for pupils to think or discuss with a partner before answering. Where possible, use open questions that allow more pupils to respond and/or allow pupils to give a more extended response. You can also target an individual or group with particular challenges suited to their abilities or needs, such as pupils at the earlier stages of learning English, very able pupils, or pupils with special educational needs. You may sometimes need to give particular pupils some discreet help with the vocabulary or the method to use.

Differentiation in written work and homework

Differentiated group work is another way of catering for a range of attainment, particularly in mixed-ability classes. Planning of a unit of work might take account of three levels: expectations for most pupils, expectations for pupils who have not made as much progress and expectations for pupils who have progressed further.

Written tasks and homework can be adapted to suit particular needs without varying either the task or the level of difficulty – for example, by presenting them in enlarged print or on audio tape. Some pupils may need tasks broken down into structured steps. For others, you may need to identify and explain key words, or use extra diagrams or illustrations for particular points. There may also be pupils who continue to need apparatus to support their thinking and suitable resources, such as a scale selector for graph work, need to be available.

Some pupils work faster than others, perhaps because they use shortcuts or are generally more confident and more able. They may need to move on to extension or enrichment tasks linked to the theme of the lesson so that they use and apply their skills in more challenging contexts. Others may need longer to practise and consolidate what they have been learning and need examples at each level of difficulty. For any group of pupils, it is more beneficial to do selected key questions from each section of an exercise than to work through from the beginning.

Some pupils take longer to record or present their work. You need to allow for this and to be aware that it can be a gender issue.

- Girls may prefer to write more than boys, or brighter boys may prefer to write for long periods compared with the rest of their peer group.
- Some pupils, often boys, rush through written tasks so that they can move on quickly to the use of ICT or equipment in experimental activities.

Able pupils and those who are gifted and talented

The yearly teaching objectives in the science Framework are targets for the majority of pupils in a year group (see the links to National Curriculum levels, page 23). Able pupils deal with abstract science more readily than other pupils do. They will progress more quickly through these programmes and will need extension and enrichment activities to develop the breadth of their science and the depth of their thinking. They can be stretched by being given extra challenges and harder investigations when other pupils are consolidating, and by offering occasional differentiated group work. Homework also provides opportunities to set suitably challenging tasks. This challenging work should require able pupils to demonstrate extensive understanding and more advanced knowledge and skills.

Sometimes special arrangements are made for the truly gifted and talented. For example, where there are sufficient numbers of them they may be taught in an express set. There they can benefit from discussion with other pupils working at a similar, more advanced level. Where this is not possible, gifted and talented pupils who are markedly ahead of the rest of their class can follow individualised programmes at appropriate times, with a wider range of contexts and applications, including work that draws on other subjects. They should be given more challenging problems to tackle, including work outlined in the level 8 and exceptional performance level descriptions of the National Curriculum. Of course, they still need teaching to ensure that they understand what they have done and read, and that they know how to present their work.

All pupils, but especially the gifted and talented, need to carry out sustained scientific investigations both in school and, where appropriate, continued at home. They may enjoy the challenge of the World Class Tests on problem solving for 13-year-olds (see www.worldclassarena.org). There are many good publications to support this kind of work, including materials from problem-solving websites. The DfES Standards website provides further information under ‘Gifted and talented’: www.standards.dfes.gov.uk/excellence/policies/GiftedAndTalented.

Pupils who make less than expected progress

The number of pupils below level 4 at age 11 is relatively small in science. However, the Ofsted report *Progress in Key Stage 3 science* (March 2000) states that this small number of pupils makes too little progress during the three years of study at Key Stage 3. Currently, almost 30% of pupils who were below level 4 in science at the start of Key Stage 3 are still working at level 3 by the end of Year 9.

Some of this group of pupils face relatively minor difficulties in learning, reflected in scientific attainment just below the level expected at entry to Year 7. Many will have misconceptions remaining from earlier work in science and often they will be in English or mathematics catch-up groups because weaker literacy and numeracy skills have impeded their progress. Some may have been disadvantaged by circumstances at home. Some may have been moved to a number of different schools, or have gaps in learning resulting from missed or interrupted schooling – for example, travellers, refugees, those in care or those with medical conditions. For all these pupils, Key Stage 3 gives them an opportunity to catch up in science.

