**Key Stage 3**
*National Strategy*

Science

# Scientific enquiry

Notes for tutors

# Contents



 

# Overview of the unit

This pack contains the materials, background notes and guidance for the unit on scientific enquiry. As the Key Stage 3 science consultant or tutor you will use these materials as part of the Key Stage 3 National Strategy for science.

The unit is intended for all science teachers. It complements the scientific enquiry element of the unit on planning and managing progression. The teacher attending the scientific enquiry unit should already have had some feedback from their Key Stage 3 science coordinator on the main messages about planning for progression in scientific enquiry.

This unit includes follow-up work of two sorts: one for the participant to develop their own teaching and the other to disseminate some of the ideas from the unit to colleagues in the department.

## Unit objectives

- To clarify the nature and extent of scientific enquiry, including ideas and evidence
- To emphasise the need to teach scientific enquiry explicitly, using appropriate objectives, and drawing on the Framework yearly teaching objectives
- To clarify how specific skills and processes of scientific enquiry can be taught within the context of practical and enquiry activities
- To explain the central role of evidence and thus why teaching and learning about ideas and evidence is important
- To provide a range of strategies for teaching pupils about ideas and evidence and about how scientists work
- To determine priorities and actions for follow-up in school

## Outline programme

| | |
|---|---|
| **Session 1** | Introduction to scientific enquiry (1 hour) |
| **Session 2** | Teaching scientific enquiry skills and processes explicitly (1 hour 5 minutes) |
| **Session 3** | Types of scientific enquiry (40 minutes) |
| **Session 4** | Ideas and evidence in Key Stage 3 science (35 minutes) |
| **Session 5** | Some strategies for teaching about ideas and evidence (1 hour 15 minutes) |
| **Session 6** | How scientists work (35 minutes) |
| **Session 7** | Conclusions and follow-up (15 minutes) |

## Synopsis

### Session 1 Introduction to scientific enquiry

The main objective for the session is that participants recognise that scientific enquiry is complex and needs to be taught explicitly in a planned and manageable way. The unit opens with an audio clip from an interview with Lewis Wolpert, a contemporary scientist, which touches on how scientists work. This is followed by a short activity which focuses on the Framework yearly teaching objectives for scientific enquiry to provide insights into both identifying lesson objectives and progression in Sc1. In the next activity participants explore how to recognise the varying demands which different enquiries make on pupils. They use a simple classification system to identify easier and more demanding activities from the QCA scheme of work. The session concludes with a short review of the work of Richard Gott and others on concepts of evidence. In Key Stage 3 this focuses on the requirements to increase the accuracy and reliability of evidence. Gott *et al.*'s analysis of scientific enquiry into basic skills, concepts of evidence and procedural understanding provides a useful introduction to session 2.

### Session 2 Teaching scientific enquiry skills and processes explicitly

This session develops the idea of the importance of developing investigative skills through explicit teaching. Participants use examples from the QCA scheme of work to derive lesson objectives from one or two yearly teaching objectives for scientific enquiry in the Framework. This helps participants recognise the need to have lesson objectives for scientific enquiry and to use the yearly teaching objectives as a resource. The rest of the session is devoted to two activities which illustrate teaching approaches. The first activity uses a strategy for teaching pupils about planning a fair test and dealing with the results (based on posters and sticky notes), developed initially for primary teachers but modified for use in Key Stage 3. The second is about the value of repeat readings. Although both can be taken and used with pupils it is important to keep in mind the principle of teaching specific skills and processes explicitly. Participants will be given A0 copies of the posters to take away for their own and their colleagues' use in school.

### Session 3 Types of scientific enquiry

The main objective for session 3 is for teachers to recognise the types of enquiry activities they need to teach and how to identify questions from existing work to meet that range. The National Curriculum requires pupils to be taught and use a range of scientific enquiry activities, including investigations other than fair tests. Participants are given an illustration of the range collated from the QCA scheme of work. The first task requires them to sort a set of enquiry questions into the different categories of enquiry. In the second activity they consider the types of questions that can be constructed in common Key Stage 3 science topics that lead to enquiry activities other than fair tests.

## Session 4 Ideas and evidence in Key Stage 3 science

Session 4's objective is for participants to recognise what the National Curriculum requires them to teach about ideas and evidence. The session opens with participants exploring what they understand science to be and listening to an audio clip from Lewis Wolpert. The interplay between ideas and evidence is summarised in a model. Participants go on to consider what the National Curriculum programme of study for Key Stage 3 requires by identifying relevant statements in the level descriptions for each of levels 4 to 7.

## Session 5 Some strategies for teaching about ideas and evidence

The main objective for session 5 is for participants to recognise a number of strategies for teaching aspects of ideas and evidence. This session takes up almost half of the afternoon and consists of three parts, each of which includes ideas for classroom activities. The first part concentrates on teaching pupils to recognise evidence, offering them some relatively simple strategies. In the second part, participants learn strategies for helping pupils to see the value of the cycle of hypothesis – prediction – test – new hypothesis, etc. There are three activities that can be demonstrated practically. Tutors should demonstrate at least one. In the final part of the session participants look at teaching about analysing evidence to decide between two conflicting 'theories' of how we see.

## Session 6 How scientists work

The main objective for session 6 is for participants to consider how scientists have worked in the past and work today, and how this can be taught. It is introduced by a third audio clip from Lewis Wolpert. Two activities follow. The first, based on the work of Lavoisier, is a card sort to explore how he worked; the task's structure also teaches pupils about working in groups. The second models a clinical trial and is easily done practically if the tutor is prepared and has sufficient time at the end of the day. Participants take away the instructions for both activities. There is also a list of references to easily available books and websites that contain more ideas and resources for similar activities.

## Session 7 Conclusions and follow-up

This session provides two short activities that enable participants to consider how they will develop their own practice in the light of what they have learned and how to disseminate the training to colleagues in their department. Summary sheets to support this are in the participants' pack. Participants choose from two lists which the tutor could photocopy to help prioritise their own in-school follow-up work.

 

# Preparing for the unit

## A model programme with timings

The following example programme may provide a useful start to planning your day.

| | |
|---|---|
| 9.00–10.00 am | Session 1 |
| 10.00–11.05 am | Session 2 |
| 11.05–11.20 am | Coffee (you may prefer to take coffee part way through session 2, for instance just before task E at around 10.40) |
| 11.20–12.00 noon | Session 3 |
| 12.00–1.00 pm | Lunch |
| 1.00–1.35 pm | Session 4 |
| 1.35–2.50 pm | Session 5 |
| 2.50–3.25 pm | Session 6 |
| 3.25–3.40 pm | Session 7 |
| 3.40 pm | End – offer refreshments prior to departure *(this may provide some time for you to photocopy completed follow-up forms)* |

## Writing to schools before this unit

You will need to prepare and send to schools in advance a programme based on the outline of the unit, tailoring times of sessions to suit your local circumstances. Send a map of how to get to the venue and include a contact telephone number for the venue that delegates can use. You may want to remind participants that they should have received some feedback from their Key Stage 3 coordinator on the main messages about planning for progression in scientific enquiry.

You may also want to prepare and send a list of participants' names and their schools to those who are attending.

There is no specific pre-unit task for this unit. There is, however, a range of post-unit activities, many of which may require your support.

## Tasks for participants before attending this unit

Before this unit all departments represented should have attended the unit on planning and managing progression and in consequence may have begun work on reviewing and modifying the Key Stage 3 scheme of work to incorporate a more explicit plan for teaching scientific enquiry.

## Tasks for you to do

You may need to refresh your memory of the notes and guidance provided in the tutor's notes for the launch unit of the science strand under the subheadings:

- Some tips on using these notes
- Preparing for the unit

The resources needed for each session are listed below for convenience.

Other preparations consist of making sure you are familiar with:

- *Framework for teaching science: Years 7, 8 and 9*, particularly the section on scientific enquiry and the relevant yearly objectives including appendix 2;
- the QCA scheme of work;
- these notes (including the tasks for participants), PowerPoint slides and handouts.

You will need to research information and practise the activities for some of the sessions.

### Session 1

Look up the research of Richard Gott *et al.* which is described in 'Understanding scientific evidence: why it matters and how it can be taught' by R. Gott and S. Duggan, in *The ASE guide to secondary science education* edited by M. Ratcliffe (ASE/Stanley Thornes, 1998; ISBN 0 86357 291 X). Gott also provides information on his work on http://www.dur.ac.uk/~ded0www/evidence_main1.htm.

### Session 2

You will need to familiarise yourself with the scientific enquiry posters and the nature of the planning process involved by reading through and practising the activity before using it with teachers.

Investigate the AKSIS materials, published by and available from the ASE (2000). If possible have copies of these available for participants to look at during the unit:

- *Investigations: developing understanding* by A. Goldsworthy, R. Watson and V. Wood-Robinson;
- *Getting to grips with graphs* by A. Goldsworthy, R. Watson and V. Wood-Robinson;
- *Investigations: targeted learning* by A. Goldsworthy, R. Watson and V. Wood-Robinson.

  (Not all of these are used in this unit.)

### Session 3

For task F you need to have a clear idea of possible categories for the questions and to have identified a number of questions which could fall into one or more category.

**Session 6**

*The Faber book of science*, edited by John Carey (Faber, 1995; ISBN 0 571 17901 0) is well worth looking at.

### Unit evaluation

At the beginning of each unit you should ask participants to retrieve the evaluation form from their pack. Collect the completed forms at the end of the unit. You will need to read them and to summarise the data. This will be collected as part of the monitoring and evaluation of the Key Stage 3 National Strategy.

As well as an evaluation sheet for participants, there is one included for you, as the tutor. Complete this after completion of the unit and your analysis of the participant evaluation sheets. Please return them to:

Science Team Senior Regional Coordinator
Centre for School Standards
60 Queens Road
Reading RG1 4BS

## Resources needed for each session

### Session 1 Introduction to scientific enquiry

**For tutor**

Slides 1.1–1.3, 1.8, 1.11–1.12

Audio clip 1 Interview with Lewis Wolpert

Some copies of:
*Framework for teaching science: Years 7, 8 and 9*
QCA scheme of work for Key Stage 3 science

Some extra copies of Framework page 25 for task A

**For participants**

Handouts
1.4 Transcript of audio clip 1
1.5 Scientific enquiry in Key Stage 3
1.6 Task A
1.7 Task A: planning grid
1.9 Classifying practical activities
1.10 Task B

### Session 2 Teaching scientific enquiry skills and processes explicitly

**For tutor**

Slides 2.1, 2.6–2.8, 2.12

A0 copies of the three scientific enquiry posters for demonstration
A3 copies of the posters for task D

Sticky notes of two different colours

 

Some copies of the *Framework for teaching science: Years 7, 8 and 9*

At least one copy of each of the AKSIS materials for participants to look at, particularly *Investigations: developing understanding* by Anne Goldsworthy, Rod Watson and Valerie Wood-Robinson (ASE, 2000)

### For participants

Handouts
2.2 Task C: instructions
2.3 Task C: response sheets
2.4 Scientific enquiry posters
2.5 Using the scientific enquiry posters
2.9 Pupils' understanding of repeat readings
2.10 Task E
2.11 Answers to task E

Five sets of A0 versions of the three posters to take away for use in school
A few calculators for task E

## Session 3 Types of scientific enquiry

### For tutor

Slides 3.1–3.3, 3.6, 3.8

Flipchart version of handout 3.7

### For participants

Handouts
3.4 Task F
3.5 Cards for task F
3.7 Task G

For each pair of participants, a set of cards for task F

## Session 4 Ideas and evidence in Key Stage 3 science

### For tutor

Slides 4.1–4.3, 4.5, 4.7–4.8, 4.10

Audio clip 2 Interview with Lewis Wolpert

### For participants

Handouts
4.4 Transcript of audio clip 2
4.6 Task I
4.9 The nature of science, scientists and evidence: some views

Highlighter pens

 

## Session 5 Some strategies for teaching about ideas and evidence

### For tutor

Slides 5.1, 5.9

Materials for task K: lemonade or equivalent fizzy drink (cola works well); small amounts of sugar, salt, chalk powder, flour, sugar solution and other materials of choice; tall beaker or measuring cylinder; plastic tray to catch spills, paper towels.

Materials for task L optional activity 1 (burning magnesium): magnesium strip; metal tray with heat-proof mat; matches; eye protection; possibly crucible; electronic balance.

Materials for task L optional activity 2 (pineapple jelly): tinned and fresh pineapple pieces; jelly dissolved but not yet set; a number of small containers, e.g. 100 ml beakers.

### For participants

Handouts
5.2 Strategies for helping pupils recognise evidence
5.3 Task J
5.4 Task J activity 2: cards
5.5 Task K
5.6 Task L activity 1
5.7 Task L activity 2
5.8 Task M

For each pair of participants, a set of cards for task J

## Session 6 How scientists work

### For tutor

Slides 6.1, 6.3, 6.12

Audio clip 3 Interview with Lewis Wolpert

A copy of *The Faber book of science* for participants to look at

Materials for task O (optional): see handout 6.8

### For participants

Handouts
6.2 Transcript of audio clip 3
6.4 Task N: teaching notes
6.5 Task N: observation sheet
6.6 Task N: cards
6.7 Ideas and evidence: resource list
6.8 Clinical trial simulation: teacher's notes
6.9 Clinical trial simulation: record sheet
6.10 Clinical trial simulation: analysis
6.11 Clinical trial simulation: some definitions

For each group of three participants, a set of cards for task N

 

## Session 7 Conclusions and follow-up

### For tutor

Slide 7.1

Access to a photocopier if possible

### For participants

Handouts
7.2 Personal follow-up work
7.3 Follow-up work with the department
Summary sheet

# Evaluation: Scientific enquiry

## For completion by teachers

What were the most successful aspects of today's sessions?

What changes would you suggest if today's sessions were repeated?

Please grade each session on the basis of how well structured and organised it is to meet the learning objectives identified.

| Session | Grade: please ring<br>1 = Very good, 4 = Poor | Comment |
|---|---|---|
| 1 Introduction to scientific enquiry | 1 2 3 4 | |
| 2 Teaching scientific enquiry skills and processes explicitly | 1 2 3 4 | |
| 3 Types of scientific enquiry | 1 2 3 4 | |
| 4 Ideas and evidence in Key Stage 3 science | 1 2 3 4 | |
| 5 Some strategies for teaching about ideas and evidence | 1 2 3 4 | |
| 6 How scientists work | 1 2 3 4 | |
| 7 Conclusions and follow-up | 1 2 3 4 | |
| Overall grade for the unit | 1 2 3 4 | |

School ______________________________

Post held ______________________________

Please return this form to your tutor before leaving.

 

# Summary evaluation: Scientific enquiry

**For completion by consultants or tutors after the unit has taken place**

LEA ______________________________________

Date of training _____________________________

What were the most successful aspects of today's sessions?

What changes do you suggest might be made to improve this unit?

a. From the tutor's point of view.

b. From the participants' point of view.

Please grade the tutor's material 1 to 4 for clarity of material, pitch of material, ease of use, appropriateness for teachers and so on. Use additional sheets of paper if you wish to provide more detailed comments.

| Session | Grade: please ring<br>1 = Very good, 4 = Poor | | | | Comment |
|---|---|---|---|---|---|
| 1 Introduction to scientific enquiry | 1 | 2 | 3 | 4 | |
| 2 Teaching scientific enquiry skills and processes explicitly | 1 | 2 | 3 | 4 | |
| 3 Types of scientific enquiry | 1 | 2 | 3 | 4 | |
| 4 Ideas and evidence in Key Stage 3 science | 1 | 2 | 3 | 4 | |
| 5 Some strategies for teaching about ideas and evidence | 1 | 2 | 3 | 4 | |
| 6 How scientists work | 1 | 2 | 3 | 4 | |
| 7 Conclusions and follow-up | 1 | 2 | 3 | 4 | |
| Overall grade for the unit | 1 | 2 | 3 | 4 | |

Please collate the grades given to each session by the teachers attending. Please provide numbers, not percentages.

Total number of teachers ______________

| Session | Grade | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | No grade |
| 1 Introduction to scientific enquiry | | | | | |
| 2 Teaching scientific enquiry skills and processes explicitly | | | | | |
| 3 Types of scientific enquiry | | | | | |
| 4 Ideas and evidence in Key Stage 3 science | | | | | |
| 5 Some strategies for teaching about ideas and evidence | | | | | |
| 6 How scientists work | | | | | |
| 7 Conclusions and follow-up | | | | | |
| Overall grade for the unit | | | | | |

Please return this form to:

Science Team Senior Regional Coordinator
Centre for School Standards, 60 Queens Road, Reading RG1 4BS

Session 1

# Introduction to scientific enquiry

## Objectives

- To clarify the nature and extent of scientific enquiry
- To clarify the need to explicitly teach the skills and processes of Sc1
- To clarify progression in teaching scientific enquiry as exemplified in the Framework yearly teaching objectives

## Resources

### For tutor

Slides 1.1–1.3, 1.8, 1.11–1.12
Audio clip 1 Interview with Lewis Wolpert

Some copies of:
*Framework for teaching science: Years 7, 8 and 9*
QCA scheme of work for Key Stage 3 science

Some extra copies of Framework page 25 for task A

### For participants

Handouts

| | |
|---|---|
| 1.4 | Transcript of audio clip 1 |
| 1.5 | Scientific enquiry in Key Stage 3 |
| 1.6 | Task A |
| 1.7 | Task A: planning grid |
| 1.9 | Classifying practical activities |
| 1.10 | Task B |

## Session outline **1 hour**

| | | |
|---|---|---|
| **Introduction**<br>Considering the unit as a whole and introducing ideas on scientific enquiry | Talk<br>Whole group | 10 minutes |
| **Using the yearly teaching objectives**<br>Comparing a range of practical activities with the Framework teaching objectives to identify effective matches | Talk, task A<br>Pairs | 20 minutes |
| **Progression in scientific enquiry**<br>Two mechanisms for considering the level of demand of practical activities to determine their best use | Talk, task B<br>Pairs, whole group | 25 minutes |
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group | 5 minutes |

 

## Introduction

**10 minutes**

Welcome participants to the day and deal with any domestic or administrative matters.

