The National Strategies
Secondary

Effective demonstrations

Science study guide

department for
children, schools and families

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Effective demonstrations

First published in 2008

Ref: 00094-2008DVD-EN

Contents

How to use this study guide

This guide is one of a suite of five guides that have been produced in response to the government's SIIF (Science and Innovation Investment Framework) agenda. They are designed to highlight aspects of interactive teaching and give teachers practical and innovative tips and advice to ensure that pupils enjoy their science experience.

This study guide offers practical suggestions for you to use in the classroom when considering effective demonstrations. All the strategies suggested have been tried and tested by teachers. They draw upon academic research and the experience of *Strengthening teaching and learning through using different pedagogies* (DfES 0703-2004 G). While there are similarities with these materials you will find that this unit gives specific advice that will be immediately relevant.

Your science consultant can help you work through this unit or you should team up with a colleague(s) who also wishes to better enhance the quality of effective demonstrations for pupils. The unit contains case studies and tasks for you to undertake which may encourage you to consider the advice or try out new techniques in the classroom. It also contains 'reflections' which will help you revise an idea or change your own practice. Finally you are invited to reflect on the experience of having tried out new materials and to identify follow-up work.

You can work through the materials in a number of ways:

- Start small; choose one class to work with. Ask another teacher or your subject leader to help by providing a sounding board for your ideas.
- Work with your science consultant on developing and planning the use of a demonstration. After three weeks, meet together to review progress. Discuss which strategies have been the most effective with one class and plan to use these with other classes.
- Find another science teacher to pair with and team-teach. Design the activities together and divide the teacher's role between you.
- Work with a group of teachers in the department. Use the unit as a focus for joint working, meet regularly to share ideas and then review progress after a few weeks.

Identify the sections of the unit that are the most appropriate for you and focus on those. You may find it helpful to keep a learning log as you work through the tasks. You could add this to your personal CPD portfolio.

Introduction

In this guide we consider how the use of demonstration experiments can contribute to enhancing the quality of teaching and learning in science.

Within the different sections of this guide we will explore:

- reasons for carrying out demonstration experiments;
- different types of demonstrations and the different situations in which demonstrations are used;
- how to make demonstrations as effective as possible.

In your teaching, you will already be using 'demonstrations' in a whole variety of ways on a day-to-day basis. Perhaps, for example, you have shown the pupils how to interpret a graph using a data projector or interactive whiteboard. This and other types of practical activity are considered in more detail in one of the other guides in this suite, '*Interactive Practicals*'

The focus here is on practical demonstrations, which have a long tradition in the teaching and exposition of science at all levels. The use of demonstrations to illustrate scientific theories or processes has been a tool valued by scientists for many generations.

An effective demonstration is a stimulus for high quality discussion and dialogue. Through these interactions, pupils' understanding can be explored, challenged and developed with the use of appropriate questions to provide cognitive conflict and gently move pupils out of their comfort zones.

Reflection

As you work through this guide, reflect upon the four modes of interaction described by Professor Phil Scott in the introduction to the Interactive Teaching DVD.

Modes of Interaction

	Interactive	Non-Interactive
Focus on science view (Authoritative)	Presentation Q and A	Presentation Lecture
Open to different points of view (Dialogic)	Probing Elaborating Prompting	Review

Which type of interaction describes your typical demonstration?

What would a dialogic interactive demonstration look like?

Why carry out demonstrations?

Demonstrations allow you to:

- show experiments that are too dangerous or complex for pupils to carry out themselves (this may, in some cases, need to be assessed in terms of the aptitudes, attitudes and behaviour of the pupils);
- direct the pupils to specific points of interest;
- emphasise important, relevant aspects and avoid irrelevant or secondary distractions (in effect, to cut out the 'background noise');
- focus attention on the link between scientific phenomena (the practical reality) and the underlying theories;
- repeat experiments for emphasis of a specific effect or point;
- model a particular aspect of science, whilst leading pupils to explore their understanding of the phenomena they observe.

There is the perception among some that pupil engagement in scientific enquiry activities means that the pupils themselves should carry out a large amount of investigative practical work. Demonstrations can provide wonderful scientific enquiry opportunities, sometimes more effectively than pupils carrying out their own experimental work. However, in order to be effective, it is important that pupils are actively engaged with the demonstration and are aware of the purpose of the demonstration and how it links to the desired learning outcomes.

The focus on the learning objectives and desired learning outcomes of a practical activity can, occasionally, be lost when an experiment is carried out as a class practical. The pupils may be too busy collecting apparatus, finding the bits and pieces they need, reading and/or following instructions, or standing watching others doing, to recognise the point of the experiment. The pupils may be fully occupied but may also learn very little in the process.

Of course, it is a fine balancing act – there should be plenty of opportunities for pupils to carry out their own practical work. As an effective teacher, you will have considered how the class practical or demonstration contributes to the desired learning outcomes and explored the advantages and disadvantages of conducting a class practical or demonstration with a particular group of students.

Demonstrations offer you a valuable tool with which you can help pupils develop their knowledge and understanding of scientific concepts and processes. We know that effective learning takes place when pupils are actively engaged so intervention, and interactive teaching are crucial for successful learning in science (see Appendix 2).

Demonstration activities provide an ideal opportunity for leading whole-class, direct, interactive teaching. In this way, all pupils have contact with the teacher in the undertaking of a shared task. The teaching should be oral, collaborative and lively – a two-way process in which the pupils are expected to play an active part[1].