Early targeted support will help the pupils most, as it is much easier to catch problems early on than to struggle with a backlog. It is essential to base this programme on an early and complete analysis of Key Stage 2 test data. You will need to focus on the misconceptions or weaknesses the pupils have had with earlier work and build in some extra consolidation. At regular intervals, assess and review their progress and make sure that their learning of the yearly teaching objectives, in particular, is secure. Tell them regularly what progress they are making. Some mentoring sessions may be needed for pupils who are disaffected or whose behaviour causes concern to prepare them for whole-class work. You may also be able to encourage parents to help their children in specific ways.

It is crucial that pupils in English and mathematics catch-up groups in Year 7 are not withdrawn from science lessons since they need to maintain the development of their scientific understanding and skills along with their peers.

Extra support for the pupils is of great benefit, perhaps in tutorial time, at lunchtime clinics or after-school homework clubs, or in extra timetabled sessions. Teachers, other adults and older peers can then help particular pupils to prepare for or to consolidate their learning. For example, the pupils could be introduced to new vocabulary in advance of a lesson, or practise skills that will be required when new work is introduced, perhaps by using ICT.

Pupils who need help with English, including EAL learners

Reading or writing difficulties can slow some pupils' progress dramatically in science. The Key Stage 3 Strategy's training unit on *Science and literacy* can help here. Many of the strategies for helping pupils with literacy difficulties apply also to pupils learning English as an additional language (EAL).

Introduce new words carefully, breaking down pronunciation into syllables where appropriate. Teach the pupils to articulate new words clearly, followed by writing them. This is a particularly effective way to encourage pupils' use and understanding of technical or scientific terminology. Specifying the scientific vocabulary for a unit of work gives pupils opportunities to refer back to vocabulary in their exercise books, on charts, diagrams and wall displays as well as in oral questioning. While pupils must be familiar with essential vocabulary and instructions, it helps if you minimise written explanations on worksheets and exercises. Wherever possible, read through questions from textbooks and discuss them with pupils. Provide a range of directed activities related to text to help pupils to develop their reading skills.

Remember that science has a strong visual element and capitalise on this wherever you can to illuminate meaning, making all illustrations directly relevant to the text. Make frequent use of visual aids such as diagrams, graphs, computer software, physical models, and games or puzzles where the rules are picked up quickly by watching a demonstration.

It is all too easy to underestimate what pupils can achieve in science, simply because they are new learners of the English language. The expectation should be that they progress in their scientific learning at the same rate as other pupils of their age. Whole-class work can provide helpful adult models of spoken English, and time for careful listening, oral exchange and supportive, shared repetition. Group work allows intensive, focused teaching input. You will probably need to direct specific instructions to EAL pupils and to speak more slowly, emphasising key words, particularly when you are describing tasks that they are to do independently. In oral work, it may help to use extra visual clues or gestures, or translation. Use picture cues on written materials and simplify the words, but not the science (except where an EAL pupil also has special educational needs that warrant this). Help pupils to distinguish words with different meaning in scientific and everyday contexts, such as 'pitch' or 'wave'.

Peer-group talk helps pupils to make sense of and apply scientific ideas. It helps if English-language beginners can converse with other pupils or adults who speak the same home language when they are doing practical activities or working with ICT. All pupils can benefit from the experience of different cultures – for example, pupils can describe different types of diet and the nutritional balance that these provide. Aim not to ask individual pupils at the early stages of learning English to present their work orally before they are ready. Allow them time to watch and listen to those fluent in English explaining and demonstrating their methods to the class using a board or OHP. Invite them also to work through a question – they will often show capabilities that are as good if not better than their peers' – but without any pressure to accompany their demonstration with an oral explanation in English before they are ready.

Emphasise the importance early on of learning to say, read and write numbers in English, and understand signs and symbols such as % and °C, and words such as 'results' and 'conclusion'. They may well be familiar with the meanings of such words in their home language. If you can, go through things twice with them so that they get a chance to listen and repeat. As soon as English-language beginners are reasonably confident at saying something together with others, ask them to say it again on their own. Give them plenty of time and check their understanding regularly.

Even pupils whose mother tongue is English can benefit from such exercises.

Pupils with special educational needs (SEN)

At the start of Year 8, there may be pupils who have not attained level 4 by the end of Year 7 in English and mathematics. This group of pupils is likely to struggle in science as well. Alternative forms of support, as outlined above, plus some individual mentoring, can focus on this smaller identified group of pupils, so that more of them are able to attain level 4 or 5 by the end of Year 9.

