Key Stage 3
National Strategy

Science

Scientific enquiry

Notes for participants

Contents

Participants are intended to complete the evaluation form during the unit. At the end of the unit the tutor will collect the completed forms from participants.

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 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.

Slide 1.1

Scientific enquiry

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

Slide 1.2

Objectives for the unit

- 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

Slide 1.3

Objectives for session 1

- 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

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.

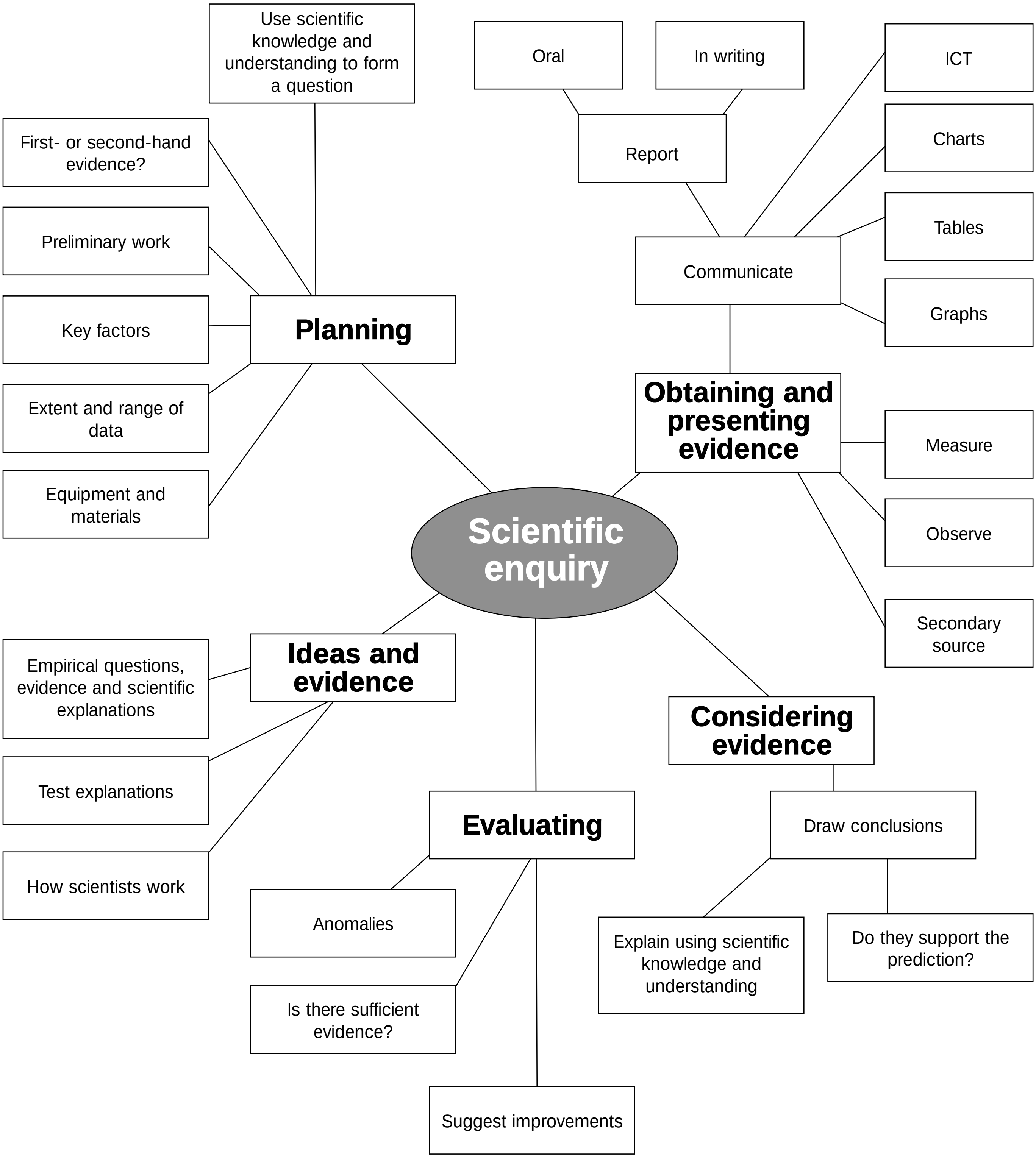
The views expressed here and in the other clips in this CPD unit were recorded in 2001 specifically for the Key Stage 3 science strand. Professor Wolpert expresses his thoughts on science and scientific methods clearly and succinctly, providing us with a starting point for our own reflection.