Reflection

Consider a demonstration experiment you have recently carried out.

How did you ensure that the pupils were actively involved? What did you do and what did the pupils do? What was the impact of the demonstration on learning?

What do you think you could do differently to improve the effectiveness of that demonstration?

Task 1

Read the following outline descriptions of two different approaches to a Key Stage 3 lesson about acids, alkalis and salts.

In which one were the pupils more actively involved?

How could this involvement have supported the learning?

Case study

Teacher A

A worksheet was handed out to the class. The pupils were introduced to the task by the teacher who went through the instructions for the preparation of sodium chloride, demonstrating each step of the process. The teacher explained words such as indicator, pH, neutralisation, filtration and saturated solution during the demonstration.

After observing the demonstration, the pupils then carried out the experiment by following the instructions on the worksheet.

Case study

Teacher B

The teacher began the lesson with a question and answer session to review ideas about the reactions of acids and alkalis. The pupils were then set the problem of how to prepare a sample of pure sodium chloride. They were provided with a set of cards and, working in small groups, used the cards to devise a sequence of instructions for preparing the salt.

An interim 'plenary' session was then held to discuss the sequence of steps required and the reasons for them. The teacher demonstrated each of the agreed steps and coordinated a class discussion about the process – the pupils made their own rough notes about the procedure before going on to prepare their salt.

Demonstrations enable pupils to experience the pleasure of discovery; of seeing, smelling and experiencing phenomena that are new to them. Well-prepared, well-performed demonstrations can inspire and motivate pupils and can be enjoyable and entertaining events.

Reviewing your own practice

Before going on to look at how you can make demonstrations more effective, it is worth reflecting on your experience to date and the range of demonstration activities undertaken in your department.

Task 2

Working with a colleague, look through your departmental scheme of work for a particular year group in either KS3 or KS4.

Make a list of the demonstration activities included in the scheme of work.

Make a brief note of the learning objectives that indicate that demonstrations were a suitable choice of activity in order to encourage learning.

Keep this list for Task 3.

Types of demonstration

When we think about demonstration experiments, the first thing that comes to mind is often the 'show' or 'performance' type of demonstration. However, in reality, most teachers employ a wide range of demonstration types throughout their lessons.

Many demonstrations are also conducted by pupils, either to the whole class (often with the support of the teacher) or informally when working in small groups. Peer demonstrations can be a useful means to spark discussion and also challenge the demonstrator to explain and justify their actions.

Type of demonstration[2]	Example
Performance: likely to be elaborate or complex experiments that may also be too difficult, or too dangerous for pupils to carry out themselves. Alternatively it may be used to model a particular skill.	A conducting sphere is suspended between two metal plates connected to a van der Graaff generator – to show that moving charge forms an electric current. Reaction of sodium with water. Radioactivity experiments. The Thermit reaction
Spontaneous: apparently unpremeditated experiments, done on the spur of the moment, within the context of the planned lesson. Used to: • clarify a point, answer a question or address a misconception • provide a reminder of factual information Note: This is not an excuse to include a demonstration without proper planning and safety consideration. Spontaneous demonstrations should make use of equipment already planned for use within the lesson, but applied so as to address emerging issues in response to pupils' progress.	Quick 'gas jar-scale' reminder of the colours of Universal Indicator. Using 'playground trolleys' and rope to provide convincing evidence that forces come in pairs. Use of kinetics trolleys to extend questions and challenge understanding about collisions.
Serial: a linked sequence of short, individual experiments designed to help pupils develop understanding of a key concept.	Series of experiments to illustrate diffusion: e.g. potassium manganate (VII) crystals in water; ammonia smell; horizontal diffusion tube with ammonia and hydrogen chloride.
Marathon: experiments that require several days, or even weeks, to be completed.	Effect of dark and light on production of starch by a series of photosynthesising plants kept in different conditions over a period of 2–3 weeks.

Task 3

Consider the types of demonstration shown in the table on page 11.

Review the list of demonstration activities you collated in Task 2.

- For each activity; decide which type of demonstration it is (**Performance**, **Serial**, or **Marathon**). Record your decisions.
- Make a note of any occasions where you have carried out a **Spontaneous** demonstration. Briefly describe why you carried out the demonstration. What questions did you ask the pupils whilst conducting the demonstration? How did this help them to make progress?

Situations for demonstrations

There is a wide range of situations in which a demonstration could be carried out, including:

- as a stimulating 'starter' activity;
- as the key activity or main focus of a lesson or series of lessons;
- as a concluding, plenary or summary activity;
- to demonstrate a technique (before pupils attempt an experiment);
- to highlight health and safety issues (before pupils attempt an experiment);
- as a revision activity;
- for 'open day' or other, similar events (see p25).

The most important issue is to consider how and why the delivery of a demonstration will be the most effective way to encourage learning.

Task 4

Reflect on a demonstration activity you have conducted in each of the situations above. For each one, decide which type of demonstration was involved and why this was appropriate for the particular situation.

- Was the demonstration effective? How do you know?

Learning objectives and learning outcomes

Like many teaching strategies, demonstrations are one strategy which can be used to focus on different aspects of teaching and learning. These could include:

- providing opportunities for direct observation of scientific phenomena and processes;
- showing how evidence links with scientific ideas;
- helping to improve and clarify pupils' knowledge and understanding of scientific concepts, models and theories;
- developing reasoning and problem-solving skills;
- exploring 'how we know'.