Some pupils with special educational needs may have a range of difficulties. Some but not all may have problems accessing science because of needs of varying degrees of complexity. These difficulties will often, but not always, lead to associated literacy problems.

In many cases, pupils' needs will be met through differentiation of tasks and materials. A smaller number of pupils may need access to specialist equipment and approaches, or to alternative or adapted activities. For example, there may be pupils in a class who need support in order to take part in whole-class work, such as:

- specific help with the recall of scientific facts, to compensate for difficulties with long- or short-term memory;
- help with the interpretation of data represented in graphs, tables or charts, to compensate for difficulties with visual discrimination;
- access to tactile and other specialist equipment for making observations and measurements during a scientific enquiry, to overcome difficulties in managing visual information;
- help in interpreting or responding to oral directions, to compensate for difficulties in hearing or with auditory discrimination.

This support may be augmented by advice and further support from external specialists as described in the SEN Code of Practice or, in exceptional circumstances, with a statement of special educational need.

It is not possible in this document to give detailed advice covering every type of special educational need. As a general guide, aim to include all pupils fully in science lessons so that they benefit from the oral and mental work and take part in watching and listening to other pupils demonstrating and explaining their methods and solutions. At times, they should make contributions themselves. Identify relevant objectives from the teaching programmes, use suitable teaching strategies and give support so that the pupils can access lessons. For example, you can simplify or modify tasks and use support staff to help consolidate key points.

Where appropriate, you could develop a 'group education plan' with common learning targets for a group of pupils who have similar difficulties.

There are four wider areas of need adopted in the SEN Code of Practice, and these relate directly to the Teacher Training Agency's specialist standards. The four areas are:

- communication and interaction;
- cognition and learning;
- behaviour, emotional and social development; and
- sensory or physical difficulties.

Communication and interaction

Pupils who have difficulty in communicating or interacting face particular challenges in science. They need clear, effective teaching, which steadily builds their confidence and participation. Use a structured approach to develop the scientific language you expect them to use. Some pupils with speech and language impairments have no other developmental difficulties and science lessons provide the opportunity to work alongside peers, practising and discovering strategies to overcome their difficulties. However, pupils who have autistic spectrum disorders require well-structured lessons with clear routines and predictable parts. They respond best when the language used is concise, teaching is explicit, and challenges are direct and well focused. Your expectations for what these pupils will learn and do, both in the lesson overall and in each separate part or activity, need to be defined very clearly.

Cognition and learning

The attainment of pupils with significant cognition and learning difficulties is likely to be well below age-related expectations. For them, a much greater degree of differentiation will be necessary. You may need to refer to the programmes of study for Key Stages 1 and 2, modifying the ideas to set them in a context suited to 11- to 14-year-old pupils. Extra 'small steps' can be inserted, and contexts for practical work and problem solving adapted. There will then be time for consolidation without sacrificing the breadth of the teaching programmes or the principle of planning from clearly defined objectives.

Some pupils may be working at pre-level 1 for much of their secondary education. QCA has published general guidelines, and some specific to science, for planning, teaching and assessing the curriculum for pupils with learning difficulties. The guidelines relate particularly to pupils whose attainment by the age of 16 is expected to remain in the range from pre-level 1 to level 2 (see section 8, page 65).

Behaviour, emotional and social development

Pupils with emotional and behavioural difficulties can present their problems in a number of ways: they may be withdrawn, isolated or anxious, or show immaturity. They sometimes present challenging behaviours because of other needs, including sensory and physical impairments or learning difficulties. For all these pupils, poor literacy and numeracy skills often result from their inability to maintain concentration and persevere with tasks. Yet if the work they are given is pitched at too low a level, they become even more demotivated and disaffected.

The Key Stage 3 Strategy can benefit these pupils in several ways. For example, the science Framework helps to ensure high expectations for their learning. Like most pupils, they respond well to structured science lessons where the rules, expectations and routines are well established, and the pace and level of oral work engages their interest and attention. In the main part of the lesson, break down independent activities and written work into ‘chunks’ that are more manageable for them, and invest time in establishing routines for the transition between one activity and another, so that they can learn independently of support staff.

Learning to work independently with increasing self-confidence is important for these pupils. This has to be introduced slowly, cultivated deliberately and rewarded as the level of support is reduced and eventually withdrawn. Tasks and timings are critical.