Slide 1.1

Slide 1.2

Show **slide 1.1** which outlines the seven sessions in the unit and **slide 1.2** which gives the objectives for the unit as a whole. Go through each slide to ensure that all participants are well briefed on the day ahead and how it is structured.

**Scientific enquiry** — Slide 1.1

| | |
|---|---|
| Session 1 | Introduction to scientific enquiry |
| Session 2 | Teaching scientific enquiry skills and processes explicitly |
| Session 3 | Types of scientific enquiry |
| Session 4 | Ideas and evidence in Key Stage 3 science |
| Session 5 | Some strategies for teaching about ideas and evidence |
| Session 6 | How scientists work |
| Session 7 | Conclusions and follow-up |

**Objectives for the unit** — Slide 1.2

- To clarify the nature and extent of scientific enquiry, including ideas and evidence
- To emphasise the need to teach scientific enquiry explicitly, using appropriate objectives, and drawing on the Framework yearly teaching objectives
- To clarify how specific skills and processes of scientific enquiry can be taught within the context of practical and enquiry activities
- To explain the central role of evidence and thus why teaching and learning about ideas and evidence is important
- To provide a range of strategies about how to teach pupils about ideas and evidence and about how scientists work
- To determine priorities and actions for follow-up in school

Make the following points:

- This unit builds on that for planning and managing progression where participants (heads of science or Key Stage 3 science coordinators) were asked to produce a map of progression in the teaching of scientific enquiry.
- In order to produce such a map it is essential that teachers recognise the need to teach elements of scientific enquiry deliberately and explicitly. This unit will focus on some strategies for doing that, i.e. short-term or lesson planning.
- The teaching of scientific enquiry needs to be integrated with the teaching of the other attainment targets in order to provide appropriate contexts and suitably demanding work. The inclusion of ‘an investigation’ in science topics in the Key Stage 3 scheme of work or the addition of a special investigation topic after the Key Stage 3 national tests is unlikely to fulfil this requirement.

Slide 1.3

Show **slide 1.3** and go through the objectives for this first session. Explain that it is important that all participants develop their understanding of these objectives.

**Objectives for session 1** Slide 1.3

- To clarify the nature and extent of scientific enquiry
- To clarify the need to teach explicitly the skills and processes of Sc1
- To clarify progression in teaching scientific enquiry as exemplified in the Framework yearly teaching objectives

Audio clip 1

Handout 1.4

Introduce audio clip 1 by telling participants that Lewis Wolpert is a working scientist who also writes and speaks on the nature of science. He gave a short interview to some regional directors of the science strand during which he explained his views on how scientists work. Play **audio clip 1**. A transcript of the clip is provided as **handout 1.4**. Point out that:

- Science at Key Stage 3 cannot concentrate on knowledge and understanding at the expense of developing pupils' abilities in scientific enquiry.
- Integrating scientific enquiry into the teaching of knowledge and understanding enables pupils to develop their understanding of how scientists work as well as providing interesting and relevant contexts and purposes for enquiries.

Handout 1.5

Refer participants to **handout 1.5** which indicates some of the elements within scientific enquiry in Key Stage 3. Explain that:

- It is clear from this handout that scientific enquiry cannot be taught just by pupils tackling enquiries or investigations, particularly when the outcomes of those enquiries are being used to assess pupils.
- Teachers need to consider how and when the various elements of Sc1 identified in the handout can and should be taught.

Mention that the process of mapping the elements of scientific enquiry was one outcome from the planning and managing progression unit; this process may well have been taken further already in participants' departments.

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### *Additional guidance*

*The audio clip is valuable because Lewis Wolpert is a working scientist. His views help to encourage participants to see the wider ambitions for the science strand of the Key Stage 3 Strategy.*

*Handout 1.5 was also included in the materials for the planning and managing progression unit so some participants may have seen it before. It highlights how much there is to Sc1. Point out 'Ideas and evidence' and the various boxes attached to 'Evaluating'. Ofsted evidence indicates that even at Key Stage 4 these aspects of scientific enquiry are often weakly taught and poorly understood. A more secure teaching programme during Key Stage 3 will not only develop pupils' enjoyment and understanding but will in all likelihood improve performance at GCSE.*

## Using the yearly teaching objectives **20 minutes**

Framework

Ask participants to turn to page 25 of the **Framework**, which identifies the yearly teaching objectives for scientific enquiry. Make the following points.

- The Framework provides yearly teaching objectives for scientific enquiry designed to help pupils reach the expected attainment and level of skills through the three years of Key Stage 3.
- Teachers will need to select appropriate practical activities and teach various aspects of enquiry skills in order for pupils to achieve these objectives.
- The usual range of practical activities in Key Stage 3 science can meet these objectives, but teachers will need to consciously tailor the activities to meet the aspiration and demand of these yearly objectives.

### Task A **15 minutes**

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***Additional guidance***

*The purpose of this task is to help familiarise teachers with the Framework yearly teaching objectives, to match typical Key Stage 3 practical activities with the objectives and to share ideas with another teacher.*

Handout 1.6

Handout 1.7

Ask participants to retrieve **handouts 1.6** and **1.7**. Go through the instructions for the task on handout 1.6. Tell participants to work in pairs. Explain that there are no correct answers for the activity. Each pair will decide their own preferred match between activity and objective.

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***Additional guidance***

*You can, if you prefer, run this as a 'cut and stick' task where participants simply cut out activities from handout 1.6 and stick them on to handout 1.7 in the appropriate place.*

*Encourage participants to think as flexibly as possible about the activities they choose to meet the different needs on the planning grid. Tell them to draw on their experiences of both their scheme of work and their pupils.*

*The main purpose of this activity is for participants to gain familiarity with the yearly teaching objectives. There is further work on lesson objectives derived from the Framework yearly teaching objectives in session 2.*

At the end of 15 minutes draw the activity to a close and ask participants to contribute their thoughts on the usefulness of the yearly teaching objectives.

If the following points do not emerge ensure you make them:

- The Framework yearly teaching objectives demonstrate good year-on-year progression and will simplify the task of adjusting participants' teaching programme for Sc1. They will also help in the assessment of pupils' progress.
- This does not require the generation of vast amounts of additional practical work. The QCA scheme of work contains enough practical work to meet these yearly teaching objectives.

- The yearly teaching objectives are quite broad and are unlikely to be achieved by one single activity. They are likely to be addressed several times during the year.
- A yearly teaching objective may need to be refined to a more specific objective for the purpose of any particular practical activity.
- Each suggested practical activity could be linked to several possible lesson objectives. It is important for teachers to recognise that they can only manage the teaching of one or two objectives at a time. They must therefore focus on the one or two objectives that are most suitable for their class.

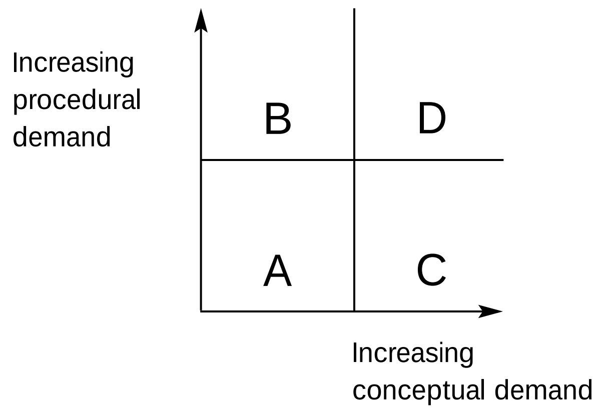
## Progression in scientific enquiry **25 minutes**

Explain that recognising the demands of any particular enquiry is a helpful step in planning for progression across the three years of Key Stage 3. The following activity is useful in helping participants to do this.

Slide 1.8

Show **slide 1.8.**

**The demand of an enquiry** — Slide 1.8




Handout 1.9

Refer to **handout 1.9** when explaining the chart on the slide. The axes refer to the challenge of carrying out the activity – called the ‘procedural demand’ – and the challenge of the underlying science knowledge and understanding – the ‘conceptual demand’. (These are also referred to on page 12 of the Framework.) The chart illustrates four sorts of enquiry:

- those in sector A are simple to do and are concerned with straightforward science;
- those in sector B are more demanding in terms of how they are carried out but the science context is still straightforward;
- those in sector C are simple to carry out but refer to some quite demanding science knowledge and understanding;
- those in sector D are demanding both in terms of how they are carried out and the science knowledge and understanding used.

Point out that, when planning for a class, teachers should:

- think about what they want pupils to learn;
- decide on what to do by selecting or modifying activities;
- manage this in the classroom.

## Task B 15 minutes

QCA SoW

Handout 1.10

For this task participants will need to use the **QCA scheme of work**. Tell them to work in pairs or small groups to consider the practical activities on **handout 1.10**, which have been selected from the QCA scheme of work. Allocate each pair or group two activities to consider. Once these are completed each pair or group can look at other examples. They should decide into which of the four sectors each activity fits.

Before taking feedback, prepare on a flipchart a large version of the chart on slide 1.8. After about 15 minutes draw the activity to a close and ask participants to place a sticky note labelled with the number of each activity in the appropriate sector on the chart. Individual decisions may provoke some discussion. At a suitable moment make the following points:

- As there are no explicit criteria for judging the extent of demand there will be variation in participants' answers. This is not important because each teacher needs to judge demand in terms of their own pupils' prior experience, knowledge, understanding and skills.
- By altering how an enquiry is approached, the level of demand can be adjusted to make it more appropriate to a class. Participants may have assumed different approaches in their answers.

At the end of the feedback, confirm if necessary that assessing procedural and conceptual demand is a tool to help teachers to reflect on and analyse the practical activities they are using. It enables them to quickly and explicitly check whether any activity provides their pupils with appropriate challenge.

### *Suggested answers and explanations for task B*

1. *Sector B*
   *In this investigation pupils prepare slides of everyday objects and observe them using a microscope. Procedurally, this will be challenging as pupils may not have used this piece of apparatus before. However, conceptually, pupils are not required to develop their scientific ideas or understanding.*
2. *Sector A*
   *In this investigation pupils measure and record details about physical features, such as eye colour, height or hand span, of classmates, on a spreadsheet and draw graphs.*
3. *Sector C*
   *Pupils carry out quick activities to demonstrate transmission of sound within a variety of mediums and then explain the results using the particle model.*

4 *Sector D*
*Weighing materials before and after change, and collecting and weighing gases produced in reactions are demanding activities. So is the understanding behind conservation of mass in reactions.*

5 *Sector C*
*Pupils carry out simple activities to determine how well different metals react, e.g. with an acid. Developing an understanding of the concept of reactivity series from these activities is demanding.*

6 *Sector A*
*Pupils use an indicator to identify solutions as either acid or alkali – procedural and conceptual demand both low.*

7 *Sector D*
*Planning this investigation requires consideration of many factors including sample size, concentration range, and data to collect. Linking this to plant growth is conceptually demanding.*

8 *Sector B*
*Procedurally, this is challenging as it requires pupils to consider how to make the test fair using equipment they may not have encountered and to measure temperature rise as an indicator of energy output. However, conceptually, pupils only need to appreciate that some fuels give out more energy (heat) than others.*

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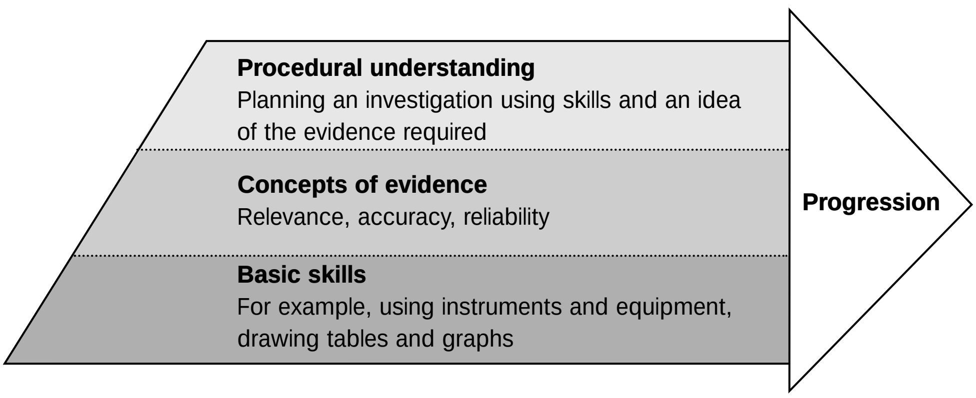
### ***Additional guidance***

*The final part of this session refers to some work developed by Richard Gott, Sandra Duggan and others at Durham University. This work can become quite complex and difficult to follow, particularly during a pacy INSET session. However, it is worth making the main points and perhaps directing any particularly interested individuals to the website for further information:*
*www.dur.ac.uk/~ded0www/evidence_main1.htm*

Slide 1.11

Explain that Richard Gott and others have analysed Sc1 to arrive at a description which also indicates progression in understanding. The description is illustrated in **slide 1.11**.

**Illustrating progression in scientific enquiry** — **Slide 1.11**




Based on ideas developed by Richard Gott, Sandra Duggan and others at Durham University, website: www.dur.ac.uk/~ded0www/evidence_main1.htm

Say that there are three elements to progression:

- The **basic skills** are those that pupils need to be taught and to master if they are to carry out any form of practical work. These skills can be simple (e.g. using a top-pan balance or a filter funnel) or quite complex (e.g. setting up a microscope or a datalogger). They also include the skills of drawing up a results table or graph. Teachers should plan to teach these skills when required over the key stage and then carry out one or more enquiries which utilise them.
- **Concepts of evidence** encompasses how pupils' understanding of what constitutes adequate evidence can be developed. In Key Stage 3 the development focuses on:
  - ensuring the *relevance* of evidence, for example by selecting appropriate variables, the scale to measure with, the range of measurements;
  - improving the *accuracy* of evidence through increasingly accurate observations or measurements;
  - improving the *reliability* of evidence through repeating observations or measurements.
- **Procedural understanding** is the level of understanding needed to plan a sound scientific enquiry, taking into account pupils' own skills and the evidence required. Once carried out, procedural understanding is needed to evaluate the enquiry through weighing the quality of the evidence and whether or not it allows an appropriate conclusion to be drawn.

Explain that this progression is not simply linear and that pupils should be taught elements of all three parts throughout the key stage. Pupils will be at different levels of procedural understanding depending on their level of basic skills and their understanding of evidence. The Framework yearly teaching objectives give useful guidance on this.

## Plenary

**5 minutes**

Slide 1.12

Use **slide 1.3** to remind participants of the objectives for this session. Then show **slide 1.12** and ask participants how far the objectives have been met.

**Plenary for session 1**

Slide 1.12

By the end of the session participants should:

- be clear about the structure of the unit;
- recognise the need to teach explicitly the skills and processes of scientific enquiry;
- be clearer on the structure and potential use of the Framework yearly teaching objectives for scientific enquiry;
- have considered some ways of determining the level of demand of an enquiry and how this might affect how enquiries are structured and introduced, and pupils supported.

Evaluation form

Invite any further questions and points participants might like to make and encourage them to complete the **evaluation form** for session 1. Tell them that now is a good time to note any points which they want to follow up in school.

# Transcript of audio clip 1

Lewis Wolpert is a distinguished embryologist, author and broadcaster. He is Professor of Biology as Applied to Medicine at University College. A CBE and a Fellow of the Royal Society, he has for many years been involved in the public debate about the nature of science. He was chairman of the Royal Society Committee for the Public Understanding of Science for four years.

The views expressed here and in the other clips in this CPD unit were recorded in 2001 specifically for the Key Stage 3 science strand. Professor Wolpert expresses his thoughts on science and scientific methods clearly and succinctly, providing us with a starting point for our own reflection.

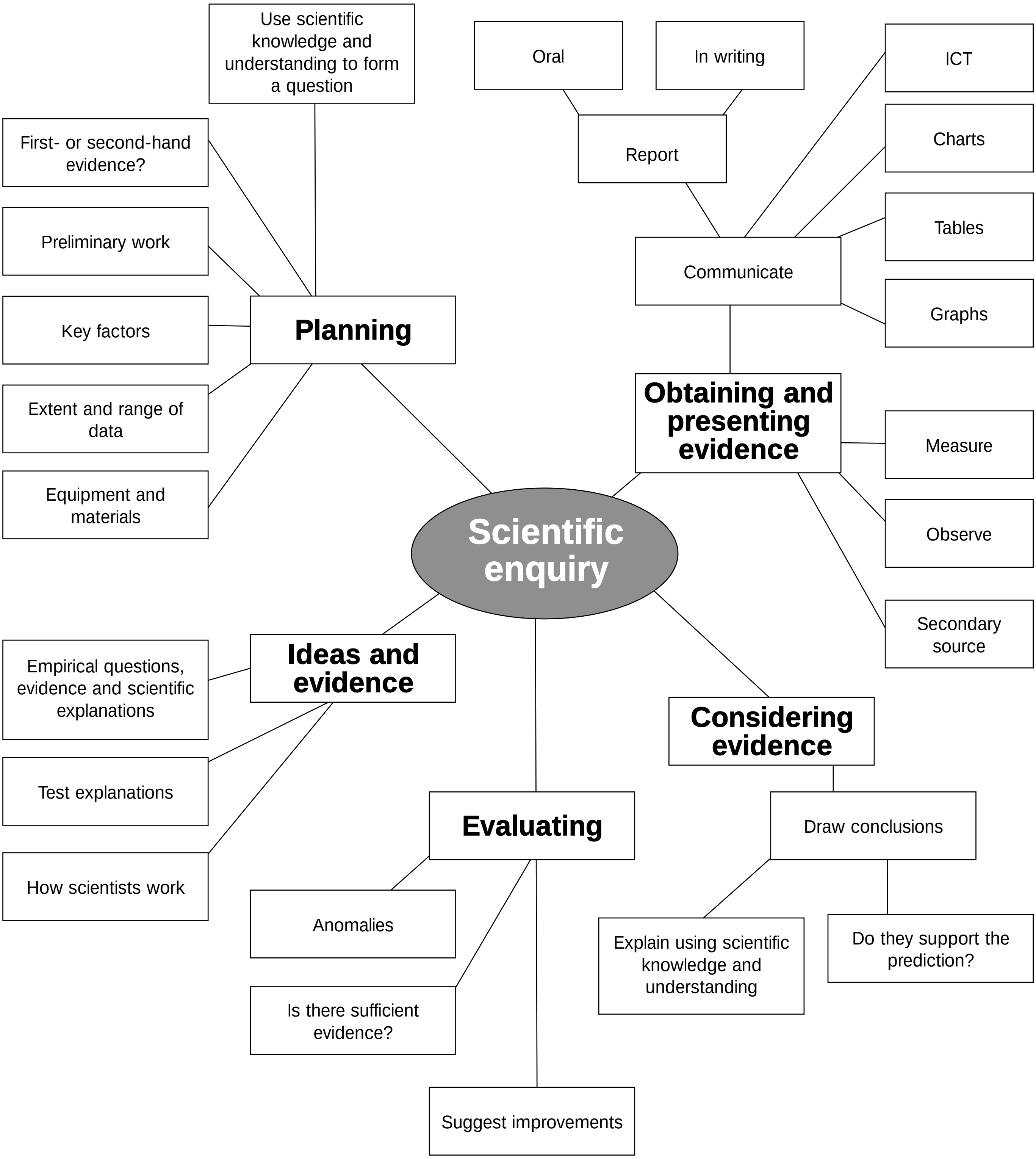
## Lewis Wolpert on the nature of science

Science requires imagination, can be creative, and it's quite misleading to think that science is just about collecting facts. Of course you need the information, you need facts, but that's not the basis of science. Science is about understanding and putting those facts into a framework so that you can understand what they are all about.