The choice to demonstrate an activity, rather than conducting a group or class practical, should be governed by the expected learning outcomes. It is the nature of the interaction and discussion between the teacher and pupils, and within groups of pupils, during the demonstration which makes this approach suitable for developing pupils' understanding of science.

Task 5

Review again your collated list of demonstrations from Tasks 1–4.

- Categorise the demonstrations according to the teaching and learning aspects described above.

Refer to this list as you work through the rest of the guide.

Reflection

In Tasks 1–4 you reviewed some aspects of the demonstrations included in your scheme of work for a particular year group.

You have:

- considered the subject-specific reasons for carrying out the demonstrations;
- classified the demonstrations by 'type': Performance, Serial, Marathon or Spontaneous;
- considered the situations in which the demonstrations were carried out;
- categorised the demonstrations by teaching and learning aspect.

How satisfied are you with the decision-making process behind choosing to carry out a demonstration activity?

Are there now any decisions you would want to change? Why?

What makes a demonstration effective?

Some of the key features of an effective demonstration include:

- the presentation is interactive, lively and engaging and the pupils are actively involved and required to think or apply their knowledge;
- the activity is clearly focused on the lesson objectives (i.e. they are 'fit for purpose');
- the teacher is well prepared and has, if necessary, rehearsed both the practical and interactive aspects of the activity;
- the demonstration makes an impact on learning;
- the demonstration is safe;
- the demonstration is well presented, tidy and uncluttered;
- the demonstration is visible to the whole class.

Demonstrations should be interactive, lively and engage the pupils

This needs some careful thought. What will you do and what will the pupils do throughout the demonstration in order to ensure that the activity maintains the pupils' attention and enables progression to take place?

Carrying out a demonstration and teaching effectively at the same time is not easy to do well and is a skill that should not be underestimated. As the teacher, you need to concentrate on what you're doing with the experiment as well as being able to ask questions, keep the pupils' attention and ensure the demonstration helps them to progress towards the desired learning outcomes. This is why rehearsal is often essential.

A variety of activities can be used to engage and focus the pupils during a demonstration. These include:

- arranging a pre-prepared series of statements (e.g. cards describing the process being demonstrated) into the correct order;
- using mini-whiteboards (on which to make notes or draw diagrams or concept cartoons) in response to your questions and prompts;
- completing a 'structured' worksheet by recording observations for further discussion after the demonstration;
- 'traffic lighting' a series of statements according to their relevance to the process being observed;
- predicting and explaining what the outcome of the next stage might be;
- contributing to the selection of variables and the direction of the demonstration when this is possible (and safe to do so).

For some demonstrations, it may be appropriate to involve a pupil in carrying out one or more of the steps (refer to the *Safety and some myths* section). You may also be able to involve the technician or teaching assistant.

Demonstrations should be 'focused on the learning objectives'

Demonstrations should be carried out to meet specific teaching and learning objectives. The inclusion of a demonstration activity should be an integral part of lesson planning and the decision to include a specific demonstration should be driven by the desired outcomes.

Demonstrations should be well prepared and, if necessary, rehearsed

Thorough preparation is essential. A demonstration that does not work can have a negative impact on teaching and learning (although a confident or more experienced teacher can turn the 'failed experiment' into a valuable learning experience regarding scientific enquiry!).

The demonstration should be rehearsed in full before performing it in front of a class. Never be tempted to 'have a go' at a new demonstration for the first time with a class in the laboratory.

As you practice each stage of the experiment, think about how to make each step interactive.

- What do you expect pupils to do during the demonstration?
- What do you expect pupils to learn during the demonstration?
- What questions will you ask to check pupils' understanding of what they are observing and to move their understanding forward?

As you rehearse you will be able to see what happens, how long things take, what could 'go wrong', how and where to lay things out, what apparatus and materials you need to hand and how much space you will need; you will have the opportunity to think through the activities that the pupils can do during the demonstration and be able to pre-empt some of the pupils' questions.

Don't forget that some of the apparatus, materials and techniques may be very new to the pupils. Names, spellings and functions may need to be explained. Consider the level of understanding and background knowledge of your audience.

It is a good idea to jot down some reminder notes or 'prompts' for the lesson as you rehearse the experiment.

Ideally, you should aim to have the demonstration ready at the start of the lesson before the pupils arrive. Make sure that you also have spare apparatus and materials (e.g. chemicals) as appropriate. Involve your technician at the earliest possible stage in planning.

Demonstrations should make an impact

The best demonstrations are memorable because they vividly illustrate scientific phenomena. Effective demonstrations help the pupils to make vital links between the physical reality of their experience and abstract theory. Even the simplest demonstrations can have a long-lasting, positive effect on learning.

Demonstrations must be safe

Safety is an important consideration and more detailed information is provided in the *Safety and some myths* section.

Most of the above points apply to all types of demonstration. Some additional consideration needs to be given to demonstrations other than the 'performance' style. These styles of demonstration include:

- **Spontaneous:** Often, when planning your lessons, you may be able to identify, or pre-empt a 'spontaneous' demonstration. This will enable you to have the relevant materials and apparatus to hand and to have thought through the implications (in terms of the learning objectives and health and safety issues). Do not be tempted to perform a demonstration you are unsure of.
- **Serial:** Demonstrations that require you to carry out a series of short, individual experiments will need careful planning. Lay out the experiments in the order you intend to carry them out. Consider putting the different 'part' experiments in different locations in the classroom.
- **Marathon:** Demonstration experiments that run over several days or weeks can be very difficult to manage effectively. Give some thought about how to maintain the pupils' interest in the experiment (what will they do on each separate occasion?). 'Forgotten' or 'abandoned' marathon experiments can be a great source of frustration for keen pupils.