Sensory or physical difficulties

Some pupils with physical or sensory difficulties are intellectually able but may need to develop proficiency with particular aids. These pupils will work on the same science programme as their peer group. Expectations for them should remain high, with the focus on giving them maximum access and independence.

For example, support to overcome difficulties with mobility or manipulative skills should have been identified and provided for science and other lessons. Some pupils may use ICT to assist them in reading or recording their work; others may have physical help. This support should enable them to take part safely and as fully as possible in experimental work. Modifications to science materials, equipment and furniture, and the use of specialist science items, will also help to meet their needs.

Where pupils with sensory impairments need signing support, Braille or materials written in signs or symbols it is likely that provision will be through a statement of special educational needs. The provision of relevant materials and adult support for them will apply to all subjects. Where necessary, text should be adapted to a larger print size, or translated into Braille or symbols. ICT should help those with visual impairments to gain better access and understanding.

Pupils with hearing impairments will need to be appropriately positioned in a class and should be helped to gain as much access as possible to science activities by the use of oscilloscopes and sound level meters, the provision of visual demonstrations and using the sense of touch to feel vibrations.

Pupils with visual impairments may need extra time to manage visual information when they are using microscopes, or making observations in experimental work. They may also need extra support in lessons about light and to be encouraged to use their knowledge that many light sources produce heat.

Using teaching assistants, including support for SEN and EAL

Support staff, where they are available, can help to make sure that particular pupils take part in their science lessons as independently as possible. The aim is inclusion – support is not a substitute for careful thinking about how each individual can be involved in the lesson. Planning for effective deployment of assistants and other adults at each stage of the lesson is essential, whether the support is by a parent, teaching assistant or learning support staff. Science technicians, because of their particular training, expertise and experience, can provide invaluable help to pupils, especially with practical work. The success of any support will depend on good communication and working relationships between the science department and the staff managing individual pupil support. Although science technicians will need less support with the science than other adults, any role in the classroom should be discussed with them so that their time and expertise is used effectively.

Give support staff copies of this Framework and, if possible, involve them in planning and departmental meetings. Brief them thoroughly about each lesson and their particular role in it. Make sure that they know not only what pupils are to do but also what they are to learn. Draw their attention to the key vocabulary to focus on.

During any whole-class oral work – both the starter and the teaching input in the main part of the lesson – ask support staff to position themselves close to any pupils who need special help and provide this discreetly, for example, by:

- prompting shy or reticent pupils;
- providing symbols, or signing or translating core vocabulary or phrases;
- helping pupils to use specific individual resources to support their learning, such as a notebook or small whiteboard for jottings, a number line or a calculator, and scientific equipment, such as a simple slope meter or stop watch;
- operating individualised ICT resources as indicated in a pupil's statement of special educational needs.

They should also observe carefully the responses of pupils they are working with to inform the support they will provide.

While pupils are working more independently on practical activities and written tasks, support staff should work with identified pupils, providing help by:

- helping pupils to assemble and use scientific equipment;
- helping pupils to use personal learning resources such as number lines and squares, calculators and other ICT devices, simple data charts, visual or practical aids;
- ensuring that pupils interpret instructions correctly, concentrate and behave responsibly;
- reminding pupils of teaching points made earlier in the lesson;
- questioning pupils and encouraging their participation, using questions and prompts that you have suggested;

- looking for and noting any common difficulties that pupils have, or mistakes that they make, so that you can address these in the plenary and in future lessons;
- helping to recognise pupils' successes so that they can be moved on.

Using the science Framework in special schools

Many of the Framework's principles are applicable to special schools, such as planning from clear teaching objectives, an emphasis on oral and mental work, visual interest, involvement and interaction, and keeping pupils working together as far as possible. Special schools are encouraged to adopt this Framework but should also adapt their schemes of work to suit their particular circumstances. For example, the notion of 'whole-class teaching' can be modified, as it is different when there are 10 to 14 pupils in a class, and the teacher is at times supported by other staff. There may be times when all the pupils are taught together for their science lesson, just as in a mainstream school. At other times two 'whole-class lessons' may be taking place in the same room, with the class teacher teaching one half of the class, and a teaching assistant working with the other half.

In some special schools, all or nearly all of the pupils in a class will have learning difficulties that extend to science. For these pupils, the routine of the science lesson is best built up over a period of weeks. Aim first to establish regular oral and mental work. Then introduce routines for the main part of the lesson and the plenary, concentrating on a strong oral or other communication technique which promotes interaction, combined with a good range of practical activities, visual images, models and suitable experiments.