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

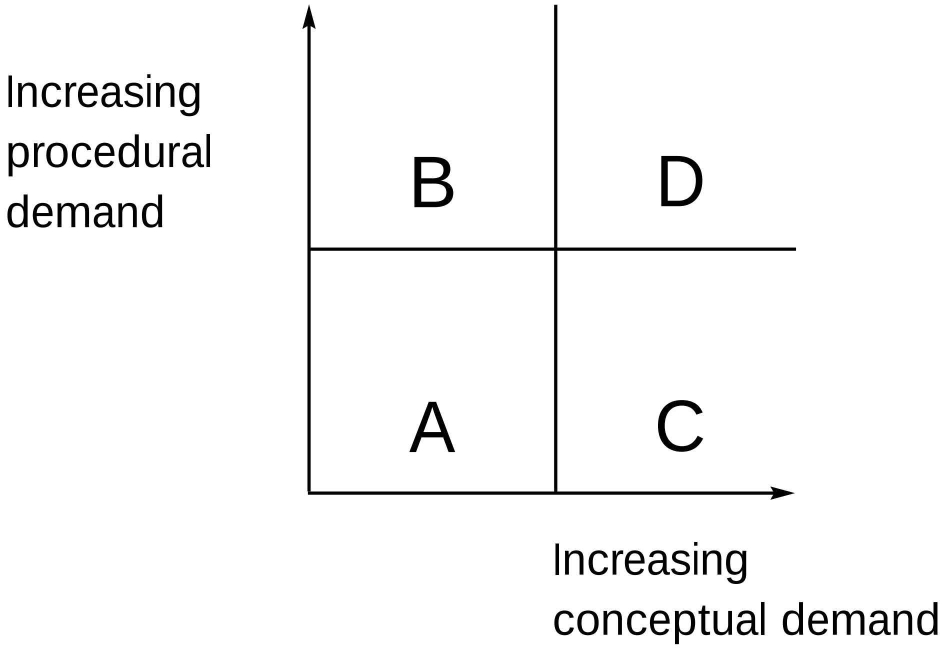
Objective	Activity	Notes
Consider how some early scientific ideas do not match present-day evidence, and describe how new creative thinking has been used to provide a scientific explanation.		
Identify more than one strategy for investigating questions and recognise that one enquiry might yield stronger 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

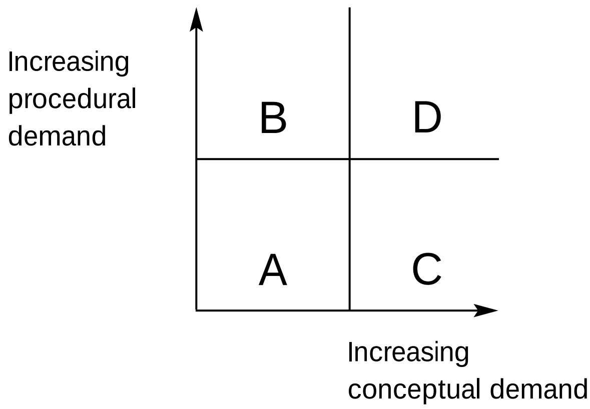
Objective	Activity	Notes
Explain how scientific ideas have changed over time; describe some of the positive and negative effects of scientific and technological developments.		
Select and use a suitable strategy for solving a problem; identify strategies appropriate to different questions, including 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		

Slide 1.8

The demand of an enquiry



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 …'

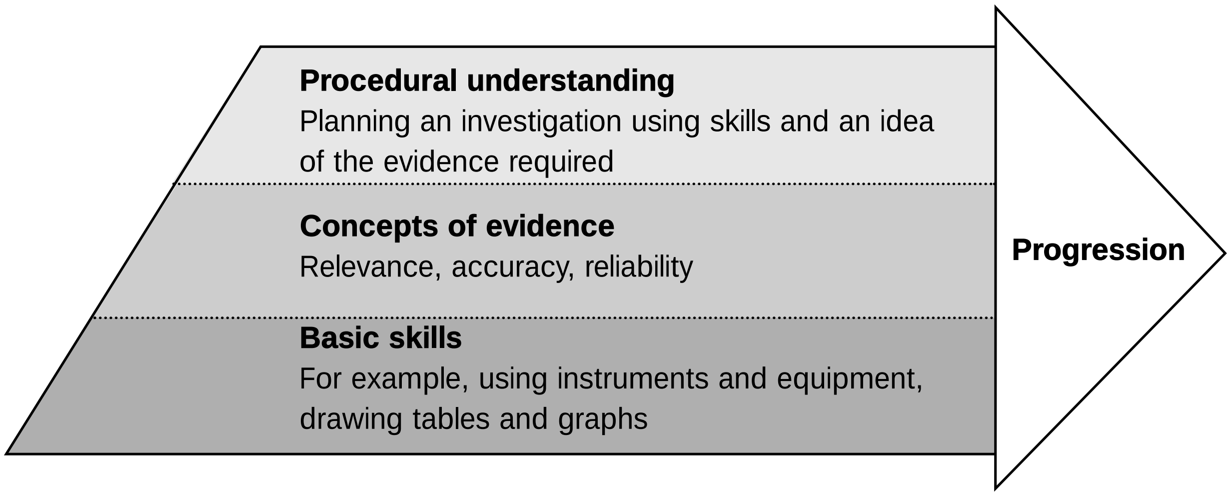
6 QCA Unit 7E 'Acids and alkalis'
Page 2 'How can acids and alkalis be identified and distinguished from each other?'
4th activity beginning: 'Provide pupils with a range of acidic and alkaline solutions …'

