The National Strategies
Secondary

Science subject leader development materials

Spring 2010

department for
children, schools and families

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First published in 2010
Ref: 00004-2010DOM-EN

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Contents

Powerpoint™ handouts

Handouts

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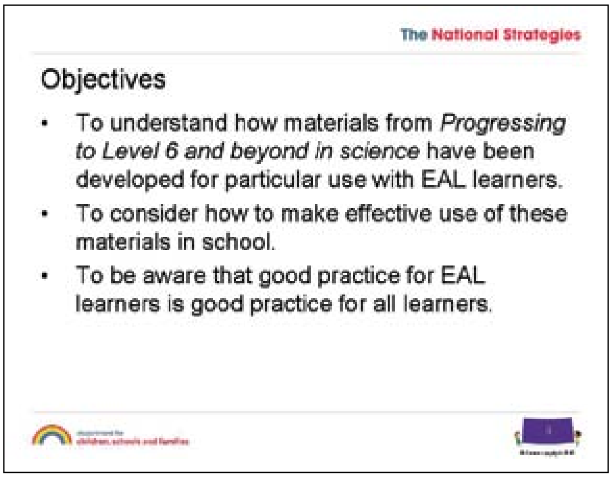
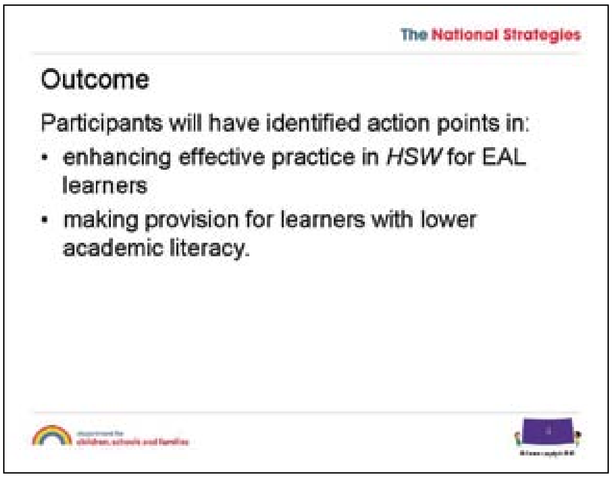
HSW with additional guidance for supporting EAL learners



Objectives

- To understand how materials from *Progressing to Level 6 and beyond in science* have been developed for particular use with EAL learners.
- To consider how to make effective use of these materials in school.
- To be aware that good practice for EAL learners is good practice for all learners.



Outcome

Participants will have identified action points in:

- enhancing effective practice in *HSW* for EAL learners
- making provision for learners with lower academic literacy.

Additional materials have been added to this resource to support:

- the teaching of *How science works*
- understanding *How science works*
- the writing of descriptions, explanations and arguments

They can be accessed from **Lab C** and the **CPD room** in the local school or from the grouped resources button. The underlying approach is based on a simple '**Steps and Layers**' and the **Steps 1–4 overview** shows the suggested steps in 10 areas that can prevent pupils progressing to level 6 and beyond.

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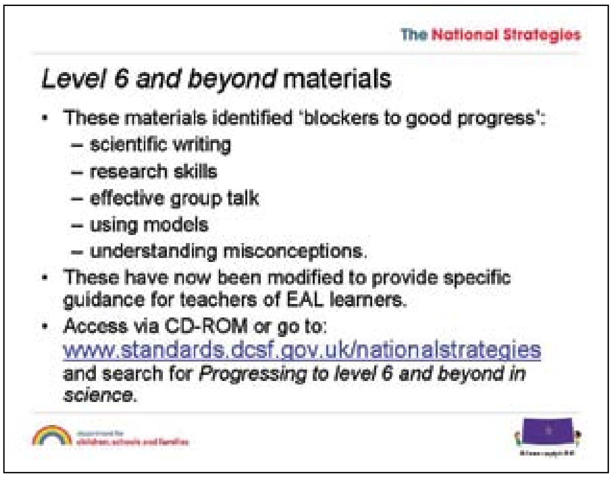