8 Related publications and websites

A number of other publications complement the Framework.

Those marked DfES are available from DfES Publications (tel: 0845 6022260), and are on the Standards website at www.standards.dfes.gov.uk.

Those marked QCA can be obtained from QCA Publications, PO Box 99, Sudbury, Suffolk CO10 2SN (tel: 01787 884444, fax: 01787 312950).

Council for Science and Technology *Science teachers*
A report on supporting and developing the profession of science teaching in primary and secondary schools (February 2000)
www.cst.gov.uk/cst/reports.htm

DfES *Auditing a subject in Key Stage 3*
This guide leads you through the judgements to be made for all subjects and provides space to record them.
DfES ref: 0756/2001
www.standards.dfes.gov.uk/keystage3/publications

DfES *Science supplementary audit 2002–03*
This guide leads you through the judgements to be made for science and indicates the professional development requirements of the department and the individual teachers in the science department.
DfES ref: 0150/2002
www.standards.dfes.gov.uk/keystage3/publications

DfES *Securing improvement: the role of subject leaders*
DfES ref: 0102/2002
www.standards.dfes.gov.uk/keystage3/publications

DfES *Year 9 booster kit: science*
DfES ref: 0017/2002
www.standards.dfes.gov.uk/keystage3/publications

DfES/QCA *Science: a scheme of work for Key Stage 3*
ISBN 1 85838 382 X; QCA ref: QCA/00/445
www.standards.dfes.gov.uk/keystage3/publications

DfES/QCA *Target setting for pupils with special educational needs*
Guidance for effective target setting for SEN pupils.
DfES ref: 0065/2001 (March 2001)
www.standards.dfes.gov.uk

National College for School Leadership *Leading from the middle*
Management guidance for subject leaders

Ofsted *Progress in Key Stage 3 science*
Ofsted ref: HMI 221 (March 2000)
www.ofsted.gov.uk

QCA *Planning, teaching and assessing the curriculum for pupils with learning difficulties: science*
QCA ref: QCA/01/740
www.nc.uk.net/ld

QCA *Standards report in science*

Published every year by QCA. The reference for 2001 is QCA/01/819.
www.qca.org.uk/ca/tests

QCA *TestBase*

This CD-ROM includes the *Standards report in science* and samples of questions at different levels from the National Curriculum tests for Key Stages 3 and 2.
QCA Publications (as above) or TestBase, PO Box 208, Newcastle-upon-Tyne NE3 1FX; email: info@testbase.co.uk

Websites

DfES Standards website (The Standards Site)

www.standards.dfes.gov.uk

Health and safety information and advice

Association for Science Education: www.ase.org.uk
CLEAPSS: www.cleapss.org.uk

'Gifted and talented' websites

www.standards.dfes.gov.uk/excellence/policies/GiftedAndTalented
www.nc.uk.net/gt
www.worldclassarena.org (World Class Tests)

Appendix 1
From Key Stage 2 to Key Stage 3

This appendix describes what most pupils should have learned in science by the end of Key Stage 2, particularly those aspects that relate to the yearly objectives in Key Stage 3.

Scientific enquiry

By the end of Year 6, most pupils should be able to:

- Consider how scientists have combined evidence from observation and measurement with creative thinking to suggest new ideas and explanations for phenomena.
- Decide how to turn an idea into a form that can be tested and, where appropriate, to make predictions using scientific knowledge and understanding.
- Plan and carry out a fair test.
- Identify factors that are relevant to a particular scientific situation.
- Choose what evidence to collect to investigate a question, ensuring the evidence is sufficient.
- Choose what equipment to use.
- Make a variety of relevant observations and measurements using simple apparatus correctly.
- Decide when observations and measurements need to be checked, by repeating, to give more reliable data.
- Use tables, bar charts, line graphs and diagrams to present results.
- Make comparisons.
- Evaluate repeated results.
- Identify patterns in results and results that do not appear to fit the pattern.
- Use results to draw conclusions and to make further predictions.
- Suggest and evaluate explanations for predictions using scientific knowledge and understanding.
- Say whether the evidence supports any prediction made.

Life and living processes

By the end of Year 6, most pupils should know and understand that:

- Living things feed, grow and reproduce.
- Animals generally move, mostly because of the need to feed (on plants and/or other animals) or to escape being eaten.