There's no simple scientific method; there are many different styles in science. Some scientists are good experimentalists, some are good theoreticians, some are a mixture of both – it's a complicated business. The key feature, though, is that you must be internally consistent – there mustn't be any contradictions in your ideas – that you must be explaining your observations (the observations must be reliable). And that is the ultimate test: you're testing your ideas against reality, and if they don't fit you've got to change your theory.

# Scientific enquiry in Key Stage 3



# Task A

Work in pairs. Match some of the activities below to the yearly teaching objectives (Framework page 25) and write them into the cells of the planning grid of handout 1.7 in the 'Activity' column. If preferred, use examples of activities from your own teaching where they match the objectives.

Explain to your colleague how the selected activity enables pupils to meet the objective.

Use the 'Notes' column on handout 1.7 to add comments such as how the activity needs to be focused or modified in order to match the objective.

| | | |
|---|---|---|
| Change of mass when magnesium burns | Sampling populations on a school field | Investigating balance around a pivot (see-saw) |
| Investigating carbonate content of different limestones | Comparing historical and current data about pollution | Determining speed by measuring distance and time |
| Measuring the energy content of foods | Investigating oxygen production rate in pond plants | Investigating the strength of an electromagnet |
| The change of solubility with temperature | Survey of variation in individuals of the same species in different habitats | Investigating the rate of $CO_2$ production by yeast |
| Investigating the effect of household anti-microbial compounds | Measuring heat loss from model houses | Use of a microscope to observe cells |
| Comparing methods of extracting salt from rock salt | Investigating the effectiveness of different antacids | Investigating the constituents of food (food tests) |

| | | |
|---|---|---|
| Measuring the current in series and parallel circuits | Testing the starch content of a leaf | Stretching a spring/rubber bands |
| Testing the reactivity of metals with acids | Optimum conditions for digestion by enzymes | Relating crystal size to rate of cooling |

# Task A: planning grid

## Year 7

| Objective | Activity | Notes |
|---|---|---|
| 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. | | |

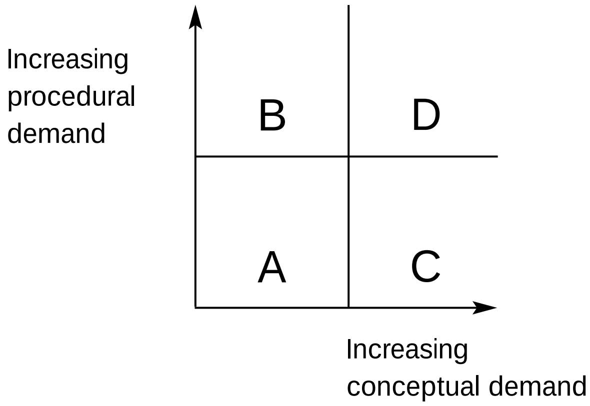
## Year 8

| Objective | Activity | Notes |
|---|---|---|
| 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. | | |

## Year 9

| Objective | Activity | Notes |
|---|---|---|
| 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 | | |

# Classifying practical activities




### Sector A (bottom left): low procedural and low conceptual demand

These activities are simple for pupils to carry out and do not require a high level of scientific knowledge. They should be used to develop basic investigative skills, or to introduce scientific ideas. They are of little use in developing high levels of understanding, either conceptual or procedural. An example is dissolving a solute and evaporating the solution to dryness.

### Sector B (upper left): higher procedural demand and low conceptual demand

Activities in this area do not involve difficult science concepts. They can be used to develop procedural skills and understanding. Examples include using ICT to sample local habitats, or an investigation to find out whether the distance travelled by a model car depends on (1) its weight, and (2) the force used to get it moving.

### Sector C (bottom right): lower procedural demand and higher conceptual demand

Activities in this area do not involve difficult enquiry or investigative skills. They can be used to develop conceptual understanding of difficult concept areas in science. Examples are investigating whether all limestones are different, as part of the rock cycle, and investigating whether the rate at which fermentation takes place depends on the temperature of the solution.

### Sector D (upper right): higher procedural demand and higher conceptual demand

These activities are very challenging and involve pupils applying high-level procedural skills in demanding conceptual areas or contexts. An example is investigating the requirements of photosynthesis for suitable temperature, light and carbon dioxide levels.

# Task B

Work in pairs or small groups.

For the two activities which you have been allocated:

- read through the relevant section of the QCA scheme of work to identify the context and purpose of the activity;
- decide where on the chart on handout 1.9 you think the activity fits.

Make brief notes on the back of this handout to justify your decision and to prepare for feedback.

**1** QCA Unit 7A 'Cells'
Page 1 'How can using a microscope give us information about structure?'
3rd activity beginning: 'Help pupils make slides of common objects …'

**2** QCA Unit 7D 'Variation and classification'
Page 1 'How do individuals of the same species differ from each other?'
2nd activity beginning: 'Collect the data …'

**3** QCA Unit 8L 'Sound and hearing'
Page 3 'How does sound travel through solids, liquids and gases?'
2nd activity beginning: 'Ask pupils whether sound travels through solids …'

**4** QCA Unit 9H 'Using chemistry'
Pages 3–4 'What happens to atoms and molecules when new materials are made?'
1st activity on page 4 beginning: 'Remind pupils of work they did earlier about making compounds from elements…'

**5** QCA Unit 9F 'Patterns of reactivity'
Page 2 'Is the order of reactivity of metals with water the same as that with acid?'
1st activity beginning: 'Remind pupils of work they did in unit 9E …'

**6** QCA Unit 7E 'Acids and alkalis'
Page 2 'How can acids and alkalis be identified and distinguished from each other?'
4th activity beginning: 'Provide pupils with a range of acidic and alkaline solutions …'

**7** QCA Unit 9D 'Plants for food'
Page 2 'How do fertilisers affect plant growth?'
3rd activity beginning: 'Extend this work by asking pupils to plan and carry out an investigation …'

**8** QCA Unit 7I 'Energy resources'
Page 1 'Why are fuels useful?'
4th activity beginning: 'Ask for examples of uses of different fuels. Discuss with pupils how to carry out a fair test …'

Session
2

# Teaching scientific enquiry skills and processes explicitly

## Objectives

- To clarify how lesson objectives appropriate for scientific enquiry can be drawn from the yearly teaching objectives
- To clarify how specific skills and processes of scientific enquiry can be taught within the context of practical activities

## Resources

### For tutor

Slides 2.1, 2.6–2.8, 2.12

A0 copies of the three scientific enquiry posters for demonstration
A3 copies of the posters for task D

Sticky notes of two different colours

At least one copy of each of the AKSIS materials (see page 8), particularly *Investigations: developing understanding* by Anne Goldsworthy, Rod Watson and Valerie Wood-Robinson (ASE, 2000)

Some copies of the *Framework for teaching science: Years 7, 8 and 9*

### For participants

Handouts

| | |
|---|---|
| 2.2 | Task C: instructions |
| 2.3 | Task C: response sheets |
| 2.4 | Scientific enquiry posters |
| 2.5 | Using the scientific enquiry posters |
| 2.9 | Pupils' understanding of repeat readings |
| 2.10 | Task E |
| 2.11 | Answers to task E |

Five sets of A0 versions of the three posters to take away for use in school
A few calculators for task E

## Session outline — 1 hour 5 minutes

| | | |
|---|---|---|
| **Identifying lesson objectives**<br>Emphasising that clarity of appropriate objectives guides teachers' lesson planning | Talk, task C<br>Whole group, pairs | 15 minutes |
| **Activities for explicitly teaching scientific enquiry**<br>Two examples for teaching specific aspects of scientific enquiry | Talk, tasks D and E<br>Whole group, pairs | 45 minutes |

| | | |
|---|---|---|
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group | 5 minutes |

## Identifying lesson objectives **15 minutes**

Slide 2.1

Introduce this session by showing **slide 2.1** and going through the objectives.

**Objectives for session 2** Slide 2.1

- To clarify how lesson objectives appropriate for scientific enquiry can be drawn from the yearly teaching objectives
- To clarify how specific skills and processes of scientific enquiry can be taught within the context of practical activities

Make the following points:

- This session builds on task A from the previous session.
- Objectives for scientific enquiry are often not explicit in schemes of work or lesson plans. They are implied or taken for granted.
- If teachers are to manage the learning of their pupils effectively, lessons should not have more than one or two objectives.
- Lesson objectives framed in terms of science knowledge and understanding are often accorded a higher priority than any implied or explicit objectives for scientific enquiry.
- In order to enhance the teaching of scientific enquiry, it is essential that teachers identify specific objectives for Sc1 and accord them appropriate priority.

T

***Additional guidance***

*In Key Stage 3 teachers often assume pupils will learn how to do practical work through doing it. Although this is partially true, pupils' learning is faster and more secure when the teacher makes plain what has to be learned. In GCSE coursework (Key Stage 4), teachers often focus explicitly on the assessment criteria. These are shared with pupils and work is marked in such a way as to highlight specific weaknesses. There is generally no equivalent approach in Key Stage 3 and the use of Key Stage 4 assessment criteria during Key Stage 3 is debatable. The purpose of this part of the session is to point out that individual lessons and clusters of lessons should have one or more objectives for scientific enquiry rather than objectives for knowledge and understanding.*

### Task C

about 12 minutes

Handout 2.2

Handout 2.3

This brief activity allows participants to quickly identify the sort of objective they could use in their lessons or clusters of lessons. The instructions are on **handout 2.2**, including an example of how a yearly teaching objective can be refined into more specific lesson objectives. Participants should note their own responses on **handout 2.3**.

While the participants are working, provide support as necessary. After 10 minutes take feedback from the pairs in terms of the ease of the task and whether it helped participants to identify effective lesson objectives. Record any important points on a flipchart.

T

***Additional guidance***

*It is important that by the end of task C participants recognise the need to identify objectives specific to manageable elements of scientific enquiry. This is a process of refining the 'big picture' yearly teaching objectives into smaller lesson objectives.*

## Activities for explicitly teaching scientific enquiry

**45 minutes**

This session uses two examples to illustrate how to teach the skills and processes of scientific enquiry explicitly. The first example uses posters to help pupils plan and follow fair-test investigations. These posters proved extremely useful during the pilot. All participants will be given sets of large posters to take back to school.

### Planning a fair test

15 minutes

T

***Additional guidance***

*The activity in this section involves a set of posters developed for whole-class use. It is essential to familiarise yourself with the resources and the planning process involved by reading through and practising the activity before using it with teachers.*

*You model the use of the posters and then participants have a go themselves. The particular task is to support pupils in planning a fair test. However, emphasise that this is only one use for the posters: they can be used to teach other aspects of scientific enquiry such as how to record data, produce graphs and draw conclusions.*

*The posters are based on materials produced by Anne Goldsworthy and Rosemary Feasey in the ASE publication* Making sense of primary science investigations *(revised edition 1997), and developed for Key Stage 3 in the AKSIS publication* Investigations: developing understanding *by Anne Goldsworthy, Rod Watson and Valerie Wood-Robinson (ASE, 2000). Explain that this unit draws significantly on the AKSIS materials and participants might find benefit from consulting them for other ideas on teaching scientific enquiry. [AKSIS = ASE and King's College Science Investigations in Schools project]*

Explain that you will demonstrate a teaching and learning approach developed for use with a whole class; it focuses on how to teach pupils to plan a fair test.

Planning poster

The process, based on the **planning poster**, involves a number of stages explained in more detail below. The stages are:

- identifying the general question to be investigated;
- identifying the variables involved;
- identifying what could be measured;
- refining the question to one which can be investigated;
- identifying the independent and dependent variables;
- identifying the factors to be controlled.

The activity involves planning an investigation into the effectiveness of indigestion remedies (linked to unit 7E, 'Acids and alkalis', in the QCA scheme of work). This can be introduced through the general question: *'What's the best way to cure indigestion?'*; this is written on a sticky note and stuck to the poster in the 'We are investigating' box. Point out that the question can be refined to make it more precise once the variables and possible measurements have been considered.

Explain that a general question, in which the definition of the word 'best' is left open, is used so that pupils can be involved in making decisions about the factors to be investigated. If necessary, point out that asking *'Which indigestion remedy is the quickest?'* identifies for pupils the two variables, type of remedy and time to neutralise!

Ask the participants to identify what factors could be changed to find 'the best way to cure indigestion'. Write each factor on a sticky note and add to the planning poster (there may be more than six factors; this is OK, just squeeze them on).

Factors might include:

- type of remedy;
- quantity of remedy;
- type of acid;
- quantity of acid;
- whether the remedy is ground up or in a tablet;
- temperature;
- how long you leave it;
- whether you stir it.

The next stage is to identify what to measure or observe. Point out that if pupils are asked *'What can we measure?'* they will simply repeat some of the factors identified above. Instead, you want to *elicit* the dependent variable. What is said to pupils at this stage is important.

Ask: *'If we change one of these* (the factors already identified), *what can we measure or observe to see if it has made a difference?'*

Here the participants should identify factors such as:

- the time to neutralise;
- the one which becomes the most alkaline (highest pH);
- whether litmus goes blue.

These should be written on sticky notes *of a different colour* and stuck on the appropriate place on the planning poster.

At this point, refine the question to make the fair test manageable. Refining the question coincides with choosing a factor to investigate. For example, if you choose to change the quantity of remedy and measure how long it takes to neutralise some acid, the question is refined to something like *'Does changing the amount of remedy affect how quickly it works?'* or *'Does increasing the amount of remedy mean it works faster?'* For some classes the question could be further refined to make it more demanding, for example *'Will doubling the amount of remedy mean it works twice as quickly?'*

Write the refined question on a sticky note and place it in the 'Our question is' box. Place the sticky notes for the independent and dependent variables in the appropriate places on the planning poster.

Make the point that the selection of the independent and dependent variables is important in providing pupils with the best opportunities for making predictions, and also for enabling them to take appropriate measurements and to draw and interpret graphs. If the prediction, measurement, graphing or interpretation skills are the emphasis in terms of specific objectives, the teacher may wish to direct the pupils to investigating particular variables out of the possible ones they have identified.

To establish how factors can be controlled to make the test 'fair' ask the participants: *'What do we need to keep the same to make it a fair test?'* Participants are likely to say that all the other factors in the 'We could change' box must be kept the same.

Move all those sticky notes to the appropriate place on the planning poster. Explain that pupils may identify each of the factors in turn, and it is important they recognise that all factors but the one under investigation must be controlled to make the test fair. This is why two different colours of sticky notes are used.

The sticky notes can be easily replaced in their original positions, and teachers can demonstrate the fair test stage again by deciding on a different factor to test, such as the type of remedy. This helps more of the pupils to realise that one factor only is changed, and the rest kept constant.

Before you move on to task D, make the following points:

- The scientific enquiry posters, and other similar writing frames, are teaching aids which help pupils engage with the skills of scientific enquiry.
- Teachers should use their professional judgement to decide when pupils should use this type of resource with support, and when independently.
- Teachers should also judge when pupils should be able to plan, carry out and record scientific enquiry work without the need of these resources.

T

### *Additional guidance*

*After the planning activity teachers may want pupils to record their investigation plans, for example, by using a writing frame. Explain that if the lesson objective is planning the investigation, then pupils need only to record their plans. Encourage teachers to use their professional judgement in deciding when to use a writing frame and when to tell pupils to write up their practical work independently.*

### Task D 10 minutes

Handout 2.4

Handout 2.5

Give out the A3 copies of the posters for use during task D. Explain that A4 versions of them are included in the participant's pack as **handout 2.4** and that participants will be given A0 copies of the posters for use in school. **Handout 2.5** contains guidance both for task D and for teachers in school. Ensure there is a good supply of two colours of sticky notes.

Slide 2.6

Ask participants to work in pairs to complete the planning process for one of the activities on **slide 2.6**; they should also work through the other two posters in order to trace how the whole investigative process can work.