Also consider where to store the experiment so that observations can continue but so that it is not in the way of other practical work or in danger of being interfered with.

Demonstrations should be tidy and uncluttered

Make sure that the bench where you are carrying out the demonstration is free from all clutter (this includes random bits of apparatus, textbooks and last week's marking pile!).

You may find it helpful for some demonstrations to use a contrasting backdrop (e.g. pieces of thick black or white card) to help ensure that the demonstration itself is at the centre of attention.

Demonstrations should be visible to all pupils and as large-scale as possible (if appropriate and safe)

For some experiments, it is possible to scale up the amounts and/or the size of the apparatus.

For example, a demonstration of the effect of dry ice (solid carbon dioxide) on the pH of a Universal Indicator solution can be carried out using gas jars rather than boiling tubes or beakers.

In other cases it may be appropriate to use visual aids or ICT facilities. A flexicamera connected to a data projector or interactive whiteboard can be useful when demonstrating a necessarily small-scale experiment, such as helping pupils to understand the view down a microscope when studying plant and animal cells.

Think carefully about where you will perform the demonstration. As part of your rehearsal, walk around the laboratory and view the demonstration from the pupils' perspective.

- Where will they be sitting or standing?
- Will they get a clear view of what's going on?
- Will they need to write things down during the demonstration?
- What do you need to consider if the demonstration is being carried out elsewhere (e.g. outside)?

How will you resolve these issues? The art of presentation is an essential part of being an effective teacher. Think about visibility, audibility, focus of attention, pupil participation, contrasts and comparisons.

Always remember, however, that the demonstration, not the demonstrator, should be the focus of attention!

Using demonstrations to develop higher-order thinking skills

Demonstration activities are ideal opportunities to develop scientific enquiry skills so it is important for you to consider the thinking skills being assumed or targeted during the activity.

The table in Figure 1 below suggests one way of relating the focus of a demonstration, in terms of the teaching objectives and learning outcomes, to the hierarchy of thinking skills based on Bloom's Taxonomy.

All too often, demonstrations are aimed at lower-order thinking skills. How can you use a demonstration to target some of the higher-order skills?

Figure 1

<table>
<tr><th></th><th>Thinking skill</th><th>Focus of demonstration</th><th colspan="2">Action words</th><th>Dialogue / questions</th></tr>
<tr><td rowspan="6">Lower-order ↑ … Higher-order ↓</td><td>Knowledge</td><td>Observing and recalling scientific phenomena and processes</td><td>Name
Recall</td><td>Identify
State</td><td rowspan="6">Give me the equation for …

What happens when …?

Identify the main parts of …

What did you observe …?

How could you classify …?

What's the difference …?

How can we find out …?</td></tr>
<tr><td>Compre-hension</td><td>Linking evidence with scientific ideas</td><td>Describe
Compare</td><td>Explain
Classify</td></tr>
<tr><td>Application</td><td>Clarifying knowledge and understanding of concepts, models and theories</td><td>Interpret
Relate</td><td>Apply ideas
Solve</td></tr>
<tr><td>Analysis</td><td>Applying scientific ideas in new contexts or situations</td><td>Prioritise
Reason</td><td>Infer
Draw conclusions</td></tr>
<tr><td>Synthesis</td><td>Developing reasoning and problem-solving skills</td><td>Reflect
Design</td><td>Predict
Speculate / hypothesise</td></tr>
<tr><td>Evaluation</td><td>Exploring 'how we know'</td><td>Summarise
Judge</td><td>Assess</td></tr>
</table>

Task 6

Appendix 1 shows some of the statements for a selection of topics taken from the KS3 Programmes of study (existing and 2008) plus some statements for the same topics from the 2006 GCSE Science and Additional Science Criteria.

- For each of the main topic areas shown in Appendix 1, work with another teacher (for example, another subject specialist) or your science consultant to think of some ideas for *demonstrations* that could be developed to challenge pupils' higher-order thinking.
- Display your list in the department base or prep room and ask other colleagues to add to the list.

Some suggestions for demonstrations linked to the topic areas shown in *Appendix 1* are given in Figure 2. Most of these suggestions are taken from one or more of the sources listed in *Appendix 3*. It provides a list of just a few of the many sources of information and ideas for demonstrations. Many of the resources provide detailed instructions for specific experiments.

Task 7

Spend 15–20 minutes searching some of the websites listed in Appendix 3.

Aim to find at least one additional demonstration activity for each of the main topic areas listed in Appendix 1.

Add these ideas to the list of demonstrations from Task 6.

Share your findings with the rest of the department.

Figure 2

Topic area	Demonstration examples
Plant nutrition (KS3) Energy flow and element cycles (GCSE)	(A) 'The amazing concertina cactus' – to investigate the uptake of water by plants. See Appendix 3 (2). (B) Using algal balls to investigate photosynthesis. See Appendix 3 (2).
Genetics (KS3) Organisms, behaviour and health (KS3 '08) Organisms and health (GCSE)	(C) Using rapid-cycling brassica plants to investigate inheritance and variation. See Appendix 3 (2).