- Plants do not move because they make their own materials using sunlight. They need water and a few minerals which they take in through their roots.
- The bodies of animals (such as humans) have parts which do different jobs, all of which helps the animal to live more successfully. Some of these parts are the heart, skeleton and muscles, and reproductive organs.
- Plants also have parts which do different jobs, all of which help the plant to live more successfully. Some of these are leaves, roots and flowers.
- The environment (e.g. temperature, water, sunlight, available nutrients, other living things) varies across the world and affects how animals and plants live. Animals and plants are adapted to suit their environment.
- In any part of the world some animals eat plants and some animals eat other animals. This is known as a food chain.
- Micro-organisms are living things which are too small to be easily seen. They feed, grow and reproduce. Some are useful to humans and some are harmful.
- Humans need to look after their bodies to stay healthy. Human bodies change as they grow.

Materials and their properties

By the end of Year 6, most pupils should know and understand that:

- Everyday objects and materials can be compared and grouped according to their properties.
- Substances can be grouped into solids, liquids and gases:
  - solids have a fixed shape and volume;
  - liquids flow and take up the shape of the container, and have a fixed volume;
  - gases have no fixed shape or volume: they spread out to fill all the available space.
- Heating can cause solids to melt to form liquids, and liquids to evaporate to form gases. Cooling will reverse these changes.
- Melting and dissolving are different processes.
- The terms *evaporating*, *condensing*, *melting*, *boiling* and *freezing* describe physical changes.
- Water changes state in the water cycle.
- Changes can be reversible or irreversible.
- Burning and some other everyday chemical reactions are irreversible.
- Insoluble solids can be separated from solutions by filtration.
- Dissolved solids can be recovered by evaporation.

Physical processes

By the end of Year 6, most pupils should know and understand that:

- Components need to be connected in a circuit for them to work. Altering the components in the circuit can make bulbs brighter or dimmer.
- A series circuit can be represented in a diagram using conventional symbols.
- A force is measured in newtons.
- A force can be described as a push or a pull. It has both size and direction. Pupils should be able to use this to explain:
  - the attraction and repulsion between magnets and magnetic materials;
  - objects falling towards the Earth;
  - moving objects slowing down or stopping;
  - how some objects are more difficult than others to start moving.
- Light travels in straight lines; pupils should be able to use this to explain:
  - formation of shadows;
  - reflection at different surfaces;
  - how humans see things.
- Sound travels by vibrations; pupils should be able to use this to explain:
  - changes in pitch and loudness;
  - the need for a medium for sound to travel through;
  - how humans hear things.
- The position of the Sun appears to change throughout the day.
- The Earth spins on its axis; pupils should use this information to explain day and night.
- The Earth orbits the Sun once each year; pupils should use this information to speculate about seasonal changes.

Appendix 2 Yearly teaching objectives for scientific enquiry (Sc1)

The table below shows how the yearly teaching objectives relate to the strands of scientific enquiry (Sc1).