> **Task D** — Slide 2.6
>
> Work in pairs on one of the following investigations, or another of your choice:
>
> - 'What affects photosynthesis?' (linked to QCA unit 9C 'Plants and photosynthesis')
> - 'What affects solubility?' (linked to QCA unit 7H 'Solutions')
> - 'What affects rusting or corrosion?' (linked to QCA unit 9F 'Patterns of reactivity')
> - 'How can friction be reduced?' (linked to QCA unit 9K, 'Speeding up')
>
> First complete the planning poster, then work through the other two posters.

While participants are working go around to check their understanding. There may be no need to draw the activity to a close other than by checking that all participants have completed at least one planning activity

### Task E 20 minutes

T

***Additional guidance***

*This activity is adapted from AKSIS materials and shows how pupils can be taught the value of repeating readings. The activity 'At what temperature do enzymes work best?' is adapted from* Investigations: developing understanding*. It is set in the Key Stage 3 context of studying digestion. Although it could be used with pupils, participants on this unit will find it useful, and it should take about 10 minutes. For your information the answers are given on handout 2.13.*

Slide 2.7

Show **slide 2.7** which quotes the appropriate part of the Key Stage 3 programme of study and the similar section from Key Stage 2.

> **Extracts from the programmes of study** — Slide 2.7
>
> **Key Stage 3**
> Pupils should be taught to:
>
> - make sufficient relevant observations and measurements to reduce error and obtain reliable evidence (Sc1/2h)
>
> **Key Stage 2**
> Pupils should be taught to:
>
> - to check observations and measurements by repeating them where appropriate (Sc1/2g)

Slide 2.8

Explain that **slide 2.8** gives some possible objectives derived from this part of the Key Stage 3 programme of study.

| **Possible objectives** | Slide 2.8 |
|---|---|
| • To know how to take repeat readings and calculate the average (mean)<br>• To understand the purpose of taking repeat readings | |

Explain that:

- Pupils will have been encouraged to repeat readings at Key Stage 2 to check their data.
- In Key Stage 3 it is important that they appreciate the purpose of repeat readings, what they show and how they can be used. Handout 2.10 gives further information on this.

Handout 2.9

Handout 2.10

Handout 2.11

Ask participants to read through **handout 2.9**, which gives some background information, and **handout 2.10**, which gives some experimental data and related questions. Tell them to work in pairs or small groups to answer the questions. They may find calculators helpful. Allow them 10 minutes to complete the activity and then discuss the outcomes. **Handout 2.11** contains the answers.

T

***Additional guidance***

*Do not worry if participants want to point out flaws in the data. Make the point that if pupils did this it would demonstrate emerging understanding of reliability and repeat readings.*

Finally take a few minutes to take feedback on participants' views on the activity, whether they would consider using it with their own pupils, and whether their pupils would be helped by an activity of this sort.

## Plenary **5 minutes**

Slide 2.12

Show **slide 2.1** to remind participants of the objectives for the session. Then show **slide 2.12** and ask participants how far the objectives have been met.

| **Plenary for session 2** | Slide 2.12 |
|---|---|
| By the end of the session participants should:<br>• be clearer about what constitutes an appropriate lesson objective for scientific enquiry;<br>• be clearer on the value of using the yearly teaching objectives for scientific enquiry;<br>• have considered some ideas on how to teach scientific enquiry skills and processes explicitly. | |

Invite any further questions and points from participants and encourage them to complete the evaluation form for session 2. Tell them that now is a good time to note any points which they want to follow-up in school.

# Task C: instructions

Work in pairs.

Turn to appendix 2 of the Framework (page 71). Using the section on ‘Obtaining and presenting evidence’, choose any of the Year 7 objectives. Following the example below, refine the chosen objective into more specific objectives suitable for one or two lessons. Relate these to practical activities you would use, or have used.

Make brief notes on handout 2.3.

If you have time, repeat the process for a Year 8 and a Year 9 objective.

Be prepared to give feedback on your work.

## Example: Year 7 teaching objective

Describe and explain what their results show when drawing conclusions; begin to relate conclusions to scientific knowledge and understanding

| Lesson objective | Activity | Written outcome |
|---|---|---|
| Describe results clearly. | In the context of looking at cells under the microscope (e.g. QCA unit 7A), pupils should be taught to produce appropriately sized and detailed drawings of one or two cells, and be able to explain why the drawings are effective. | Cell drawings |
| Describe and explain results. | In the context of an investigation into antacids (e.g. QCA unit 7E), pupils are taught (if necessary) to record results clearly in a suitable chart and to explain conclusions by referring to both the results and the variables which are controlled. | Results chart and conclusion |
| Relate conclusion to scientific knowledge and understanding. | This is covered in a number of practical activities but is a specific focus in an investigation into floating (e.g. QCA unit 7K). Pupils are taught the importance of explaining the science underpinning their conclusions, in this case the forces and the density of the liquid. | A well-explained conclusion |

# Task C: response sheets



## Year 7 teaching objective

| Lesson objective | Activity | Written outcome |
|---|---|---|
| | | |
| | | |
| | | |

# Year 8 teaching objective

| Lesson objective | Activity | Written outcome |
| --- | --- | --- |
| | | |
| | | |
| | | |

# Year 9 teaching objective

| Lesson objective | Activity | Written outcome |
|---|---|---|
| | | |
| | | |
| | | |

# Planning

We are investigating …

We could change …

We could measure/observe …

We will change …
(independent)

We will measure/observe …
(dependent)

Our question is …

We will keep these the same …

Prediction (if appropriate)

When we change | | we think what will happen to | | is …

This is because …

## Obtaining evidence

Change …
(independent)

Measure
(dependent)

| | | | | Average |
|---|---|---|---|---|
| | | | | |

## Presenting the results

Title

Measure
(dependent)

Change …
(independent)

# Considering evidence and evaluating

When we changed | what happened to | is …

Why did this happen? (Explain the pattern scientifically if you can.)

Was the prediction correct?

Were there any unusual readings?

Why do you think these happened?

In what ways could we have improved what we did?

What could we do next?

# Using the scientific enquiry posters

Introduce the activity, which involves planning an investigation to answer a broad question. Discuss issues which might need raising with pupils, such as practical constraints on equipment etc.

Introduce pupils to the planning poster for a fair test/comparison. On a sticky note, write the broad question for the investigation.

Now ask pupils to identify what factors could be changed to find the answer to the question. Write each factor on a sticky note and add to the poster (there may be more than six factors; this is OK, just squeeze them on).

You want to *elicit* the dependent variable. Say to pupils *'If we change one of these* (the factors already identified), *what can we measure or observe to see if it has made a difference?'* Here the pupils should identify the dependent factors. These should be written on sticky notes of a different colour and stuck in the appropriate place on the planning poster.

Choose a factor to investigate, and what you will measure/observe, and put these sticky notes in the appropriate places on the planning poster.

At the same time refine the question so that it is more focused on the planned investigation. Write this question on a sticky note and put it in the 'Our question is' box.

Ask pupils *'What do we need to keep the same to make it a fair test or comparison?'* They are likely to identify each of the factors in the 'We could change' boxes of the poster in turn. Move the appropriate sticky notes down into the 'We will keep these the same' boxes of the poster as the pupils list them.

The sticky notes can be easily replaced in their original positions, and you can demonstrate the fair test/comparison stage again, by deciding on a different factor to test. This helps more of the pupils to realise that one factor only is changed, and the rest kept constant.

The sticky notes for the dependent and independent variables can be moved from the planning poster to that for obtaining evidence and presenting the results. In the first part they provide clear guidance to pupils on how to organise their results table and in the second on how to structure a graph of the results.

Finally the sticky notes can be moved to the poster for considering evidence and evaluating in order to guide pupils towards a sentence to express their conclusion. The remaining prompts on this poster help pupils to reflect on their investigation to explain their findings and consider whether these were the ones expected, and to think of improvements and extensions.

# Pupils' understanding of repeat readings

Research shows that some pupils think that:

- repeat readings are done to check that they have the 'right value', e.g. that a reading of 10.1 might be 'right' whereas 10.2 would be 'wrong' – they find it hard to understand that both readings are an indication of the value;
- the 'best result' should count – they believe that their biggest or most extreme value should be the one that is used.

Teachers need to ensure that pupils understand and appreciate that:

- repeat readings are not to get the 'right value' but to get closer to the true value;
- repeat readings taken under the same conditions will almost certainly be slightly different;
- the reason for different readings is because small differences will always occur in the way we use and read measuring instruments;
- repeat readings give information about the reliability of results;
- if repeat readings are very closely clustered there is little point in taking more of them;
- repeat readings that are less closely clustered are less reliable and more readings might help them get closer to the true value.

Pupils need to know that when we repeat readings, even when we try to do it under the same conditions, we will almost certainly get slightly different values. Despite our best endeavours, small differences will occur in the way we carry out the investigation and in the way we use and read our measuring instruments. Taking an average is a way of reducing error.

In some investigations, the differences between repeat readings will be quite large, in others fairly small. If the repeat readings are likely to be the same or very closely clustered, for example when measuring the stretch of an elastic band or the current in an electric circuit, the results will be reliable. There will be little point in taking several repeat readings. However, in investigations such as measuring respiration rates in different organisms or the factors that might affect the pH of rainwater, the repeat readings are likely to be less closely clustered and therefore less reliable. In these cases, repeating the readings will be of much greater importance.

While taking repeat readings is a good 'scientific habit' to foster, it takes time. Try to help pupils balance the need for repeat readings in seeking better quality evidence against the time available to carry out the investigation.

# Task E

Groups of pupils were investigating at which temperature amylase digests starch quickest. One group tried their test four times because they weren't sure how good their results were. Their results are in the tables below.

The first table is complete and shows their results after one go.

| **Temperature in °C** | **Time in seconds** |
|---|---|
| | 1st try |
| 5 | 562 |
| 20 | 395 |
| 35 | 270 |
| 50 | 260 |

| **Temperature in °C** | **Time in seconds** | | |
|---|---|---|---|
| | 1st try | 2nd try | Mean |
| 5 | 562 | 578 | |
| 20 | 395 | 245 | |
| 35 | 270 | 372 | |
| 50 | 260 | 388 | |

| **Temperature in °C** | **Time in seconds** | | | |
|---|---|---|---|---|
| | 1st try | 2nd try | 3rd try | Mean |
| 5 | 562 | 578 | 522 | |
| 20 | 395 | 245 | 530 | |
| 35 | 270 | 372 | 210 | |
| 50 | 260 | 388 | 801 | |

| **Temperature in °C** | **Time in seconds** | | | | |
|---|---|---|---|---|---|
| | 1st try | 2nd try | 3rd try | 4th try | Mean |
| 5 | 562 | 578 | 522 | 330 | |
| 20 | 395 | 245 | 530 | 378 | |
| 35 | 270 | 372 | 210 | 128 | |
| 50 | 260 | 388 | 801 | 711 | |

## Questions

1 Work out the means for each temperature in the other three tables.

2 At which temperature does the enzyme work fastest:

(a) after one reading?

(b) after two readings?

(c) after three readings?

(d) after four readings?

Tick the set of results that you think gives the best evidence. Explain your choice.

3 Why did the group keep going until the fourth set of readings?

4 Another group got this set of results.

| **Temperature in °C** | **Time in seconds** | | | |
|---|---|---|---|---|
| | 1st try | 2nd try | 3rd try | Mean |
| 5 | 402 | 425 | 439 | 422 |
| 20 | 346 | 369 | 383 | 366 |
| 35 | 194 | 217 | 231 | 214 |
| 50 | 620 | 643 | 657 | 640 |

Why did this second group think they didn't need a fourth set of readings?

5 Which of these ideas would give the class more reliable evidence? Tick the right ones.

❑ Use more accurate thermometers.

❑ Add all the class groups' results together to get better averages.

❑ Do ten tries at each temperature to get a more accurate average.

❑ Repeat the experiment at temperatures below 5 °C.

❑ Repeat the experiment at temperatures above 50 °C.

❑ Repeat the experiment at other temperatures between 20 °C and 50 °C.

❑ Ignore any results that are obviously anomalies.

❑ Compare the patterns in the results for each group in the class.

Explain your reasons.

# Answers to task E

1

| **Temperature in °C** | **Time in seconds** | | |
|---|---|---|---|
| | 1st try | 2nd try | Mean |
| 5 | 562 | 578 | 570 |
| 20 | 395 | 245 | 320 |
| 35 | 270 | 372 | 321 |
| 50 | 260 | 388 | 324 |

| **Temperature in °C** | **Time in seconds** | | | |
|---|---|---|---|---|
| | 1st try | 2nd try | 3rd try | Mean |
| 5 | 562 | 578 | 522 | 554 |
| 20 | 395 | 245 | 530 | 390 |
| 35 | 270 | 372 | 210 | 284 |
| 50 | 260 | 388 | 801 | 483 |

| **Temperature in °C** | **Time in seconds** | | | | |
|---|---|---|---|---|---|
| | 1st try | 2nd try | 3rd try | 4th try | Mean |
| 5 | 562 | 578 | 522 | 330 | 498 |
| 20 | 395 | 245 | 530 | 378 | 387 |
| 35 | 270 | 372 | 210 | 128 | 245 |
| 50 | 260 | 388 | 801 | 711 | 540 |

2 (a) after one reading 50 °C (260 s)
(b) after two readings 20 °C (320 s)
(c) after three readings 35 °C (284 s)
(d) after four readings 35 °C (245 s)

3 Only at the fourth set was there consistency of result (not measurement) with the previous result.

4 The second group achieved consistency in their results.

5 Repeat the experiment at other temperatures between 20 °C and 50 °C.
Ignore any results that are obviously anomalies (flukes).
Compare the patterns in the results for each group in the class.

Session 3

# Types of scientific enquiry

## Objective

- To clarify what type of enquiry activities and investigations are required in Key Stage 3

## Resources

### For tutor

Slides 3.1–3.3, 3.6, 3.8

Flipchart version of handout 3.7

### For participants

Handouts

| | |
|---|---|
| 3.4 | Task F |
| 3.5 | Cards for task F |
| 3.7 | Task G |

For each pair of participants, a set of cards for task F.

## Session outline **40 minutes**

| | | |
|---|---|---|
| **Introduction**<br>Identifying the requirements of the programme of study | Talk<br>Whole group | 2 minutes |
| **Identifying types of enquiry**<br>Describing types of scientific enquiry | Talk, task F<br>Pairs | 15 minutes |
| **Using and developing different types of enquiry**<br>Considering existing practice and identifying opportunities to extend the range | Talk, task G<br>Individual, pairs | 18 minutes |
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group | 5 minutes |

## Introduction

**2 minutes**

T

***Additional guidance***

*Throughout the programme of study for science in Key Stage 3 teachers are required to teach a range of aspects of scientific enquiry. The breadth of study section specifically describes a 'range of scientific investigations including whole investigations'. In this session these are identified in more detail, drawing on an analysis of the QCA scheme of work. There is a similar analysis in the AKSIS materials which you may find useful.*

Slide 3.1

Show **slide 3.1** which has both the objective for the session and a quotation from the 'Breadth of study' section of the Key Stage 3 programme of study for science.

**Objective for session 3**

**Slide 3.1**

- To clarify what type of enquiry activities and investigations are required in Key Stage 3

Breadth of study

*During the key stage, pupils should be taught the knowledge, skills and understanding through:*

- *using first-hand and secondary data to carry out a range of scientific investigations, including complete investigations (1e)*

Make the following points:

- One of the key findings from the AKSIS study (*Education in Science*, no. 185, Nov. 1999, pp. 16–17), which examined investigative work at Key Stages 2 and 3, was that most investigations carried out were of the 'fair test' type.
- This is also often true of investigations undertaken for GCSE coursework.
- Teachers and pupils often tried to make investigations into fair tests, where the investigations didn't necessarily fit the criteria for a fair test.

T

***Additional guidance***

*If necessary, illustrate this by the example used by the AKSIS team: 'Do the people with the longest legs jump the highest?' In this enough data can only be collected by testing a lot of people, so it's not a fair test but a pattern-seeking investigation. It is impossible to actually conduct a fair test on this question because the only variable you can change is leg length. It is, however, a good example to use when teaching about collecting reliable evidence when variables cannot be controlled, and when considering the importance of sample size.*

## Identifying types of enquiry

**15 minutes**

Slide 3.2

Show **slide 3.2**.

> **Types of scientific enquiry** — Slide 3.2
>
> - Surveys and correlations (pattern seeking)
> - Using secondary sources
> - Controlling variables (fair test)
> - Identification and classification
> - Using and evaluating a technique
> - Using experimental models and analogies to explore an explanation, hypothesis or theory

Make the following points:

- This classification of types of enquiry is drawn from an analysis of the enquiry activities in the QCA scheme of work.
- Some of the activities in the QCA scheme are whole investigations and others are not.
- Some enquiry activities do not fit neatly into a single category; there is overlap between them.

In Key Stage 3, using experimental models and analogies to explore an explanation, hypothesis or theory is the least frequently used type of enquiry. Some examples in Key Stage 3 include:

- using a model to investigate why elephants throw water over themselves;
- using visking tubing to investigate absorption of food following digestion.

Because this type of enquiry is much less common, we will focus only on the first five types for the remainder of this session.

### Task F

**10 minutes**

Slide 3.3

Cards for task F

Handout 3.4

In this task participants are given a set of questions on cards which they allocate to one or other (or more) of the first five types of investigation outlined on slide 3.2. Distribute the **cards for task F**. The instructions are on **slide 3.3**. Participants should use **handout 3.4** in their sorting.

> **Task F** — Slide 3.3
>
> Work in pairs.
>
> Retrieve handout 3.4 and a set of cards, each of which has a single question.
>
> Allocate the cards to the most appropriate category of enquiry on handout 3.4.
>
> Any which are difficult to allocate, place in the box labelled ‘Other’.
>
> Be prepared to offer feedback.

Explain that some of the questions cannot be answered scientifically. Allow about 5 minutes for the task. While participants are carrying out the task, circulate among the groups asking about decisions made and emphasising that there is often more than one way of tackling a particular question.

Take brief feedback from the groups, focusing on cases where there was more than one possible category or differences of opinion in allocating questions. Ask participants into which categories most questions fell.