Figure 2

Topic area	**Demonstration examples**
Particles (KS3) Chemical & material behaviour (KS3 '08, KS4) Structure and bonding (GCSE)	(D) Using helium balloons to demonstrate diffusion or demonstrating diffusion with nitrogen dioxide (rather than bromine). See Appendix 3 (1). (E) Demonstrating crystal growth under a microscope to investigate ideas about the arrangement of particles in solids and liquids[2]. (F) Testing a non-Newtonian fluid or 'silly putty' to illustrate states of matter and how structure and bonding affects properties. (G) Using a top-pan balance and marbles to illustrate how gas molecules exert pressure. See Appendix 3 (3).
Forces (KS3) Energy, electricity and forces (KS3 '08) Forces and motion (GCSE)	(H) 'Egg and sheet' demonstration to illustrate force and the effectiveness of 'air bags'. See Appendix 3 (3). (I) Using sparklers, a drill, a marble and a drainpipe, a bung on a string and an apple to introduce circular motion! See Appendix 3 (3). (J) Galileo's Rolling Ball experiment (Newton's First Law and a hint at his Second Law). See Appendix 3 (3).
Electricity and magnetism (KS3) Energy, electricity and forces (KS3 '08) Forces and motion (GCSE)	(K) Large-scale demonstration to show that electrically charged materials exert forces on each other that may be attractive or repelling. See Appendix 3 (3). (L) Lamps in parallel – demonstration to show that the current flowing in a circuit increases as more lamps are added in parallel with each other. See Appendix 3 (3).

[2]School chemistry experiments – a collection of tried and tested experiments for use in schools, R.F Farley (ASE, 2001).

The level of thinking skill that the pupils will need to employ will obviously depend on the nature of the demonstration, the way in which pupils are involved and the 'thinking demand' of the activity you set for them. For any given demonstration, there are two levels of demand which need to be considered; the conceptual demand of the situation being demonstrated and the thinking demand provided by the nature of the questions being asked. Ideally, the pupils will be engaged in a variety of tasks which target a range of thinking skills, progressing from lower to higher order.

Task 8

The table overleaf provides some suggested activities linked to the demonstrations described above.

- Select five demonstrations from the list that you collated in Tasks 6 and 7. Try to ensure that you have a range of 'types' of demonstration and that at least one of the demonstrations comes from a topic you are going to teach soon.
- Working with another teacher, devise a range of pupil activities for each demonstration. Ensure that the activities for any given demonstration cover a range of higher-order thinking skills where possible. Use the examples in the table below to help.
- Keep a written record of your ideas.
- Working with another teacher, devise a range of questions that you could ask pupils during three of the demonstrations listed. Ensure that the questions you write are appropriate to develop the thinking of pupils with a range of abilities.

	Focus of demonstration	Example of activities (Linked to examples identified in figure 2)
Lower-order thinking	Observing and recalling scientific phenomena and processes	(L) Produce a visual representation of the circuit by arranging a series or pre-prepared 'component' cards including ammeters with appropriate values. (A), (B) Complete a pre-prepared table to describe how these particular plants obtain each of the things they need to be able to grow in their environments. (D) Write a diary description of your observations after a helium balloon is released in the laboratory and left for 3 days.
	Linking evidence with scientific ideas Clarifying knowledge and understanding of concepts, models and theories	(D) Using your understanding of particles, draw a cartoon to explain why the brown gas took so long to diffuse into the top gas jar.
	Applying scientific ideas in new contexts or situations	(C) Why do the brassica plants grown in the F1 generation show the characteristics they do? What are their phenotypes and genotypes? How could you confirm the genotypes?
	Developing reasoning and problem-solving skills	(I) When considering circular motion, sketch what you predict will happen to the marble in the drainpipe. Explain why you think this will happen. (I) On the diagram, sketch what actually happened to the marble. Discuss your observations with a partner and work as a pair to come up with an explanation using your understanding of forces.
Higher-order thinking	Exploring 'how we know'	(E) What experimental evidence do we have that the particles in a solid are regularly arranged and packed tightly together? How valid and reliable are the conclusions we can draw from this evidence?

Planning demonstrations

The inclusion of a demonstration activity must be an integral part of the lesson-planning process and it is essential to plan demonstration experiments carefully if they are to be an effective device in your teaching repertoire. 'Spontaneous' demonstrations arise naturally during the course of a lesson but they still require careful thought.

Think it through. Before investing time and effort in the developing, planning and carrying out a demonstration, be absolutely clear in your own mind that the demonstration provides the best opportunity for delivering the learning objectives and outcomes you want to achieve for that particular group of pupils.

In developing a lesson plan, you should aim to be able to answer each of the following questions with reference to the proposed demonstration activity.

- **Why** is a demonstration appropriate? How will it support pupil learning?
- **What** demonstration experiment will be carried out?
- **What** is the main objective of the demonstration?
- **What** will you do?
- **How** will you make the demonstration interactive for the pupils? (What questions/prompts will you use? How do you expect pupils to respond? What misconceptions may this demonstration unearth? How will you help all pupils to develop their understanding during the demonstration?)
- **How** will the demonstration be carried out?
- **How** much guidance do you need?
- **How** can you find out more about doing the demonstration?
- **Where** will the demonstration take place?
- **Where** will the demonstration be laid out?
- **Where** will the pupils be?
- **When** in the lesson will the demonstration take place?
- **What** will be the sequence of events?
- **Who** will be involved in the planning, preparing and carrying out?