	Year 6	**Year 7 pupils should be taught to:**	**Year 8 pupils should be taught to:**	**Year 9 pupils should be taught to:**
Ideas and evidence	Consider how scientists have combined evidence from observation and measurement with creative thinking to suggest new ideas and explanations for phenomena.	Consider early scientific ideas, including how experimental evidence and creative thinking have been combined to provide scientific explanations.	Consider how some early scientific ideas do not match present-day evidence, and describe how new creative thinking has been used to provide a scientific explanation.	Explain how scientific ideas have changed over time; describe some of the positive and negative effects of scientific and technological developments.
Planning	Decide how to turn ideas into a form that can be tested. Where appropriate, use scientific knowledge and understanding to make predictions. Identify factors relevant to a situation. Choose what evidence to collect to investigate a question, ensuring the evidence is sufficient. Choose what equipment to use.	Use scientific knowledge to decide how ideas and questions can be tested; make predictions of possible outcomes. Identify and control the key factors that are relevant to a particular situation.	Identify more than one strategy for investigating questions and recognise that one enquiry might yield stronger evidence than another. Recognise that a range of sources of information or data is required.	Select and use a suitable strategy for solving a problem; identify strategies appropriate to different questions, including those in which variables cannot be easily controlled. Carry out preliminary work such as trial runs to help refine predictions and to suggest improvements to the method.
Obtaining and presenting evidence	Make a variety of relevant observations and measurements using simple apparatus correctly. Decide when observations and measurements need to be checked by repeating to give more reliable data. Use tables, bar charts, line graphs and diagrams to present results. Make comparisons.	Select and use appropriate equipment, including ICT, to make observations and measurements correctly, e.g. 1 °C or 1 newton. Use repeat measurements to reduce error and check reliability. Present and interpret experimental results through the routine use of tables, bar charts and simple graphs, including line graphs.	Use a range of first-hand experience, secondary sources of information and ICT to collect, store and present information in different ways, including the generation of graphs. Use appropriate range, precision and sampling when collecting data during a scientific enquiry, and explain why these and controlled experiments are important.	Make sufficient systematic and repeated observations and measurements with precision, using an appropriate technique. Select and use appropriate methods for communicating qualitative and quantitative data.
Considering evidence	Identify patterns in results that do not appear to fit the pattern. Use results to draw conclusions and make further predictions.	Describe and explain what their results show when drawing conclusions; begin to relate conclusions to scientific knowledge and understanding.	Draw conclusions from their own data and describe how their conclusions are consistent with the evidence obtained, using scientific knowledge and understanding to explain them.	Describe patterns in data; use scientific knowledge and understanding to interpret the patterns, make predictions and check reliability.
Evaluating	Evaluate repeated results. Suggest and evaluate explanations for predictions using scientific knowledge and understanding. Say whether the evidence supports any prediction made.	Evaluate the strength of evidence, e.g. in bar charts and graphs; indicate whether increasing the sample would have strengthened the conclusions.	Consider whether an enquiry could have been improved to yield stronger evidence (e.g. improving the accuracy or sufficiency of measurements or observations); explain any anomalous results.	Describe how evidence or the quality of the product supports or does not support a conclusion in their own and others' enquiries; identify the limitations of data in conclusions.

Appendix 3
Scientific vocabulary

This appendix lists the scientific terms and technical language found in the QCA schemes of work for science for Key Stage 2 and Key Stage 3, and in materials produced by the Key Stage 3 Strategy to support the teaching of literacy, mathematics or science. Pupils should be able to use them accurately in a range of contexts. For convenience, the words are arranged by year and, for Key Stage 3, by the units from the QCA scheme of work. Words in the lists appear only once although pupils will meet them in other units and in later year groups.

Year 6

By the end of Year 6 most pupils will have used these scientific terms and technical language.

Sc1 Scientific enquiry

accurate, average, bar line graph, bar chart, collect, compare, conclusion, data, graph, explain, evaluate, evidence, fair test, idea, identify, interpret, limitation, line graph, observation, measurement, pattern, predict, present, record, repeat measurements, repeat observations, results, secondary data, test

Sc2 Life processes and living things

alcohol, artery, balanced diet, carbohydrate, circulate, consumer, dispersal/disperse, dissolve, drug, egg, energy, exercise, fat, fertilisation/fertilise, fertiliser, fibre, food chain, germ, germination/germinate, growth, health, heart beat, life cycle, petal, plant food, pulse, pulse rate, microbe, muscle, nutrients, nutrition, ovary, oxygen, pollen, pollination/pollinate, predator, prey, producer, pump, reproduction/reproduce, starch, teeth, tobacco, sepal, side effect, stamen, stigma, style, vein, virus

Sc3 Materials and their properties

air, ash, baking powder, bath salts, bicarbonate of soda, boiling temperature, bubbles, carbon dioxide, cement, change, change of state, charcoal, condense, conditions, dissolve, evaporation/evaporate, filter, freeze, gas, hazard, heat, insoluble, irreversible, liquid, melt, mixture, natural gas, oxygen, plaster of Paris, reversible, solid/solidify, soluble, solution, state, steam, washing soda, water cycle

Sc4 Physical processes

air, at rest, axis, buzzer, cell, circuit diagram, circuit symbol, complete circuit, component, conductor, force meter, gravity, insulator, light, light beam, loudness, mirror, newton, opaque, orbit, pitch, reflection/reflect, revolve, rotation/rotate, sound, sphere/spherical, spin, stationary, tension, tuning, upthrust, vibration/vibrate, water, weight

Year 7

Sc1 Scientific enquiry

correlation, data logger, generalisation, line of best fit, prediction, reliability, repeat reading, sample size, strength of evidence, theory