If they do not emerge, make the following points:

- The questions that cannot be answered scientifically were included to emphasise that these often require opinions rather than simply evidence. This is an important point to make with pupils. Although scientists try hard to look for evidence, it is not uncommon for evidence to be interpreted differently by different scientists and other interested people. Say that you will revisit this later in the unit.
- There is often more than one way of finding the answer to a question and pupils may sometimes take a quite different approach from that expected by the teacher. The Key Stage 3 programme of study requires pupils to 'decide on an appropriate approach' (Sc1/2a).

Handout 3.5

Tell the participants that the first part of **handout 3.5** contains the questions used in this activity, which were based on Sc3. Similar questions based on Sc2 and Sc4 can be used with colleagues in their departments if participants wish.

T

***Additional guidance***

*It is helpful to have a clear idea of possible categories for the questions and to have identified a number of questions which could fall into one or more category. However, the emphasis of the activity should be on the different types of scientific questions that can be asked and the variety of ways in which these can be answered. Some questions (e.g. 'Which is the most dangerous acid?') probably fall into one category ('Other', because the answer is an opinion) whereas others (e.g. 'Can a solid be acidic?') could be investigated practically or through use of reference sources.*

## Using and developing different types of enquiry — 18 minutes

Slide 3.6

Show **slide 3.6**. Ask participants to think about their school's scheme of work for Key Stage 3 and their own teaching, and to jot down answers to the questions on the slide (allow about 5 minutes maximum).

**Using different types of enquiry** — Slide 3.6

- Are pupils given opportunities, throughout the key stage, to be taught and to carry out all these types of investigation?
- Are there particular types of investigation I need to use more in my teaching?
- Are pupils given opportunities to think about different types of scientific question and how they could be investigated?

Take feedback of how participants responded to each question. Make the following points:

- Some topics lend themselves to certain types of enquiry better than others. For example, Sc2 offers all sorts of opportunity for surveys and Sc3 for evaluating a technique. Pupils should experience a good range during the key stage.
- Pupils can be taught to identify types of investigation, but for this to be successful pupils need to be secure in their knowledge and understanding of a topic so that they can consider whether any particular approach would be useful and interesting.
- Pupils should be given opportunities to decide their own questions and the approach to answering them. This contributes to the requirement that pupils should be taught to 'use scientific knowledge and understanding to turn ideas into a form that can be investigated, and to *decide on an appropriate approach*' (Sc1/2a).

## Task G

**10 minutes**

Handout 3.7

Slide 3.8

Ask participants to retrieve **handout 3.7** which includes a list of topics taught in Key Stage 3. The instructions for the task are on **slide 3.8**.

**Task G** **Slide 3.8**

Work in pairs.

Handout 3.7 lists some topics taught during Key Stage 3.

Beginning with topics which come most easily to mind, identify a question which could lead to an enquiry of a sort other than a fair test.

Record the question and the type of enquiry.

Complete as many as you can in 7 or 8 minutes.

Allow about 7 or 8 minutes for the activity and then take feedback, by asking for examples of questions for each topic. Record these on a flipchart version of handout 3.7.

The following points should be made if they do not emerge:

- Some teachers may be concerned that they will need to spend a lot of time creating new learning activities, and to throw away activities which they already do and which enable pupils to work well. This is not the case. Many existing activities can be transformed into different types of investigation.
- Many activities commonly used in science can be modified by using current resources differently, by changing the context in which the activity is presented to pupils, or by reframing the question. This promotes a different type of response from pupils.
- When planning an activity, teachers need to identify the investigative skills to be developed.

T

***Additional guidance***

*It may be useful to offer to have the outcomes of task G typed and circulated to the participants. This will enable some sharing of ideas and be a useful prompt for participants a few weeks after the training.*

## Plenary

**5 minutes**

Slide 3.1

Use **slide 3.1** to remind participants of the single objective for this session. Ask how far this objective has been met.

Invite any further questions and points participants might like to make and encourage them to complete the evaluation form for session 3. Tell them that now is a good time to note any points which they want to follow up in school.

*This is likely to be the point to take lunch. Don't forget to tell the participants the start time for the next session.*

# Task F

Work in pairs.

Allocate the task cards to the most appropriate category of enquiry below. Any which are difficult to allocate should be placed in the box labelled ‘Other’.

Be prepared to offer feedback.

| | |
|---|---|
| **A Surveys and correlations** | **B Using secondary sources** |
| **C Controlling variables (fair test)** | **D Identification and classification** |
| **E Using and evaluating a technique** | **F Other** |

# Cards for task F

## Questions about acids and alkalis (Sc3)

| | |
|---|---|
| Can a solid be acidic? | What is acid rain? |
| Are nettles acidic and dock leaves alkaline? | How can we make indicators from natural materials? |
| How can you ‘cure’ acid indigestion? | Do all parts of Britain get the same amount of acid rain? |
| How can we classify acids and alkalis? | Do all metals react with acids? |
| Do strong acids cause more damage than weak ones? | Do metals react with alkalis? |
| What happens to the pH when acid is added to alkali? | Do different soils have different pHs? |
| Why is lime used by gardeners and farmers? | Which is the most dangerous acid? |
| Are strong acids the same as concentrated acids? | |

## Questions about woodlice (Sc2)

| | |
|---|---|
| Where do woodlice live? | Are the same kinds of woodlice found all over Britain? |
| What kind of animal is a woodlouse? | What do woodlice eat? |
| What is it about their habitat that they prefer? | Do woodlice move faster in bright light than in dim light? |
| What are the different kinds of woodlice? | Do woodlice spread disease to humans? |
| How do woodlice respond to variation in temperature? | Do most people think woodlice are disgusting? |
| Are the small ones babies or are they a different kind from the big ones? | Is it cruel to investigate woodlice in a school laboratory? |
| Woodlice huddle together to keep warm. Is this true? | How can you keep a lot of woodlice in school for study? |
| Are woodlice horrible? | |

(AKSIS, *Education in Science*, no. 185, November 1999)

## Questions about energy (Sc4)

| | |
|---|---|
| What types of energy are there? | Do breakfast cereals give you energy? |
| Do all fuels contain the same amount of energy? | How much does energy cost? |
| What are renewable energy resources? | Is more heat energy lost from a paper cup or a polystyrene one? |
| How much energy is there in a piece of wood? | How can we reduce energy waste? |
| How much energy is used in Britain each year? | How does electricity transfer energy? |
| Do boys use more energy than girls? | What would happen if the world ran out of energy resources? |
| What is the cheapest form of energy? | |

# Task G

Work in pairs.

This handout lists some topics taught during Key Stage 3.

Beginning with topics which come most easily to mind, identify a question which could lead to an enquiry of a sort other than a fair test.

Record the question and the type of enquiry.

Complete as many as you can in 7 or 8 minutes.

| Topic | Possible question | Type of enquiry |
| --- | --- | --- |
| The importance of a healthy diet | | |
| Looking at cells | | |
| Reactions of acids with metals, and carbonates | | |
| Properties of elements | | |
| Displacement reactions of metals | | |
| Patterns of brightness of bulbs in a circuit | | |
| Friction and moving | | |
| The strength of electromagnets | | |
| The planets | | |
| Reducing energy wasted through heat loss | | |

Session
4

# Ideas and evidence in Key Stage 3 science

## Objective

- To clarify what pupils should be taught in Key Stage 3 about ideas and evidence

## Resources

### For tutor

Slides 4.1–4.3, 4.5, 4.7–4.8, 4.10
Audio clip 2 Interview with Lewis Wolpert

### For participants

Handouts
4.4 Transcript of audio clip 2
4.6 Task I
4.9 The nature of science, scientists and evidence: some views

Highlighter pens

## Session outline

35 minutes

| | | |
|---|---|---|
| **Introduction**<br>Brief overview of the afternoon and session 4 | Talk<br>Whole group | 2 minutes |
| **What do we mean by science?**<br>Considering what is meant by science in the context of Key Stage 3 | Talk, audio clip, task H<br>Whole group, individuals, pairs | 15 minutes |
| **How are ideas and evidence described in the National Curriculum?**<br>Review of what the programme of study and level descriptions include | Talk, task I<br>Whole group, groups | 13 minutes |
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group | 5 minutes |

## Introduction

**2 minutes**

Slide 4.1

Introduce the afternoon by showing **slide 4.1** which outlines what each session includes.

**Ideas and evidence** — Slide 4.1

| | |
|---|---|
| Session 4 | Ideas and evidence in Key Stage 3 science |
| Session 5 | Some strategies for teaching about ideas and evidence |
| Session 6 | How scientists work |
| Session 7 | Conclusions and follow-up |

Explain that in order to more fully understand how to approach teaching about ideas and evidence in Key Stage 3, session 4 explores what is meant by 'ideas and evidence', session 5 focuses on practical strategies that could be used in lessons and session 6 explores some examples of ways in which scientists work. The final session allows participants to consider ways of following up this unit.

Slide 4.2

Show **slide 4.2** and outline the objective for this session.

**Objective for session 4** — Slide 4.2

- To clarify what pupils should be taught in Key Stage 3 about ideas and evidence

Say that:

- Teaching about ideas and evidence tends to take place coincidentally alongside the teaching of scientific knowledge and is rarely planned for in any systematic way.
- To some extent scientific ideas and evidence are 'self-evident' to science teachers and are therefore not taught explicitly.
- As with other aspects of scientific enquiry, effective teaching about ideas and evidence requires a specific emphasis using relevant objectives and a check that these have been learned.

## What do we mean by science?

**15 minutes**

Before beginning to explore the answer to the above question we need to identify and recognise what we mean by science. This is not mere rhetoric: it is important that participants review what they mean by science in order that their ideas can be linked to the science they are teaching in Key Stage 3.

### Task H

**8 minutes**

Slide 4.3

The instructions for this task are on **slide 4.3**. This PowerPoint slide has been arranged to introduce each element of the task separately. Do not display the whole slide at the outset.

**Task H** **Slide 4.3**

Working individually, write a brief definition of science.

Listen to Lewis Wolpert's view on the nature of science.

Review your definition. Make any changes you wish.

Compare your definition with another participant's. Are they similar?

Give feedback on significant points or words. How could or should these influence science teaching in Key Stage 3?

Ask participants to work on their own to write down in a few words what they mean by the word 'science'. Allow a couple of minutes but emphasise that you are looking for their views, not a predetermined answer.

Audio clip 2

Handout 4.4

Play **audio clip 2** of the interview with Lewis Wolpert. The transcript of this is on **handout 4.4**. After listening to the clip, ask participants to review what they wrote and make any changes they wish.

Ask participants to share their writing in pairs to enable some discussion. Allow 3–4 minutes. Then take feedback from the whole group, recording key words and phrases on a flipchart. This will generate a list of ideas about the nature of science (the list could be typed up for participants but this is not essential).

The outcome is that each participant has made explicit what they think science is about. You need to use their ideas and place them in the context of science teaching in Key Stage 3. The precise nature of this discussion will depend on participants' ideas. However, it is important to establish that science teaching in Key Stage 3 should get over to pupils more than just scientific knowledge, understanding and investigative skills.

T

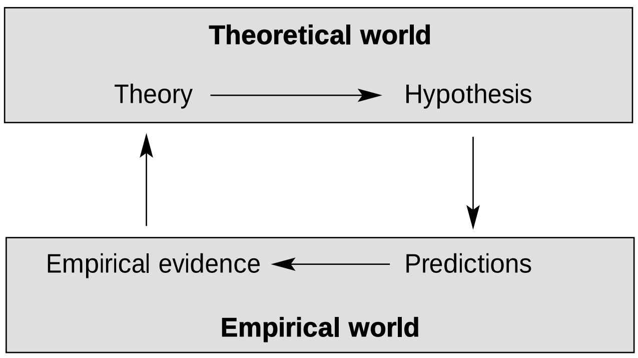
***Additional guidance***

*Some participants may question what their view of science has to do with teaching science in Key Stage 3. It is important to give them a chance to reflect on whether their teaching of science matches what they think science is about. In teaching science we are trying to give pupils not only some scientific knowledge but in addition some appropriate understanding of the limitations of this knowledge.*

Slide 4.5

**Slide 4.5** illustrates a model, produced by Robin Dunbar, of the interplay between ideas and evidence. This diagram provides a useful conclusion to task H.

**The interplay between ideas and evidence** **Slide 4.5**




Based on the work of Robin Dunbar

T

***Additional guidance***

*Scientists often use the words 'explanation' and 'theory' interchangeably. They strive for explanations/theories. Hypotheses are based on these even if the explanation/theory is only half-formed in the mind of the scientist. Predictions are made and tested to see if they are correct. Sometimes a scientist's work enters the cycle at the empirical evidence stage. Having observed something the scientist attempts an explanation and so on.*

Say that:

- The model is useful because it emphasises the cyclic nature of ideas and evidence. The model does not account for the establishment of absolute truth, because scientists retain the possibility that new evidence may yet emerge.
- However, for practical everyday purposes, science has developed a body of knowledge and understanding which can be regarded as being secure. Most of what is taught in Key Stage 3 falls into this category. It is important to remember that much of the science in the news is still at the stages of hypotheses, and gathering and reviewing evidence, although it is not always reported in this way.

## How are ideas and evidence described in the National Curriculum?

**13 minutes**

### Task I

Explain that in this activity participants review appropriate parts of the National Curriculum (programme of study and level descriptions) to consider what they mean.

Handout 4.6

Ask participants to retrieve **handout 4.6** which contains the part of the Key Stage 3 programme of study which covers ideas and evidence and which gives the level descriptions for levels 4–7 for scientific enquiry.

Slide 4.7

Before participants embark on the task, show **slide 4.7** which gives useful definitions of three of the terms used in the National Curriculum. Go through these definitions and explain that participants will need them for the task. Ask participants to volunteer examples of each of the terms.

**Definitions of terms**

Slide 4.7

**Empirical question**
A question based on observation, not on theory

**Hypothesis**
A tentative explanation of a phenomenon based on your knowledge and understanding or arising from empirical evidence

**Scientific explanation**
A generally accepted explanation of a phenomenon using all the available evidence; the explanation may be considered scientifically accurate at the time but further evidence may come to light which means that the explanation is not fully correct

T

### *Additional guidance*

*Allow participants some time to come up with their own examples. If none are forthcoming you may wish to offer the following:*

- *Empirical question: What happens when things burn?*
- *Hypothesis: It is the oxygen in the air which is needed for combustion.*
- *Scientific explanation: During burning oxygen combines with elements in the burning materials to produce new products, some of which are gases and liquids. Both may be lost into the atmosphere.*

Say that explanations and explanatory theories may also go beyond the evidence. Scientists can be creative when producing models and theories to explain a phenomenon; final elements of supporting evidence only emerge later.

Slide 4.8

The instructions for task I are on **slide 4.8**. Ask participants to work in groups of three or four. They should highlight in the level descriptions on handout 4.6 the phrases or sentences that refer to ideas and evidence.

**Task I** — Slide 4.8

Work in groups of three or four.

Read through the extracts of the programme of study for ideas and evidence at the start of handout 4.6.

On the level descriptions highlight any phrases or sentences which refer to ideas and evidence.

You will be asked to comment briefly on the teaching necessary to achieve progression in ideas and evidence.

After about 5 minutes take feedback from different groups. Point out that the yearly teaching objectives for scientific enquiry include ideas and evidence. These are clearly indicated in the Framework on page 25 and in appendix 2 (page 71). Allow participants a minute or so to look at appendix 2.

Handout 4.9

Conclude the session by going briefly through **handout 4.9** which is a collection of views about the nature of science, scientists and evidence. Also identified are some difficulties that pupils in Key Stage 3 might have with evidence, and which teachers need to recognise and challenge.

## Plenary

**5 minutes**

Slide 4.10

Show **slide 4.2** to remind participants of the objective for this session. Show **slide 4.10** and ask how far the objective has been met.

| **Plenary for session 4** | **Slide 4.10** |
|---|---|

By the end of the session participants should:

- be clearer about what the programme of study and level descriptions mean for ideas and evidence;
- have considered how science teaching in Key Stage 3 reflects their own views of what science is;
- be beginning to review where in the scheme of work aspects of ideas and evidence are already met or could be met.

Invite any further questions and points participants might like to make. Encourage them to complete the evaluation form for session 4. Tell them that now is a good time to note any points which they want to follow up in school.

# Transcript of audio clip 2

## Lewis Wolpert on the nature of science

The essential nature of science for me is that it is the best way to understand how anything in the world works. And what's peculiar about science is that it was only ever invented once in history, and that was by the Greeks. So it's not a natural mode of thought: if there hadn't been the Greeks, there may never have been science, and it's a very special way of thinking. It's also that it works by consensus and it's universal. In other words, there's no British science or Italian science or Chinese science – science is universal. In other words, wherever you go water is $H_2O$ and Newton's laws are appropriate for bodies that don't move too fast.

# Task I

## Extracts from the National Curriculum programme of study for Key Stage 3 science

### Ideas and evidence

Pupils should be taught:

(a) about the interplay between empirical questions, evidence and scientific explanations using historical and contemporary examples [for example, Lavoisier's work on burning, the possible causes of global warming]

(b) that it is important to test explanations by using them to make predictions and by seeing if evidence matches the predictions

(c) about the ways in which scientists work today and how they worked in the past, including the roles of experimentation, evidence and creative thought in the development of scientific ideas.

## Extracts from the level descriptions for Sc1

### Level 4

Pupils recognise that scientific ideas are based on evidence. In their own investigative work, they decide on an appropriate approach to answer a question. Where appropriate, they describe, or show in the way they perform their task, how to vary one factor while keeping others the same. Where appropriate, they make predictions. They select information from sources provided for them. They select suitable equipment and make a series of observations and measurements that are adequate for the task. They record their observations, comparisons and measurements using tables and bar charts. They begin to plot points to form simple graphs, and use these graphs to point out and interpret patterns in their data. They begin to relate their conclusions to these patterns and to scientific knowledge and understanding, and to communicate them with appropriate scientific language. They suggest improvements in their work, giving reasons.