Find and develop resources. Experienced teachers are often an excellent source of information and ideas and some teachers are always on the lookout for new ideas or interesting 'twists' on the tried and tested experiments. Technicians often have some great ideas and it is always sensible to involve them in your planning at the earliest stage possible.

There are many other good sources of information for practical experiments. Some are described in Appendices 3 and 4.

Selecting, and then carrying out, a suitable demonstration can be quite difficult. There are some simple steps that you can take towards ensuring that the demonstration activities you carry out are effective – in terms of the learning objectives and outcomes as well as in terms of impact and enjoyment. If both you and the pupils enjoy and understand the demonstration, then this is more likely to enhance the learning that takes place.

Practical tip

Some useful points to consider as a 'checklist' or to bear in mind when planning a demonstration activity include:

- **What do you want the main learning objective of the demonstration to be?**
- **How will the demonstration help pupils clarify their understanding?**

  Will the demonstration challenge pupils' thinking?

  What key questions will you need to ask?

  What misconceptions might emerge during the demonstration?

  How will you support pupils who hold these alternative views to make progress?

  How does the demonstration allow the active engagement of pupils?

  What interactions are possible?

Task 9

- Considering a demonstration from a topic that you are going to teach soon (Task 8), plan a lesson to include this demonstration, indicating how the inclusion of this demonstration will support pupils in their learning.
- Make notes on the demonstration which include answers to: **Why? What? How? Where? When?** and **Who?** Ensure your plan includes a range of activities that will engage the pupils and which challenge the pupils' thinking.
- Teach the lesson and evaluate how successful it was.
- This would be a good opportunity for you to be observed teaching by your teacher partner or science consultant, and to jointly reflect on the effectiveness of the demonstration lesson.

Demonstrations for 'open days' and similar events

School science departments are often involved in putting on displays or demonstrations for events such as 'open days', science-week activities and primary liaison days.

These demonstrations need to be planned carefully since a number of additional factors need to be taken into account over and above the demands for a 'standard' classroom lesson demonstration.

Some key points to consider include:

- **Visitors** The age, knowledge levels, health and behaviour of visitors will vary greatly and be largely unknown (e.g. a visitor may have asthma or a severe allergy). Visitors are unlikely to be familiar with laboratory rules.
- **Risk assessments** If the aim of the event is to illustrate the normal range of activities that pupils engage in, then it would make sense to demonstrate some of the activities from the science department's scheme of work for the year groups in question. If this is the case, then a risk assessment will already be available. If, however, the decision has been made to arrange 'spectacular' demonstrations, not normally performed in the course of the academic year, then additional risk assessments will need to be made.

  Visitors should take part in an activity only if the risk is minimal or if the risks have been assessed, and appropriate control measures put in place.
- **Supervision** This can be very difficult during 'open day' type events and places an additional burden on science teaching and support staff. Thought should be given to organising the activities so that the teachers involved in actually supervising or carrying out a demonstration are not also required to act as 'host' for the visitors. Those involved in supervising must ensure that eye protection is worn when necessary and that other safety measures are adhered to. Consider cordoning off demonstration areas.
- **Security** Give some thought as to how to prevent accidental or wilful theft of apparatus and materials, especially chemicals. Ensure that visitors cannot gain access to unsupervised laboratories or the prep room.
- **Workload** Events such as these add substantially to the workload of all concerned. Allow sufficient time for planning, preparing, setting out and clearing away. Involve your technicians and teaching assistants in the discussions and decision making at the earliest opportunity.

Safety and some myths

Some myths Disappointingly, there continues to be the perception among many people associated with, or interested in, science education in schools that health and safety concerns restrict what is and what is not possible in terms of experimental work.

In 2005, CLEAPSS was commissioned by the Royal Society of Chemistry (RSC) to investigate whether effective teaching of practical science (across all the sciences) was being inhibited on spurious health and safety grounds. The report, *Surely that's banned?*, found that these concerns were largely justified. The investigation found that:

There are significant misunderstandings on the part of teachers and technicians about the chemicals and scientific activities which are banned in secondary schools and some teaching is inhibited by unjustified concerns about health and safety.

In addition, the report stated that there were very few local authority bans which could be blamed for restricting practical science activities in schools.

While acknowledging that lack of resources and time may hinder some activities, the report concluded that it appeared that many teachers or heads of department simply did not access much of the advice and guidance provided.

The full report is available on the RSC website at www.rsc.org/Education/Policy/SurelyThatsBanned.asp

Encouraging practical science There is a wealth of guidance, support and information available to school science teachers to enable them to undertake exciting practical activities safely. Some of these resources are listed below and others are given in the Additional resources section of this guide. Model risk assessments and other guidance can be found in these texts. Teachers are strongly advised to consult them.

Safeguards in the School Laboratory, 11th edition, ASE, 2006

Topics in Safety, 3rd edition, ASE, 2001

*Hazcards**, CLEAPSS, 2007 (or later updates)

*Recipe cards**, CLEAPSS, 1999 (or later updates)

*Laboratory Handbook**, CLEAPSS (updated annually)

*These, and other CLEAPSS publications, are on the CLEAPSS Science Publications CD-ROM which is issued annually to members. More information about CLEAPSS can be found in Appendix 3.

Next steps

In this unit there have been several suggestions for you to pair with another teacher or your science consultant as a means of support while you develop your confidence in planning and carrying out practical demonstrations.