Sc2 Life processes and living things

adolescence, baby, cell, fetus/foetus, gestation, hereditary, inherited, mammary glands, menstruation, nucleus, ovary, oviduct, ovulation, penis, placenta, puberty, sperm, testis, tissues, uterus, vagina

carnivore, consumer, dormant, food web, habitat, hibernation, insulation, interdependence, light intensity, migration, organisms, over-wintering, producer

abdomen, amphibian, association, characteristics, classify, feature, invertebrate, limb, mammal, multi-cellular, reptile, species, taxonomic group, variation, vertebrate

Sc3 Materials and their properties

acid, alkali, caustic, colour change, corrosive, equation, hazard, hydrochloric acid, hydroxides, indicator, litmus, neutral, pH range, reaction, risk

carbon, carbonates, combustion reactions, element, hydrogen, line graph, methane, oxide, oxygen, product, reactant, word equation, zinc

compressible, diffusion, expansion, gas pressure, particle, particle theory, proximity, vibration

attracted, chromatography, chromatogram, compound, distillation, filtration, insoluble, saturated solution, separate, solute, solution, solvent, suspension, trace

Sc4 Physical processes

air resistance, attraction, conservation, density, drag, energy transfer, friction, fuel, lubricants, magnetic, magnitude, mass, repulsion

asteroid, atmosphere, eclipse, orbit, planet, satellite

Year 8

Sc1 Scientific enquiry

anomalous results, data search, environmental conditions, epidemic, evaluate, hypothesis, opinion, population size, precision, quadrat sampling, qualitative, quantitative, range, reliable data, repeats, sample size, sequence of events, sufficient data, time-lapse photography, transect, trial measurements, trials, using secondary sources, variable

Sc2 Life processes and living things

absorption, albumen, digestion, enzyme, intestine, minerals, molecules, protease, protein, starch, sugars, villus, vitamins

aerobic, artery, breathing, bronchus, circulation, exhale, glucose, haemoglobin, inhale, inspire, lungs, oxygen concentration, respire, ribcage, trachea, vein, ventilation antibiotic, antibodies, bacteria, epidemic, food poisoning, fungi, hygiene, immunisation, immunity, infection, infectious disease, inoculation, micro-organisms, pathogen, sterilising, vaccination, viruses

community, conifers, distribution, ecosystem, ferns, habitat, humidity, mosses, population sizes, pyramid of numbers, transect

Sc3 Materials and their properties

atom, chlorides, chlorine, compound, element, equation, formula, molecule, reactants, sodium, symbol

composition, oxides

aligned, basalt, cooling rates, crystals, deposit, erupt, granite, igneous, lava, limestone, magma, metamorphic, mineral, obsidian, porous, precipitation, pumice, quartzite, sandstone, sedimentary, shale, slate, volcanic ash, weathering

Sc4 Physical processes

conduction, convection, insulator, joule, radiation

coil, core, electromagnet, magnetic field, magnetic field line, nickel, north-seeking pole, solenoid, south-seeking pole, steel

absorption, image, laser, luminous, mirror image, opaque, propagation, radiation, refraction, shadow, spectrum, translucent, transmission, transparent

amplitude, dynamics, frequency, noise pollution, oscillations, oscilloscope, signal generator, tuning fork, volume, wave

Year 9

Sc1 Scientific enquiry

carrying out a survey, control accuracy, controlling variables, dependent variable, developing a technique, independent variable, most appropriate equipment, precision, proportional, quantitative data, reliability/trustworthiness of data, sampling, scientific method, trial run, validity of conclusions

Sc2 Life processes and living things

asexual, breed, classification, clone, characteristics, gamete, gene, genetically modified, grafting, selective breeding, species, variety

addiction, cilia, circulation, emphysema, vitamins

biomass, chlorophyll, Elodea, etiolation, palisade cell, photosynthesis, xylem

balance, compete, competition, deficiency, fungicide, insecticide, nitrates, nutrient, pesticide, sustainable development, toxin, weedkiller, yield

Sc3 Materials and their properties

carbonates, product, salt, sulfates/sulphates

displacement, order of reactivity

acid rain, catalyst, global warming, neutralisation, ozone depletion, phlogiston theory, vegetation cover

prefixes: di-, mono-, poly-; suffixes: -ate, -ide, -ite

Sc4 Physical processes

dissipation, dynamo, electric generator, kinetic energy, potential difference, potential energy

acceleration, constant speed, light gate, resistance/drag, streamline

gravitational attraction, heliocentric, orbit, revolve, satellite

antagonistic muscles, counterbalance, hydraulic, lever, moment, pivot, pneumatic, turning effect