### Level 5

Pupils describe how experimental evidence and creative thinking have been combined to provide a scientific explanation. When they try to answer a scientific question, they identify an appropriate approach. They select from a range of sources of information. When the investigation involves a fair test, they identify key factors to be considered. Where appropriate, they make predictions based on their scientific knowledge and understanding. They select apparatus for a range of tasks and plan to use it effectively. They make a series of observations, comparisons or measurements with precision appropriate to the task. They begin to repeat observations and measurements and to offer simple explanations for any differences they encounter. They record observations and measurements systematically and, where appropriate, present data as line graphs. They draw conclusions that are consistent with the evidence and begin to relate these to scientific knowledge and understanding. They make practical suggestions about how their working methods could be improved. They use appropriate scientific language and conventions to communicate quantitative and qualitative data.

## Level 6

Pupils describe evidence for some accepted scientific ideas and explain how the interpretation of evidence by scientists leads to the development and acceptance of new ideas. In their own investigative work, they use scientific knowledge and understanding to identify an appropriate approach. They select and use sources of information effectively. They make enough measurements, comparisons and observations for the task. They measure a variety of quantities with precision, using instruments with fine-scale divisions. They choose scales for graphs and diagrams that enable them to show data and features effectively. They identify measurements and observations that do not fit the main pattern shown. They draw conclusions that are consistent with the evidence and use scientific knowledge and understanding to explain them. They make reasoned suggestions about how their working methods could be improved. They select and use appropriate methods for communicating qualitative and quantitative data using scientific language and conventions.

## Level 7

Pupils describe some predictions based on scientific theories and give examples of the evidence collected to test these predictions. In their own work, they use scientific knowledge and understanding to decide on appropriate approaches to questions. They identify the key factors in complex contexts and in contexts in which variables cannot readily be controlled, and plan appropriate procedures. They synthesise information from a range of sources, and identify possible limitations in secondary data. They make systematic observations and measurements with precision, using a wide range of apparatus. They identify when they need to repeat measurements, comparisons and observations in order to obtain reliable data. Where appropriate, they represent data in graphs, using lines of best fit. They draw conclusions that are consistent with the evidence and explain these using scientific knowledge and understanding. They begin to consider whether the data they have collected are sufficient for the conclusions they have drawn. They communicate what they have done using a wide range of scientific and technical language and conventions, including symbols and flow diagrams.

Handout 4.9

# The nature of science, scientists and evidence: some views

- Science is often counter-intuitive.
- Scientists should always retain an element of doubt.
- Evidence is objective and cannot be correct or incorrect; it can be inaccurately gathered or incomplete.
- Scientists cannot hide evidence.
- Scientists look for evidence in order to produce explanations.
- Explanations may prove to be wrong because the evidence was incomplete.
- Scientists may ‘see’ the explanation long before they have the evidence.
- The value of any evidence is established by peer review.
- Scientists work within social and cultural contexts.

Pupils in Key Stage 3 need help in distinguishing evidence from:

- opinion;
- others’ interpretations of evidence;
- hearsay;
- what they want to believe.

Session
5

# Some strategies for teaching about ideas and evidence

## Objectives

- To understand the central role of evidence and thus why teaching and learning about ideas and evidence are important
- To provide a range of strategies to teach pupils about ideas and evidence

## Resources

### For tutor

Slides 5.1, 5.9

Materials for task K: lemonade or equivalent fizzy drink (cola works well); small amounts of sugar, salt, chalk powder, flour, sugar solution and other materials of choice; tall beaker or measuring cylinder; plastic tray to catch spills, paper towels.

Materials for task L optional activity 1 (burning magnesium): magnesium strip; metal tray with heat-proof mat; matches; eye protection; possibly crucible; electronic balance.

Materials for task L optional activity 2 (pineapple jelly): tinned and fresh pineapple pieces; jelly dissolved but not yet set; a number of small containers, e.g. 100 ml beakers.

### For participants

Handouts

| | |
|---|---|
| 5.2 | Strategies for helping pupils recognise evidence |
| 5.3 | Task J |
| 5.4 | Task J activity 2: cards |
| 5.5 | Task K |
| 5.6 | Task L activity 1 |
| 5.7 | Task L activity 2 |
| 5.8 | Task M |

For each pair of participants, a set of cards for task J

## Session outline

**1 hour 15 minutes**

| | | |
|---|---|---|
| **Introduction**<br>Overview of the session | Talk<br>Whole group | 2 minutes |
| **Teaching pupils to recognise evidence**<br>Identifying evidence and how it is used, with examples for use with pupils | Talk, task J<br>Whole group, groups | 20 minutes |
| **Generating and refining hypotheses**<br>Three practical examples<br>Whole group, groups | Talk, tasks K and L | 40 minutes |

| | | |
|---|---|---|
| **Conflicting theories and ideas**<br>How evidence is used to resolve such conflicts | Talk, task M<br>Whole group, pairs | 10 minutes |
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group, individual | 3 minutes |

## Introduction **2 minutes**

Slide 5.1

Show **slide 5.1** and take the opportunity to emphasise the objectives for this session.

> **Objectives for session 5** Slide 5.1
>
> - To understand the central role of evidence and thus why teaching and learning about ideas and evidence are important
> - To provide a range of strategies to teach pupils about ideas and evidence

Explain that the session is about providing participants with a range of strategies that can be used in lessons. There are three teaching foci:

- teaching pupils to recognise evidence;
- providing activities where pupils have to produce an hypothesis and then refine it in the light of emerging evidence;
- giving pupils opportunities to consider conflicting theories and ideas.

## Teaching pupils to recognise evidence **20 minutes**

Explain that it is necessary to help pupils identify what constitutes evidence. This is an important aspect in developing citizenship as well as science. Pupils need to learn to challenge ideas that do not have supporting evidence and to question the evidence for an idea.

Teachers should provide interesting contexts to engage pupils. In some instances the contexts can be familiar but the phenomena presented are unusual or challenge pupils' previous understanding. This gives an opportunity for the teacher to prompt pupils to come up with new ideas and to look for evidence to support them.

Handout 5.2

Ask participants to refer to **handout 5.2** which offers a few simple strategies for helping pupils recognise evidence.

Make the following points:

- Very often ordinary teaching situations can be simply adapted to encourage pupils to find or distinguish evidence. For example, when asked to make a poster on a topic, pupils may focus more on their views and opinions rather than base the poster on evidence. Pupils could instead be asked to construct a poster to illustrate a conclusion (e.g. 'Smoking is bad for you because …'); then most of the poster is devoted to evidence.

- Another strategy is to ask pupils to find the evidence. This provides a good opportunity to use a range of secondary sources including those available through ICT.
- Teachers and pupils must use the word evidence in order to emphasise its importance.

The following activities illustrate some of these approaches.

### Task J — about 15 minutes

T

***Additional guidance***

*In task J participants explore what constitutes evidence, rather than (for example) irrelevant facts or opinion. It consists of two separate activities to illustrate the first two approaches on handout 5.2. For convenience each activity is on a separate handout with instructions and a commentary.*

Handout 5.3

Cards for task J

Handout 5.4

Ask participants to retrieve **handout 5.3** and provide them with the **cards for task J** (the text on these is reproduced on **handout 5.4**). Tell the participants to work in groups of three or four on each activity in turn. They can choose any order. Your task is to circulate and ensure that the commentary is understood. At the end of the task invite comments on participants' perceptions of the manageability of the activities, and whether they could see themselves trying them with their classes.

## Generating and refining hypotheses — 40 minutes

T

***Additional guidance***

*This session includes three activities. All three are designed to be used with pupils so participants could try them with their own classes. You should demonstrate the first activity (task K) and decide whether to do either of the others practically (task L) or just go through the documents. Do not exceed the time allowed for this part of the session.*

*Task K is a demonstration practical where you model a process which participants could use in their lessons. The first activity in task L is also a demonstration practical which illustrates an alternative approach to a pupil practical activity – burning magnesium. The remaining activity involves using an explanation to make a prediction and then testing it.*

*In all these activities it is important to focus on what pupils need to learn, that is, to improve their appreciation of hypotheses and evidence in arriving at explanations.* ***Note:*** *it is tempting to produce scientific explanations for the observed phenomena but in this context these are not important.*

### Task K — 20 minutes

T

***Additional guidance***

*In this activity you are exploring the reasons why adding sugar and other substances causes lemonade to fizz much more vigorously than usual.*

*It's fun and can be messy. Cola works best because of the protein content. It gives a good froth.*

*You will need to prepare some small packets (film canisters) of sugar, salt, sand, flour, gravel, lumps of chalk… and anything else you like. You will also need some sugar solution. You need either a large beaker or tall measuring cylinder for the lemonade/cola. Ideally stand this inside a laboratory 'grey tray' or other tray to catch any spill. Practise first so that you don't make too much mess.*

*A clue for those of you who must have an answer: nucleation.*

Handout 5.5

Tell the participants that you are going to adopt the role of science teacher and they need to be the pupils. The instructions and sequencing of activities are on **handout 5.5**, including the lesson objective: to explain how to use prediction and testing to refine and develop an hypothesis. Follow through the activity as described, asking questions and making points as appropriate.

Towards the end take feedback on whether or not participants would want to use this type of activity with pupils.

### Task L — 20 minutes

T

***Additional guidance***

*The approach suggested in the first activity uses the language of enquiry to enable pupils to make suggestions and arrive at an explanation. The activity is initially a demonstration, which some might view as removing some of the 'wow' factor. However, the pupils are required to do their own trial as a means of obtaining reliable evidence. They have to recognise before they get their hands on the equipment that careful working is needed to get reliable class results. The class as a whole uses the collective results to help arrive at an explanation. Although this might take longer than normally allowed, there is more learning taking place.*

*You will need to gather as much equipment as you want to use. A minimum is a small amount of magnesium strip, a tin tray with a heat-proof mat inside to contain the burning, some matches and eye protection. You could then demonstrate the burning to set the scene, following with discussion as on the handout. There is only about 10 minutes for the activity so this is the suggested approach.*

*If you are short of time you can simply talk participants through this activity and the pineapple jelly activity which follows.The pineapple jelly activity has proved very popular; if there is insufficient time to do the activity you can demonstrate it using jellies prepared beforehand. Participants can try out the activities with their own classes.*

### Activity 1: burning magnesium

Make the following points:

- Burning magnesium and measuring the gain in mass is a pupil practical used to demonstrate conservation of mass and/or to show molecules forming from a combination of atoms.

- Typically, pupils follow clear instructions, i.e. a 'recipe', to arrive at results which confirm the gain in mass.
- The alterntive approach you are about to demonstrate or discuss allows pupils to go beyond simply learning about the gain in mass.

Handout 5.6

Tell participants to retrieve **handout 5.6**. Follow the instructions by demonstrating burning magnesium and then taking participants through the sequence as outlined in the handout. Ask them to model what their pupils might say and *not* to offer the scientific explanation.

### Activity 2: pineapple jelly

T

***Additional guidance***

*Handout 5.7 provides the instructions for a further interesting activity which teachers could try. You could tackle the activity practically but it would be best if you allowed some time during the morning for you and/or participants to set up some jelly. This will allow enough time for the jelly to set if it is going to. As stated earlier you could demonstrate this activity using jellies prepared beforehand.*

Handout 5.7

Tell the participants to retrieve **handout 5.7**. Go through the handout to explain the objectives and the strategy. Allow participants 5 minutes to read it to get a clearer idea of how the practical works. Afterwards you may want to take feedback on whether or not participants would like to use this activity with their pupils.

Point out that this activity links with the next session. The process of gathering evidence, devising hypotheses and testing predictions illustrated in the pineapple jelly activity is typical of how scientists work. This will be further considered in session 6.

## Conflicting theories and ideas — 10 minutes

### Task M

Explain that this part of the session is about putting pupils in the situation of having to decide between conflicting theories and ideas.

Handout 5.8

This final task in session 5 is again one primarily for pupils. Ask participants to retrieve **handout 5.8** which contains two conflicting theories about how light travels and some evidence which may support one or other theory. Ask them to read through the handout and then to work in pairs or small groups to answer the questions.

Take feedback on whether participants think the activity will help pupils to analyse evidence and link this to theories and ideas.

## Plenary

5 minutes

Slide 5.9

Show **slide 5.1** to remind participants of the objectives for this session. Show **slide 5.9** and ask how far the objectives have been met.

| **Plenary for session 5** | **Slide 5.9** |
|---|---|

By the end of the session participants should:

- be clearer about the importance of pupils learning about evidence and how it is used to refine hypotheses and support explanations;
- have some strategies to teach pupils about evidence and its importance.

Invite any further questions and points participants might like to make. Encourage them to complete the evaluation form for session 5. Tell them that now is a good time to note any points for follow-up in school.

# Strategies for helping pupils recognise evidence

- Ask pupils what the evidence is for any phenomena or statement about some scientific ‘fact’. Such questions can be used as starters in lessons and may be given as a homework in preparation for the lesson.
- Ask pupils to sort statements into those which provide evidence to support an idea or concept and those which do not.
- Pupils could use text-marking to differentiate evidence from explanation, conjecture, conclusion, advice, etc. This works well with articles from newspapers and magazines.
- After investigations, invite pupils to reflect on whether the evidence found was sufficiently accurate and/or reliable.

# Task J

## Activity 1: Lesson starter questions

Consider one or more of the following questions as a way of introducing a topic or lesson.

1 What is the evidence that exercise is good for you?

2 What is the evidence that matter is made of particles?

3 What is the evidence that the Sun is at the centre of the Solar System?

4 What is the evidence that the current is not used up in a circuit?

5 What evidence is there to support the idea that dissolved substances are present when they have disappeared?

### Commentary

When introducing pupils to questions such as these we need to help them explore the question. We need to help them think about:

- how they might find an answer;
- where will they need to look;
- what will they need to look for.

Consider one of your own classes. What level of help or direction to resources would you provide?

Asking pupils to identify evidence can also be used as a summary activity following a topic or set of lessons in order to make pupils review what they have learned.

## Activity 2: Sorting evidence cards

Sorting cards is a good way of getting pupils to recognise evidence. Putting the cards into piles forces them to make a decision. The table illustrates a simple example of this.

| **EVIDENCE to support the view that the Earth is round** | **NOT EVIDENCE to support the view that the Earth is round** |
|---|---|
| When ships sail towards you, the mast appears first. | The Sun travels across the sky in the same direction every day. |
| If you travel west, you eventually return to the place you started from. | The Earth has a magnetic field. |
| The Earth looks spherical when viewed from space. | |

Sort the cards provided into those that provide evidence to support the view that smoking is harmful and those that do not.

### Commentary

Card sorts are easy to produce using ICT. They force pupils to consider and identify evidence which supports a view, evidence which does not, and statements which are not evidence but which may be a widely held belief or a belief they want to hold. What help would you give to pupils to complete this task?

Card sorts can also be used to help pupils recognise the distinction between correlation, and cause and effect. The latter is much more difficult to establish.

What other topics in Key Stage 3 lend themselves to this kind of card sort activity?

# Task J activity 2: cards

## Evidence cards

| | | |
|---|---|---|
| More smokers than non-smokers die of heart disease. | Cigarettes make your breath smell. | Cigarettes contain nicotine. |
| Smoking can make you feel relaxed. | The Government taxes cigarettes and makes them expensive. | A significant proportion of people who smoke develop lung cancer. |
| Women who smoke have a greater chance of having low birth-weight babies. | Smoking is banned from many public places such as restaurants, offices and planes. | Increasing numbers of young people are beginning to take up smoking. |
| Nicotine is addictive. | Many people who smoke develop bronchitis. | Young people under the age of 16 cannot buy cigarettes. |

# Task K

## Using prediction and testing to develop an hypothesis

**Objective**: To explain how to use prediction and testing to refine and develop an hypothesis

| Actions | Part of enquiry | Teacher questions | Commentary |
|---|---|---|---|
| Teacher puts a small amount of sugar into lemonade | Phenomenon / hook for the lesson | | Lemonade fizzes violently when mixed with a small quantity of granulated sugar |
| | Empirical question | Why does this happen? | |
| | Hypothesis formation | What ideas do you have? Give some reasons for your idea. | Prompts: What do we know about lemonade? What sorts of things cause a fizz? What do we know about sugar? |
| Collect suggestions from pupils | | | Typical suggestions: sugar dissolves and pushes out $CO_2$; sugar reacts with lemonade. |
| | Make a prediction | If your idea is right, what will happen when we add salt? | Pupils will make different predictions depending on their hypotheses. |
| Carry out the test | Observing<br>Collecting evidence | | |
| | Considering evidence | Is this what you expected? | The lemonade will fizz with the addition of salt. |
| | Reformulating hypotheses on the basis of evidence | Does this result make you want to change your idea?<br>Why do you think the lemonade fizzes? | |
| | Prediction | What will happen when we add insoluble chalk powder? | |
| Carry out the test | Observing<br>Collecting evidence | | |
| | Considering evidence | Is this what you expected? | The lemonade will fizz with the addition of chalk. |
| Continue questioning, using the addition of sugar solution, flour, etc. You could let pupils choose. | | | |

You could ask pupils what would be needed to prove the explanation wrong. Karl Popper made it clear that a single piece of evidence is sufficient to disprove a theory.