- Start small: select one topic for a particular year group and aim to develop or practice a few demonstration activities which will meet the required teaching and learning objectives.
- Ask another teacher, your head of department or your science consultant to help you. You may have an AST in your school who may be able to help you review the effectiveness of the pupil activities that link to the demonstration.
- Ask for some protected time to research resources and to develop your lesson plans for your teaching. You will also need some time to rehearse the demonstrations.
- Make sure your head of department or line manager knows what you are doing.
- Observe other teachers doing demonstrations and evaluate the approach they take. Discuss your ideas with them.
- Work with your science consultant or another teacher to develop a bank of effective demonstration experiments (including linked pupil activities) for your scheme of work for a particular year group.
- Invite an AST to observe you teach a lesson which includes a demonstration experiment and ask them to comment on the range of activities undertaken and questions asked by the pupils during the demonstration.

Appendix 1:

Extracts from the Programme of Study for Science

Statement from existing KS3 Programme of study	Statements from 2008 KS3 Programme of study
Pupils should be taught:	The study of science should include:
Plant nutrition Sc2 (3) • that plants need carbon dioxide, water and light for photosynthesis, and produce biomass and oxygen • to summarise photosynthesis in a word equation • that nitrogen and other elements, in addition to carbon, oxygen and hydrogen, are required for plant growth • the role of root hairs in absorbing water and minerals from the soil	
Genetics Sc2 (4) • about environmental and inherited causes of variation within a species • that selective breeding can lead to new varieties	**3.3 Organisms, behaviour and health** • all living things show variation – this includes inherited and environmental variation and variation through genetic engineering and selective breeding

Particles Sc3 (1) (2) • how the particle theory of matter can be used to explain the properties of solids, liquids and gases, including changes of state, gas pressure and diffusion • that when physical changes take place (e.g. changes of state, formation of solutions), mass is conserved • to relate changes of state to energy transfers	**3.2 Chemical and material behaviour** • the particle model provides explanations for the different physical properties and behaviour of matter
Forces Sc4 (2) • how to determine the speed of a moving object and to use the quantitative relationship between speed, distance and time that the weight of an object on Earth is the result of its gravitational attraction between its mass and that of the Earth • that unbalanced forces change the speed or direction of movement of objects and that balanced forces produce no change in the movement of an object • ways in which frictional forces, including air resistance, affect motion • that forces can cause objects to turn about a pivot • the principle of moments and its application to situations involving one pivot • the quantitative relationship between force, air and pressure and its application (e.g. use of skis and snowboards, the effect of sharp blades, hydraulic brakes)	**3.1 Energy, electricity and forces** • forces are interactions between objects and can affect their shape and motion (this includes pressure effects, linear motion and turning moments)

Electricity and magnetism Sc4 (1)	3.1 Energy, electricity and forces
• how to design and construct series and parallel circuits, and how to measure current and voltage • that the current in a series circuit depends on the number of cells and the number and nature of other components and that current is not 'used up' by components • that energy is transferred from batteries and other sources to other components in electrical circuits • that a current in a coil produces a magnetic field pattern similar to that of a bar magnet • how electromagnets are constructed and used in devices (e.g. relays, lifting magnets)	• electric current in circuits can produce a variety of effects – includes current and voltage in series and parallel circuits – electrical devices are designed to make use of a variety of effects caused by electric currents including heating, chemical changes and magnetic effects

GCSE Science Criteria	GCSE Additional Science Criteria
	Energy flow and element cycles • plant biomass provides energy and nutrients for other organisms. Through the consumption of organisms and decay, energy flows through the biosphere and chemical elements are recycled
Organisms and health • variation within species can lead to evolutionary changes, and similarities and differences between species can be measured and classified	
Chemical and material behaviour • chemical changes take place by the rearrangement of atoms in substances • the properties of a material determine its uses	**Structure and bonding** • the structure and properties of a substance are strongly dependent on the nature of the bonding which results from the forces between the electrons and nuclei of atoms
Energy, electricity and radiation • electrical power is readily transferred and controlled, and can be used in a range of different situations	
	Forces and motion • forces arise from interactions between objects. The balance, or otherwise, of these forces on an object affects its movement. Energy transfers can occur due to these interactions though the total energy remains constant

Appendix 2:

Effective teaching and learning in science

Effective learning takes place when pupils are actively engaged with it. *The Framework for teaching science: Years 7, 8 and 9* identifies intervention, direct teaching and interaction as being crucial for successful learning in science. The impact of the Secondary National Strategy on teaching and learning is acknowledged in the 2006 Annual Ofsted report:

In English, mathematics and science, results had risen steadily since the introduction of the Secondary National Strategy.

The quality of teaching and learning continued to improve as teachers applied Secondary National Strategy techniques.

Many schools have given consideration to pupils' preferred learning styles, and across a range of subjects it is evident that higher achievement is associated with active forms of learning. For example, where science was well taught, not only were basic concepts effectively addressed, lessons were also stimulating and enjoyable. In thinking about how science works, pupils researched and exchanged information, often making effective use of ICT, debating ideas and displaying knowledge and understanding of issues very relevant to their own and others' lives.