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 …'

Slide 1.11

Illustrating progression in scientific enquiry



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

Slide 1.12

Plenary for session 1

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.

Slide 2.1

Objectives for session 2

- 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

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

Handout 2.3

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.

Slide 2.6

Task D

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.

Slide 2.7

Extracts from the programmes of study

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

Possible objectives

- To know how to take repeat readings and calculate the average (mean)
- To understand the purpose of taking repeat readings

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.

Slide 2.12

Plenary for session 2

By the end of the session participants should:

- be clearer about what constitutes an appropriate lesson objective for scientific enquiry;
- be clearer on the value of using the yearly teaching objectives for scientific enquiry;
- have considered some ideas on how to teach scientific enquiry skills and processes explicitly.

Slide 3.1

Objective for session 3

- 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)*

Slide 3.2

Types of scientific enquiry

- 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

Slide 3.3

Task F

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.

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?	

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?	

Slide 3.6

Using different types of enquiry

- 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?

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		

Slide 3.8

Task G

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.

Slide 4.1

Ideas and evidence

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

Slide 4.2

Objective for session 4

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

Slide 4.3

Task H

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?

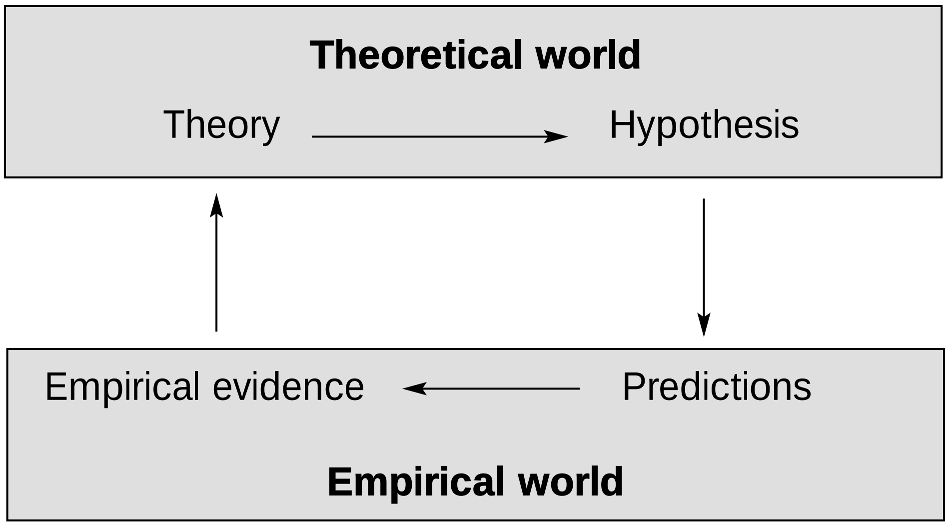
Transcript of audio clip 2

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.

Slide 4.5

The interplay between ideas and evidence



Based on the work of Robin Dunbar

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.

Slide 4.7

Definitions of terms

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

Slide 4.8

Task I

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.

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.

Slide 4.10

Plenary for session 4

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.

Slide 5.1

Objectives for session 5

- 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

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 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? Why do you think the lemonade fizzes?	
	Prediction	What will happen when we add insoluble chalk powder?	
Carry out the test	Observing 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? 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. Discuss the amount of evidence. How can you make it reliable?
6 Draw conclusions.	Is there a pattern to the results? Describe it. Draw a conclusion. How does this link with your idea?
7 Evaluate the evidence.	Is the evidence convincing? Could it have been done better? 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.

Slide 5.9

Plenary for session 5

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.

Slide 6.1

Objective for session 6

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

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?

Slide 6.3

Task N

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?

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? 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.

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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	
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12	
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14	
15	
16	
17	
18	
19	
20	

Handout 6.10

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.

Slide 6.12

Plenary for session 6

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.

Slide 7.1

Objective for session 7

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

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.