# Task L activity 1

## Burning magnesium: an enquiry approach to a practical activity

**Objective**: To enable pupils to consider and review evidence in order to come to an explanation.

**Possible outcome**: Pupils make an observation and use this, with their scientific knowledge, to predict a further observation and hence begin to form an explanation.

| | |
|---|---|
| 1 Demonstrate a phenomenon. | Burn the magnesium. |
| 2 Ask an empirical question. | What is this white powder?<br>What has happened to the magnesium? |
| 3 Talk about gathering evidence. | Suggest that some evidence beyond just observation is needed to choose between ideas. Say that we will measure the weight of the white powder and compare it with the weight of the magnesium. |
| 4 Predict an outcome. | If your idea is correct, what will you expect to find? |
| 5 Gather evidence. | Demonstrate how to gather the evidence.<br>Discuss the amount of evidence.<br>How can you make it reliable? |
| 6 Draw conclusions. | Is there a pattern to the results? Describe it.<br>Draw a conclusion.<br>How does this link with your idea? |
| 7 Evaluate the evidence. | Is the evidence convincing?<br>Could it have been done better?<br>What other evidence could you collect to confirm your idea about combustion? |

# Task L activity 2

## Pineapple jelly

The purpose of this activity is to improve pupils' understanding of:

- how scientists work today, including the roles of experimentation, evidence and creative thought in the development of scientific ideas (Sc1/1c);
- the importance of testing explanations by using them to make predictions and seeing if evidence matches the predictions (Sc1/1b).

This is a simple context that allows pupils to come up with a range of testable explanations. Some explanations are seen to be implausible following further evidence gleaned by asking questions (real scientists would research journals, talk to colleagues, etc.). Scientists only seek evidence by experiment when they have decided that an explanation is supported by all known facts.

The approach below is an example of how to manage the task, but teachers will choose their own strategies with their classes.

### Background information

Pineapple jelly made with tinned pineapple sets readily whereas pineapple jelly made with fresh fruit stays runny. The reason for this is that fresh pineapple (in common with some other fruits) contains a pectinase which 'digests' the gelatine, preventing the jelly from setting. Tinned pineapple is heat-treated, which destroys the enzyme function.

### Stage 1

Towards the end of a lesson, pupils observe small pots of jelly being assembled. Use ordinary edible jelly and make one batch as described on the packet. You will need two containers for each working group (100 ml beakers are suitable).

You will need to have some pineapple pieces from a can and also some pieces cut from a whole pineapple. The pieces should be on the same dish (so as not to give away any clues to the pupils) although they should be slightly separated to avoid pectinase in the fresh fruit contaminating the tinned variety.

Add the fruit to the jelly in the pots. Ensure that half the pots have tinned pineapple and the rest have fresh pineapple.

**Safety note**: There should be no opportunity for or suggestion that the jelly or pineapple could be eaten. If you wish the pupils to eat the jelly, then transfer the class to a food room for the whole of the activity.

## Stage 2

The next lesson pupils are given the pots of jelly to observe. Make a drama out of the strange mystery that half the pots are still liquid and half are set.

Ask the groups to think of some possible explanations. Likely explanations are:

- They were not all kept in the same conditions of, for example, temperature.
- Someone added extra water to some of the pots.
- Some of the pots weren't clean and have 'gone off' (germs have got to the jelly).
- Some of the pineapple pieces were old and allowed germs in (many pupils equate liquefying with rotting).
- There was some kind of chemical in some of the pots.

Ask pupils to say how they would find evidence to support their explanation. Tell them that they will be able to ask you and the technician questions about the experiment in a courtroom-style interrogation. They can only ask about what you did, not what you think. They need to construct their questions to ensure they get evidence to support their idea.

## Stage 3

The pupils are informed (how this is done is up to the imagination of the teacher) about the two sources of the pineapple. It is, of course, possible that some pupils will have considered this possibility and asked the question.

Pupils are asked to reconsider their explanations in the light of this new evidence. Likely explanations include:

- The tinned pineapple jellies didn't set because the tinning process uses chemicals.
- The fresh pineapple jellies didn't set because there are bacteria or germs on fresh pineapple that stop the setting process.

## Stage 4

After about 5 minutes, two new pieces of information are introduced. The pupils are told:

- the canning process involves strongly heating the pineapple but not the addition of chemicals;
- jelly is a short name for a protein called gelatine.

Again groups are asked to reconsider their explanations.

This would be a good time to take some feedback. Encourage the pupils to say how they would collect evidence to support their explanation.

## Stage 5

The last piece of evidence is introduced as a story (perhaps as a remembered newspaper article):

- Pineapple juice is used to tenderise meat – hence the traditional combination of gammon and pineapple.
- Some people get very sore mouths when eating fresh pineapple.

Groups are asked to come up with their final explanation and suggest how they would gather evidence to support it. Whole-class discussion about the range of explanations and tests models how scientists work. Groups should defend their ideas, explaining their reasoning.

There are possibilities for some challenging debates. For example, some groups will have now decided that the explanation concerns enzymes in the pineapple and to test this they may want to heat the fresh pineapple to denature the enzyme as part of a test. However, this will also have the effect of killing 'germs' so this approach does not support one explanation over another.

## Stage 6

Pupils set up their tests if you have the time, or this could be a homework exercise.

## Plenary

Discuss how this task has modelled some of the work of scientists.

- There is a phenomenon to be explained.
- A range of explanations is suggested based on knowledge and theories.
- Some explanations can be dismissed as further knowledge (evidence) is gained through reading and discussion.
- Evidence is sought to support the most plausible explanations.
- Sometimes it is hard to design an experiment that supports one explanation and refutes another.

# Task M

## Theories on light

**Theory 1**
Light rays travel from our eyes to the objects and enable us to see them.

**Theory 2**
Light rays are produced by a source of light and reflect off objects into our eyes so we can see them.

Which of the following pieces of evidence support theory 1, theory 2, both or neither?

(a) Light travels in straight lines.

(b) We can still see at night when there is no Sun.

(c) Sunglasses are worn to protect our eyes.

(d) If there is no light we cannot see a thing.

(e) We ‘stare at people’, ‘look daggers’, and ‘catch other people’s eye’.

(f) You have to look at something to see it.

Taken from *Enhancing the quality of argument in school science*, by J. Osborne, S. Erduran, S. Simon and M. Monk (ASE, 2001), pages 63–70.

Session 6

# How scientists work

## Objective

- To review how scientists work and what Key Stage 3 pupils should be taught about this

## Resources

### For tutor

Slides 6.1, 6.3, 6.12
Audio clip 3 Interview with Lewis Wolpert
A copy of *The Faber book of science* for participants to look at
Materials for task O (optional): see handout 6.8

### For participants

Handouts

6.2 Transcript of audio clip 3
6.4 Task N: teaching notes
6.5 Task N: observation sheet
6.6 Task N: cards
6.7 Ideas and evidence: resource list
6.8 Clinical trial simulation: teacher's notes
6.9 Clinical trial simulation: record sheet
6.10 Clinical trial simulation: analysis
6.11 Clinical trial simulation: some definitions

For each group of three participants, a set of cards for task N

## Session outline — 35 minutes

| | | |
|---|---|---|
| **Introduction**<br>Introducing the main idea | Talk, audio clip<br>Whole group | 3 minutes |
| **An example from history**<br>Using an historical example in class | Talk, task N<br>Whole group, pairs | 15 minutes |
| **A contemporary example**<br>A simulation of a clinical trial | Talk, task O<br>Whole group, individuals, pairs | 15 minutes |
| **Plenary**<br>Reflecting on the main points of the session | Talk<br>Whole group, individuals | 2 minutes |

## Introduction

3 minutes

Slide 6.1

Show **slide 6.1** which has the objective for this session.

**Objective for session 6**

Slide 6.1

- To review how scientists work and what Key Stage 3 pupils should be taught about this

Make the following points:

- Scientists have ideas, generate hypotheses, collect evidence, and make and test predictions; they conduct trials.
- They report and publish things in particular ways in journals and on the Internet – subject to peer review.
- Scientists often work in teams where each individual contributes something different.

Audio clip 3

Handout 6.2

Play **audio clip 3** from the interview with Lewis Wolpert. The transcript is provided as **handout 6.2**.

After listening to the clip, allow a short time for comments. Ask participants whether they have many opportunities in their present scheme of work for Key Stage 3 to discuss with pupils how scientists work. Do not labour the point; if there are no comments, move on to the next part of the session.

T

***Additional guidance***

*Part of this clip was also used in session 1. It is repeated here because it helps to set the scene for this session.*

## An example from history

**15 minutes**

T

***Additional guidance***

*The next activity is based on the work of Lavoisier. The activity is adapted from* Guide to secondary science education *(ASE, 1998; chapter 2.6, by Jonathan Osborne), and from a lesson on developing pupils' thinking skills. To keep within time constraints the activity used in this session is much shortened. Full details of how to use the activity with pupils are provided on handouts 6.3 to 6.6. The short activity is offered here to allow participants to consider how they can approach the teaching of how scientists work.*

### Task N

Slide 6.3

The instructions for task N are given on **slide 6.3**.

| **Task N** | Slide 6.3 |
|---|---|
| Work in groups of three. | |
| Read handout 6.4. | |
| Two participants read and sequence the cards. | |
| The 'observer' records the discussion on handout 6.5. | |
| Stop after 5 minutes and review handout 6.4. | |
| How far has the activity allowed you to meet the two objectives? | |

Cards for task N

Handouts 6.4 to 6.6

Give out the **cards for task N** and tell participants to retrieve **handouts 6.4 to 6.6**. Handout 6.4 gives some background to the activity and to Lavoisier. Handout 6.5 is used to record the types of dialogue that take place in the group. Handout 6.6 reproduces the statements on the cards.

Ask participants to work in groups of three to tackle the activity. Encourage them to enjoy the activity but to bear in mind how it could be used with their classes, perhaps towards the end of unit 8E, 'Atoms and elements', from the QCA scheme of work.

Either before the task or afterwards, say that:

- This method can be applied to any story of a scientific discovery.
- Through discussion in trying to sort the sequence in this case pupils will realise that leaps in scientific understanding can be as a result of developing theories and testing them.
- The activity can also be used without the thinking skills element by confining it to a card sort only.

T

### *Additional guidance*

*After about 8 minutes, draw the activity to a close by asking participants whether they had learned anything about Lavoisier, whether they could see themselves using this activity with one of their classes, and what they thought pupils might derive from the activity (perhaps what the participants might like to emphasise). Be ready to record significant words or phrases on a flipchart in order to focus the feedback.*

Say that:

- A number of publications contain stories about scientists that could be adapted in this way. One of the best sources is *The Faber book of science* (have a copy to show participants, perhaps identifying one story you have found interesting).
- Websites such as that of the Royal Society of Chemistry (www.rsc.org) provide links to many other sites with historical stories.

Handout 6.7

**Handout 6.7** contains a list of useful resources for participants.

## A contemporary example

**15 minutes**

Say that:

- Of necessity, investigations that involve living organisms cannot always, or even sometimes, be fair tests as practised in Key Stage 3 science.
- Pupils will come across the idea of scientists conducting field trials, clinical trials, experiments, enquiries and investigations. In addition, engineers conduct trials where performance is judged against predetermined criteria. Such trials can be of devices, of systems, or of the way systems integrate with each other. A wide range of trials is therefore in use in the fields of science and technology.
- Through their laboratory work pupils will have the chance to become familiar with some forms of trials, but not necessarily clinical trials.
- Lewis Wolpert mentioned the importance of clinical trials. These can be modelled in the classroom.

### Task O

T

***Additional notes***

*You can run this as a practical activity if you have the time. It works well but will take around 10 minutes extra to set up and explain. If the vegetables suggested are not easy to obtain you can substitute them with different varieties of apples and/or pears. It has been found that the texture of the vegetables/fruit can give the game away. If this is likely, put the foods through a blender to produce a purée. Note that generally a placebo is structurally similar or even identical to a treatment, but in this simulation the placebo (headband) and treatment (nose-clip) are physically different. In terms of a simulation for use in Key Stage 3 this difference has little impact but you should be aware that some participants may identify this as a weakness in the simulation.*

Handouts 6.8 to 6.11

Ask participants to retrieve **handouts 6.8 to 6.11**; these contain the instructions for a clinical trial simulation and all the resource sheets necessary for use with a class. Give participants a few minutes to read through the handouts and to discuss in pairs the feasibility of using this activity. Explain that you will be asking for their thoughts on objectives and outcomes for the activity.

Allow 7 or 8 minutes and then take feedback. Record ideas on lesson objectives and outcomes on a flipchart.

## Plenary

**2 minutes**

Slide 6.12

Show **slide 6.1** again to remind participants of the objective for the session. Then show **slide 6.12** and ask how far the objective has been met.

**Plenary for session 6** **Slide 6.12**

By the end of this session participants should:

- be clearer about how pupils can be taught how scientists work;
- be clearer on the objectives for such lessons;
- begin to recognise that there are many opportunities for teaching pupils how scientists work and that teachers can choose which of these to make use of.

Invite any further questions and points from participants. Encourage them to complete the evaluation form for session 6. Tell them that now is a good time to note any points they want to follow up in schools

# Transcript of audio clip 3

## Lewis Wolpert on scientific method

There's no simple scientific method; there are many different styles in science. Some scientists are good experimentalists, some are good theoreticians, some are a mixture of both – it's a complicated business. The key feature though is that you must be internally consistent. There mustn't be any contradictions in your ideas.

An important example of the scientific approach involves clinical trials. If you want to test whether a drug is really working you really have to try the drug on one group of people, and a non-drug on another group of people, and they mustn't know which one you are giving them; otherwise you could get quite misleading results. Anecdotes will not do. As my joke is: I could cure you of flu – if you get out of bed, sing 'God save the Queen' every morning, within three weeks your flu will be gone. Is it singing that makes the flu go?

# Task N: teaching notes

Historical case studies (which need not be very long) provide opportunities for pupils to consider the ways in which evidence is collected and how scientists work.

### Objectives

Learning objectives for this activity in this particular context would be:

- To explore how a scientist used evidence to arrive at an explanation (or theory)
- To think about how working in a group helps you to learn

### Possible outcomes

By the end of the activity pupils should:

- be able to discuss and possibly answer the question ‘Do scientists get all of their ideas from observations or do they speculate and dream up theories which they then test?’;
- be able to give some explanation about how discussion in small groups helps them to develop their ideas and understanding.

## Lesson outline (total 50 minutes)

### Background notes

Antoine Lavoisier (1743–1794) entered the Academy of Science in 1766 when he was 23. Between 1764 and 1770 he worked with others to map the geology and mineralogy of France and in 1776 he was awarded a gold medal from the king for his street-lamp design. He married Marie Anne in 1771 when she was not yet 14. All through this time, he also worked at ‘his science’, working from 6 to 9 in the morning and again from 7 to 10 at night. He was arrested on 24 December 1793 on a charge of watering soldiers’ tobacco and appropriating revenue belonging to the state in his role as tax inspector. He was executed by guillotine on 8 May 1794.

In the introduction, explain to pupils that:

- At the time of Lavoisier most people believed that substances contained an ingredient, phlogiston, which was released into the air when substances were burned (after all, we can see the smoke!). This should lead to things being lighter when they are burned.

- In a note to the French Academy on 1 November 1772, Lavoisier reported his findings of the experiment that led him to believe that the phlogiston theory was wrong.

- Lavoisier was one of the first chemists to measure things accurately. He put some mercury on a small tray which he floated on water. He covered the whole of this apparatus with a glass dome and then heated mercury by focusing the Sun’s rays through a magnifying glass on to the mercury until it burned.

| Time (minutes) | Activity | Notes and key questions |
| --- | --- | --- |
| 10 | Introduction | Set scene of the phlogiston theory at the time of Lavoisier |
| 5 | Set task | Pupils work in threes. Two of each group sort the cards into order. Observer to complete the observation sheet by ticking actions only at this stage. Model what the observer does: Which box do you tick if you hear one person in your group say ‘Which card do you think goes first?’, ‘I wouldn’t put that card there’, ‘I think that one goes last because it’s about what he thought in the end’, ‘I think we should read all the cards first’. |
| 10 | Carry out the task | |
| 5 | Observer feeds back to group | |
| 5 | Whole group complete final column of observation sheet | |
| 15 | Plenary | First discuss the story the card sort tells. For example: How does Lavoisier get the mercury to burn? Why did he repeat the experiment with phosphorus? Which piece of evidence made him think the phlogiston theory was wrong?<br><br>Then discuss how working in a group helped. For example: How did asking questions help you do the card sort? etc. |

# Task N: observation sheet

Put a tick in the box in the middle column each time someone in your group does one of the actions in the left-hand column. Do not write in the boxes in the right-hand column until later.

| What someone in the group did | Tick | How did this help? |
| --- | --- | --- |
| Ask a question | | |
| Suggest what to do | | |
| Give a reason for an idea | | |
| Disagree with someone | | |

# Task N: cards

| | | |
|---|---|---|
| He covers the floating tin with a glass dome. | He heats the mercury using a magnifying glass and the Sun's rays. | He repeats the experiment using phosphorus. |
| He weighs the ash left behind and finds it weighs more. | Lavoisier now thinks that when a substance burns it combines with something in the air to produce a heavier residue. | Lavoisier places mercury on a tin and floats it in a bath of water. |
| Lavoisier suspects that the phlogiston theory is wrong. | The phlogiston theory predicts that heated substances will lose their phlogiston and weigh less afterwards. | The residue left by phosphorus after burning also weighs more. |

# Ideas and evidence: resource list

*The Faber book of science*, edited by John Carey (Faber and Faber, 1995; ISBN 0 571 17901 0). This book contains a wonderful array of scientific writings which illustrate how scientists have worked and the thoughts they had about their work.

*Concept cartoons in science education*, by Stuart Naylor and Brenda Keogh (Millgate House Publishers, 2000; ISBN 0 9527506 2 7. Available from the ASE or the publishers direct: Millgate House, 30 Mill Hill Lane, Sandbach, Cheshire CW11 4PN.)

*Science web readers*, edited by Joan Solomon (Nelson Thornes, 2000):

- Biology (ISBN 0 17 438737 7)
- Chemistry (ISBN 0 17 438738 5)
- Physics (ISBN 0 17 438739 3)

*One hundred years of the electron* (ASE/RSC, 1997; ISBN 0 86357 276 6)

*One hundred years of radium* (ASE/BSHS, 1995; ISBN 0 86357 299 5)

*From phlogiston to oxygen* (ASE, 2000; ISBN 0 86357 317 7)

*The nature of science series* (ASE):

- *Louis Pasteur* (ISBN 0 86357 114 X)
- *The big squeeze* (ISBN 0 86357 115 8)
- *Benjamin Franklin* (ISBN 0 86357 116 6)
- *Discovering the cure for scurvy* (ISBN 0 86357 117 4)
- *Stars and forces* (ISBN 0 86357 133 6)
- *The search for simple substances* (ISBN 0 86357 113 1)

*Ideas and evidence in science* (ASE, 2002)
This concentrates on requirements for GCSE but teachers may find it helpful at Key Stage 3.