The *Framework* identifies that effective science lessons possess the following key features:

- include high expectations, clear objectives and tight structures;
- include reviews of, and build on, previous learning;
- integrate summaries and plenary sessions;
- involve activities appropriate to the learning objectives – including exposition, **demonstration**, class practical;
- make appropriate use of models and analogies and integrate questioning that challenges thinking;
- use informal assessment of progression in terms of pupils' understanding of key ideas;
- include contemporary science applications or issues, both local and national;
- involve discussions which enable pupils to air their own views, listen to the views of others and articulate their own ideas and understanding.

The Framework also identifies that effective teachers employ a balance of different teaching and learning approaches including:

- directing and telling;
- demonstrating;
- explaining and illustrating;
- questioning and discussing;
- exploring and investigating;
- reflecting and evaluating;
- summarising and reminding.

A key point emphasised in recent Ofsted reports is that practical science is an element of scientific enquiry that contributes to successful learning. The need for pupils to be actively engaged in the demonstration activity, if learning is to be successful, is clear.

The 2008 Key Stage 3 Programme of study sets out a number of key concepts and key processes that pupils need to understand and learn. These concepts and processes are developed in the 2006 GCSE specifications in terms of how science works.

In addition to the development of skills, knowledge and understanding, it is also important to recognise that it is practical work and demonstrations that are often recalled as some of the most enjoyable features of school science.

Demonstration activities provide an ideal opportunity for the teacher to lead whole-class, direct, interactive teaching and represent just one of a range of approaches that a teacher can employ to help pupils develop their knowledge and understanding of scientific concepts and processes.

[3]Annual Report of Her Majesty's Chief Inspector of schools 2005/2006, Crown copyright 2006.

[4]Annual Report of Her Majesty's Chief Inspector of schools 2004/2005, Crown copyright 2005.

Appendix 3:

Additional resources to support effective demonstrations

1. **CLEAPSS** (www.cleapss.org.uk) is a nationwide advisory service providing support for practical science and technology in schools and colleges. Among its many services, CLEAPSS provides termly newsletters, model and special risk assessments, training courses for teachers and technicians, a telephone helpline and a wide range of publications including, for example, ideas and practical guidance for some of the activities in the new science GCSEs.

   CLEAPSS services are available to members. All 180 local authorities responsible for education in England, Wales, Northern Ireland and the offshore islands are members. So all their schools are members and all their staff can use CLEAPSS services. There are also around 2000 associate members in the UK including foundations schools and independent schools.

2. **SAPS** (Science and Plants for Schools) aims to support science in schools by developing new educational resources to promote the exciting teaching of plant science and molecular biology. Resources include a range of publications, ideas for practical investigations, courses and kits.
   For more information, see www-saps.plantsci.cam.ac.uk

3. www.practicalphysics.org is for teachers (and technicians) of physics, enabling them to share their skills and experience of making experiments work in the classroom. Tried and tested physics experiments are described in sufficient detail that they will work in any school laboratory. Notes about teaching and learning, and a few web-links are also provided. The site is a joint project of the Nuffield Curriculum Centre and The Institute of Physics.

4. www.practicalchemistry.org is the chemistry equivalent of www.practicalphysics.org and is a joint project of the Nuffield Curriculum Centre and the Royal Society of Chemistry, in association with CLEAPSS.

5. www.chemistryteachers.org is designed for chemistry and science teachers worldwide and allows you to quickly find resources from the Royal Society of Chemistry (RSC) and elsewhere to use in your teaching. In addition, video clips of a number of chemistry demonstrations can be found on the RSC's learnnet website at www.chemsoc.org/networks/learnnet/videoclips.htm. A set of instructions for several of these demonstrations is available at www.chemsoc.org/networks/learnnet/videodemos.htm.

6. **The Nuffield Curriculum Centre** aims to explore new approaches to teaching and learning by developing, managing and supporting curriculum projects. Increasingly, projects are run in partnership with others. The main partner is the Science Education Group at the University of York. More information is available at www.nuffieldcurriculumcentre.org.

7. **The Salters' Institute** (www.salters.co.uk/institute) supports many curriculum development projects and organises and runs the Salters' Festivals of Chemistry and the Salters' Chemistry Camps. In addition, the Institute provides resources for schools to run science clubs. Ideas for chemistry practicals and demonstrations can be found in the two volumes of the *Salters' Chemistry Club Handbook*.
8. **National Centre for Biotechnology (NCBE)** supports science education in schools and colleges by developing and distributing a range of innovative educational resources and also provides in-service training for school biotechnology. See www.ncbe.reading.ac.uk
9. **SEP (Gatsby Science Enhancement Programme)** supports science education in the UK. It develops innovative, high-quality resources for secondary science at low cost making them affordable and easily accessible to schools, and supports science teachers at all stages of their career, providing materials and development opportunities to improve classroom practice. See www.sep.org.uk

This list represents just a very few of the resources available to teachers regarding ideas, support and advice for practical work in science. A more extensive list can be found on the *Links* page on the **CLEAPSS** website at www.cleapss.org.uk

Appendix 4:

References

Lecture Experiments in Chemistry (5th edition), G. Fowles (London, Bell 1959)

Classic Chemistry Demonstrations: one hundred tried and tested experiments, T. Lister (Royal Society of Chemistry, 1995)

Chemical Demonstrations: a handbook for teachers of chemistry, B.Z. Shakashiri (Madison; London: University of Wisconsin Press, 1982-92)

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Acknowledgements

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Audience: Science subject leaders, teachers of science and higher level teaching assistants.

Date of issue: 02-2008

Ref: **00094-2008DVD-EN**

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