*Horrible science: suffering scientists,* by Nick Arnold (Scholastic Children's Books, 2000; ISBN 0 439 01211 2)

Many new published schemes or sets of texts for Key Stage 3 contain useful science stories that can be used to teach about ideas and evidence.

## Useful websites

www.spiked-online.com/sections/science
This site offers debate on current issues in science.

www.nobel.se
This is the official site of the Nobel Foundation and includes articles on contemporary issues by scientists.

www.newscientist.com
This offers many of the articles from the magazine.

www.acclaimscientists.org.uk
Provides details of the Acclaim project. Paper copies of the Acclaim materials were sent to all schools

www.ase.org.uk
The website of the ASE

www.iob.org
The website of the Institute of Biology

www.iop.org
The website of the Institute of Physics

www.rsc.org
The website of the Royal Society of Chemistry

www.shu.ac.uk/pri/index.htm
This is the site for the pupil researcher initiative. Although mainly aimed at Key Stage 4 it offers a wealth of information and activities which could be used to help teach about ideas and evidence.

## Disclaimer

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# Clinical trial simulation: teacher's notes

## Introduction

This is a trial of a new treatment for an eating disorder. The treatment (not shared with pupils at this stage) is a nose-clip. It is administered to about one sixth of the class, with a further sixth given a placebo (a headband); these are the 'patients'. A third of the class play the role of 'doctors' administering to the patients. The rest of the pupils are 'researchers'.

The teacher will need to select two co-workers to help with the trial.

Pupils are told that the idea of the task is to model a clinical trial and that at the end there will be a discussion to compare the model to a real trial.

Pupils are asked to volunteer to be the patients. They are told they will have to eat some foods and identify them. The new treatment should prevent them from being able to distinguish between the tastes.

First, all patients are given some small pieces of food to taste. The purpose is to ensure that everyone is clear what the four different foods taste like. Any pupils who express violent dislike for any of the vegetables will need to join the doctors or researchers. (There is no reason to exclude the doctors or researchers – they can all taste the food.)

The co-workers give out portions of swede (or carrot), then apple, followed by potato and lastly pear. It is important that all patients can identify each taste.

Handout 6.11 is a pupil reference sheet containing some useful definitions of terms related to clinical trials.

### Materials

Nose-clips, each in a closed box or envelope (one for every six pupils; 1/6)

Headbands, each in a closed box or envelope (1/6)

Small cubes or purée of:

- swede (or carrot), apple, potato and pear; or
- four different tasting varieties of apples and pears.

Cocktail sticks or plastic spoons (lots)

Sets of cards labelled A, B, C or D (1/3)

Sets of cards labelled with the foods used (1/3)

Small pots or containers labelled A, B, C or D (lots)

Unlabelled small pots or containers (lots)

Record sheet (handout 6.9; 1/3)

Analysis sheet (handout 6.10; 1/3)

Definitions sheet (handout 6.11)

### Preparation

Prepare the foods by either cutting them into equal cubes of between 0.5 and 1 cm side length, or, if the texture is going to help pupils identify them, reduce them to a purée in a blender.

For each doctor prepare a set of four pots labelled A, B, C and D, into each of which are placed about 10 pieces, or an equivalent amount of purée, of one food. At this stage only the co-workers should be able to identify which label refers to which food. As far as possible the doctors should not know.

### Safety notes

- Take care with hygiene. If at all possible conduct this activity in a food technology room or even an ordinary classroom. If you do the activity in a lab stress how unusual an activity this is and that food must not normally be eaten in a lab.
- Emphasise the need for strict hygiene and that food must not come into contact with the bench surfaces.
- Ensure food remains in the clean containers and is handled only using sterile tweezers, clean cocktail sticks or clean teaspoons.
- All food preparation, i.e. cutting and/or blending, must be done outside the laboratory in a clean environment.

## Running the simulation

Pupils are placed in groups of three: a patient, a doctor and a researcher. The researcher will act as a messenger between the doctor and patient.

Stress the need for complete secrecy about what each person has been told to do. The whole trial, when started, should be carried out in silence (it will only take 5–10 minutes).

Arrange the room so that the doctors cannot see their patients’ faces.

The co-workers give each patient:

- four food cards: ‘apple’, ‘pear’, ‘swede’, ‘potato’;
- a closed box/envelope containing either a nose-clip or a headband. Half of the patients get one, the other half the other. The patients must put on their clip or headband.

The co-workers give each doctor:

- four pots labelled A, B, C, D containing the foods either as small cubes or a purée, so that the texture is not a giveaway;
- a record sheet (handout 6.9) with the first column completed as directed;
- a pair of sterilised tweezers, some clean cocktail sticks (for solid food) or lots of clean plastic spoons if the food is a purée, and a clean disposable cup.

 

### Procedure

1 The doctor places a portion of food in the disposable cup according to the list on the record sheet.

2 The researcher takes the cup to the patient who must shut their eyes before receiving it and tasting.

3 The patient, having tasted the food, identifies it by picking a food card and giving it to the researcher.

4 The researcher conveys the food card to the doctor who copies the food on to the record sheet.

5 The doctor selects the next food from the list and the researcher returns to the patient with the new food and the food card from the last sample.

6 Continue until all the spaces on the record sheet are filled.

7 As each group finishes, the co-workers collect the record sheets and write on the top the treatment that the patients received, nose-clip or headband.

8 The co-workers tell the doctors and researchers which food was in which pot and they then calculate the number of correct responses.

9 Meanwhile the co-workers ask the patients to write down how well they think they did in identifying the foods.

10 The results are analysed to determine whether the treatment (nose-clips) was successful in preventing the patients identifying the foods.

All pupils are asked to complete the analysis sheet (handout 6.10) to review how successfully the activity modelled a real clinical trial. Allow pupils to discuss in their groups of three before they complete the sheet.

Handout 6.9

# Clinical trial simulation: record sheet

| Insert here at the end of the trial the treatment the patient received: | |
|---|---|
| Insert in this column 20 letters which must be A, B, C, D in random order (there need not be equal numbers of each). The sheet for each doctor should be different. | The doctors record in this column the name of the food written on the card the patient chooses each time. |
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| 11 | |
| 12 | |
| 13 | |
| 14 | |
| 15 | |
| 16 | |
| 17 | |
| 18 | |
| 19 | |
| 20 | |

# Clinical trial simulation: analysis

| Model | Clinical trial | Comments on the model |
|---|---|---|
| Pupils volunteer to be 'patients' | Taking part in a trial is voluntary | |
| Ensure that they can identify the food tastes | Patients need to know what symptoms to report on | |
| Identifying the food tastes | Presenting symptoms that are to be cured, or reduced symptoms | |
| Some 'patients' get headbands | Some patients are given placebos | |
| 'Patients' don't know whether headbands or nose-clips are supposed to work | They don't know whether they have a placebo – this is like a blind trial | |
| 'Doctors' don't know what treatment 'patients' have got | Doctors don't know whether patients have a placebo – this is a double-blind trial | |
| The 'doctors' don't choose the order of the evidence gathered | This ensures no pattern emerges and gives more credibility to results | |
| The results from different 'doctor/patient' pairs are collated to make a bigger study | Evaluations are based on hundreds of people | |

# Clinical trial simulation: some definitions

### What is a clinical trial?

A clinical trial is a research study to answer specific questions about vaccines, new therapies or new ways of using known treatments. Clinical trials (also called medical research and research studies) are used to determine whether new drugs or treatments are both safe and effective. Carefully conducted clinical trials are the fastest and safest way to find treatments that work.

Ideas for clinical trials usually come from researchers. Once researchers test new therapies or procedures in the laboratory and get promising results, they begin planning Phase I clinical trials. New therapies are tested on people only after laboratory and animal studies show promising results.

### What is a protocol?

All clinical trials are based on a set of rules called a protocol. A protocol describes what types of people may participate in the trial and what they are expected to do. While in a clinical trial, participants are seen regularly by the research staff to monitor their health and to determine the safety and effectiveness of their treatment.

### What are clinical trial phases?

Clinical trials of experimental drugs proceed through four phases:

- In **Phase I** clinical trials, researchers test a new drug or treatment in a small group of people (20–80) for the first time to evaluate its safety, determine a safe dosage range, and identify side-effects.
- In **Phase II** clinical trials, the new drug or treatment is given to a larger group of people (100–300) to see if it is effective and to further evaluate its safety.
- In **Phase III** studies, the new drug or treatment is given to large groups of people (1000–3000) to confirm its effectiveness, monitor side-effects, compare it to commonly used treatments, and collect information that will allow the drug or treatment to be used safely.
- **Phase IV** studies are done after the drug or treatment has been marketed. These studies continue testing the study drug or treatment to collect information about their effect in various populations and any side-effects associated with long-term use.

### What is a placebo?

A placebo is an inactive pill, liquid or powder that has no treatment value. In clinical trials, experimental treatments are often compared with placebos to assess the treatment's effectiveness. In some studies, the participants in the control group will receive a placebo instead of an active drug or treatment.

## What is a control or control group?

A control is the standard against which experimental observations are evaluated. In many clinical trials, one group of patients will be given an experimental drug or treatment, while the control group is given either a standard treatment for the illness or a placebo.

## What is a blind or masked study?

A blind or masked study is one in which participants do not know whether they are in the experimental or control group in a research study. Those in the experimental group get the medications or treatments being tested, while those in the control group get a standard treatment or no treatment.

## What is a double-blind or double-masked study?

A double-blind or double-masked study is one in which neither the participants nor the study staff know which participants are receiving the experimental treatment and which ones are getting either a standard treatment or a placebo. These studies are performed so neither the patients' nor the doctors' expectations about the experimental drug can influence the outcome.

Session 7

# Conclusions and follow-up

## Objective

- To determine priorities and actions for follow-up in school

## Resources

### For tutor

Slide 7.1

Access to a photocopier if possible

### For participants

Handouts

7.2 Personal follow-up work
7.3 Follow-up work with the department

Summary sheet

## Session outline — 15 minutes

| | | |
|---|---|---|
| **Priorities and actions**<br>Outline of the purpose and scope of follow-up work. Participants identify some personal follow-up actions | Talk, tasks P and Q<br>Whole group, individuals, pairs | 15 minutes |

## Priorities and actions

**15 minutes**

Slide 7.1

Show **slide 7.1**.

| **Objective for session 7** | Slide 7.1 |
|---|---|
| • To determine priorities and actions for follow-up in school | |

Make the following points:

- It is essential that participants follow up some of the ideas they have learned today.
- In part, follow-up is about developing each participant's own classroom practice, but it is also about developing the classroom practice of others.
- It is expected that participants will provide their departmental colleagues with feedback from the unit. This could be at a department meeting, an INSET session or working with individual teachers.
- To be effective, feedback needs to include some discussion of ideas – simply handing out copies of documents received will not work. However, the summary sheet and copies of other handouts from this unit can be usefully given to other teachers as part of a feedback session.

### Task P

**5 minutes**

Handout 7.2

Ask participants to retrieve **handout 7.2** which is concerned with follow-up in their own teaching. Ask them to take 2 or 3 minutes to consider the activities listed (and any others) and to choose one or two which they want to try with classes. Invite them to complete the handout, including giving a date in the future when they will review how effectively the activity worked. Tell them to share their follow-up plans with another participant.

T

***Additional guidance***

*Go around the room to see what sort of activities are prioritised and by whom. You can use this opportunity to offer support to individuals you think need some assistance. Try to fix dates for any such support work before the participant leaves today.*

*It is useful for your follow-up to have copies of the completed handouts 7.2 and 7.3, but be aware that some participants may need persuading of this. Ask participants to put their name on the handouts and make a copy straight away if facilities are available. If not, you could take in the completed handouts, make copies later and return them by post to the participants. You could arrange to have refreshments at the end of this session which will give participants a little more time to complete the handouts and you some time to make copies.*

## Task Q

**5 minutes**

Summary sheet

This task is concerned with dissemination to colleagues in the department. Several copies of a **summary sheet** have been provided in each participant's pack to support the dissemination of ideas.

Handout 7.3

Explain that the department may have already worked out a programme for feedback from individual teachers following CPD units through the year. If so, participants will have a much clearer idea of what they will do. If not, participants will have to judge the best approach. **Handout 7.3** gives some suggestions.

Ask participants to take 2 or 3 minutes to consider the actions listed (and any others) and to choose one, two or more which they want to pursue. Tell them to make a start at completing the handout, including giving approximate time scales. Invite them to share their follow-up plans with another participant.

Draw the day to a close by asking if there is any further feedback or points participants wish to make. Encourage them to complete the evaluation form for session 7.

Finally ensure you collect in:

- the completed evaluation forms;
- handouts 7.2 and 7.3 if you have arranged to copy and return them;
- a completed register for the day.

T

### *Additional guidance*

*If you are not collecting handouts 7.2 and/or 7.3, try to arrange visits to at least some of the participants, perhaps those you identified as being likely to develop their ideas quickly (which will give you some examples of good practice to share) and those who have found the day demanding and will find giving feedback to their colleagues equally so.*

# Personal follow-up work

Select from the list below the one or two ideas from the unit that you wish to pursue and develop in your own teaching. Share your thoughts with another participant.

| Idea or activity | Priority? yes/no | Class or teaching group to work with | Review by |
|---|---|---|---|
| Using the posters to help pupils plan and manage a fair test enquiry | | | |
| Teaching about the value of repeat readings | | | |
| Teaching some other aspect of scientific enquiry | | | |
| Obtaining the AKSIS publications and trying other activities | | | |
| Trying a few short activities to help pupils understand what is meant by evidence | | | |
| Trying the lemonade fizz activity | | | |
| Developing a card sort activity to help pupils recognise evidence | | | |
| Trying the pineapple jelly activity | | | |
| Trying the Lavoisier example to help pupils understand how scientists work | | | |
| Developing another activity to help pupils understand how scientists work | | | |
| Trying the clinical trial simulation | | | |

# Follow-up work with the department

Select from the list below a few actions you wish to take in order to disseminate some of the ideas which seem to you to be significant to colleagues in the department.

| **Action** | **Priority? yes/no** | **Do you want consultant help?** | **Approximately when you intend to carry out the action** |
|---|---|---|---|
| Report back main ideas to the head of department to discuss follow-up priorities. | | | |
| Report back general issues and ideas to the department at a department meeting | | | |
| Take the whole department through the posters activity. | | | |
| Take the whole department through the repeat-reading activity | | | |
| Review the scheme of work with the person who is responsible for it to ensure teaching scientific enquiry becomes more explicit | | | |
| Demonstrate some of the ideas and evidence activities to the whole department | | | |
| Encourage colleagues to look for and develop more historical examples of how scientists worked | | | |
| Encourage colleagues to look for and develop more contemporary examples of how scientists work | | | |
| Link with another participant from today's course to share developing ideas and plans | | | |
| | | | |

# Scientific enquiry

## Main messages from the unit

- The programme of study for scientific enquiry needs to be taught explicitly. Pupils should be given opportunities to practise their developing skills.
- The Framework yearly teaching objectives for scientific enquiry can be refined to produce objectives for individual lessons or groups of lessons.
- The scientific enquiry posters offer one useful means of teaching pupils how to plan, manage, record, conclude and evaluate a fair test.
- Enquiries and investigations can challenge pupils' scientific knowledge and understanding, their investigative skills, or both. Teachers should take account of this when planning work.
- There is a range of types of enquiry which needs to be taught and practised throughout Key Stage 3.
- In Key Stage 3 there is an emphasis on increasing the accuracy and reliability of evidence and on evaluating the validity of conclusions in terms of the quality and quantity of evidence obtained.
- Scientists test hypotheses by predicting outcomes and looking for evidence to support their predictions. They also look for evidence which renders the prediction invalid.
- Pupils should be taught to discriminate evidence from other information.
- There are many historical and contemporary examples of how scientists work. It does not matter which ones teachers choose to use.
- There are many interesting examples and source materials which teachers can draw upon.

 

## Implications for the science department

The priority which the department has accorded to developing the teaching of scientific enquiry will be reflected in the action points identified for the departmental action plan. Scientific enquiry may be a priority for the whole science department or only for one or more individual teachers. In either case there are a number of actions which can be taken. Some of these actions are listed below as an aide-memoire.

### For the department

Review the scheme of work to ensure teaching scientific enquiry becomes more explicit.

Review the scheme of work to ensure scientific enquiry is taught within a structure which ensures progression.

Consider introducing the scientific enquiry posters to all classes at least in the early years of Key Stage 3.

Using the repeat-reading activity as an example, consider how to develop or find other activities which enable scientific enquiry skills to be taught explicitly.

Obtain the AKSIS publications, try other activities and then build them into the scheme of work.

Using some of the activities for teaching pupils about ideas and evidence as examples, consider how to develop or find other similar activities.

Encourage colleagues to look for and develop more historical examples of how scientists worked.

Encourage colleagues to look for and develop more contemporary examples of how scientists work.

### For individual teachers

Try using the posters to help pupils plan and manage a fair test enquiry.

Try teaching about the value of repeat readings to a class.

Try teaching some other aspect of scientific enquiry which you have identified as being a particular weakness with one class or group of pupils.

Try a few short activities to help pupils understand what is meant by evidence.

Develop a card sort activity of your own to help pupils recognise evidence.

Try the lemonade fizz activity.

Try the pineapple jelly activity.

Try the Lavoisier example to help pupils understand how scientists work.

Develop a similar activity based on a scientist whose work you know well to help pupils understand how scientists work.

Try the clinical trial simulation.