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Level 6 and beyond materials

- These materials identified 'blockers to good progress':
  - scientific writing
  - research skills
  - effective group talk
  - using models
  - understanding misconceptions.
- These have now been modified to provide specific guidance for teachers of EAL learners.
- Access via CD-ROM or go to: www.standards.dcsf.gov.uk/nationalstrategies and search for *Progressing to level 6 and beyond in science.*

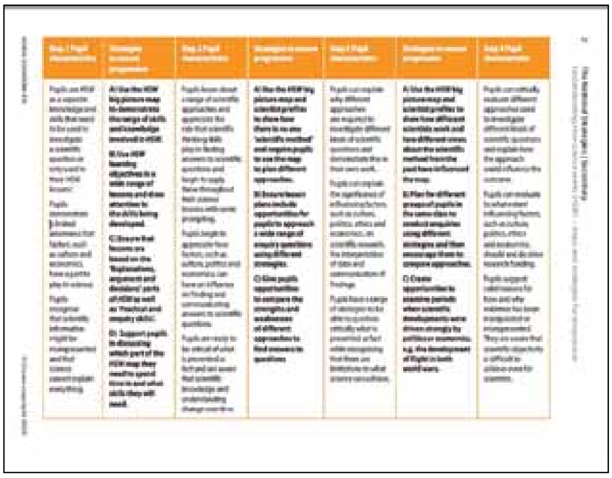
STEPS AND LAYERS APPROACH

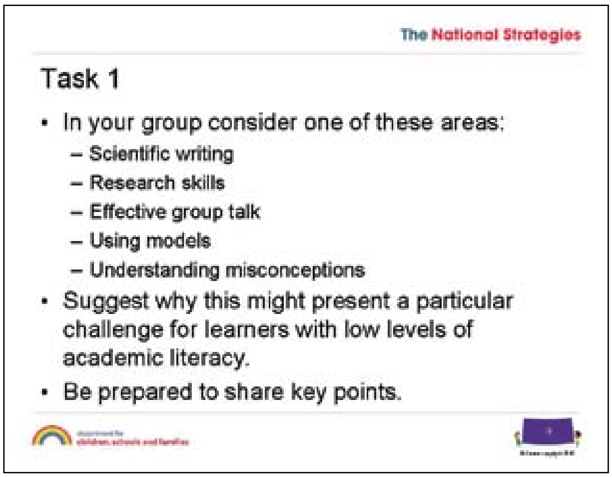
1. The approach used in this resource is based on identifying 'where the pupils are' using a simple steps table.

2. The next layer identifies some teaching strategies that could be used to move the pupils onto the next step.

3. The teacher guidance forms the final layer containing more detail on the teaching strategies and from which resources are linked.

>> More detail about the approach can be found in the Subject leader guidance or main Teacher guidance





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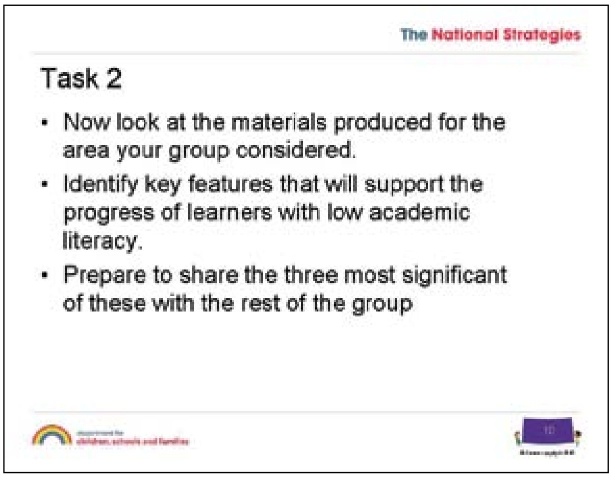
Task 1

- In your group consider one of these areas:
  - Scientific writing
  - Research skills
  - Effective group talk
  - Using models
  - Understanding misconceptions
- Suggest why this might present a particular challenge for learners with low levels of academic literacy.
- Be prepared to share key points.



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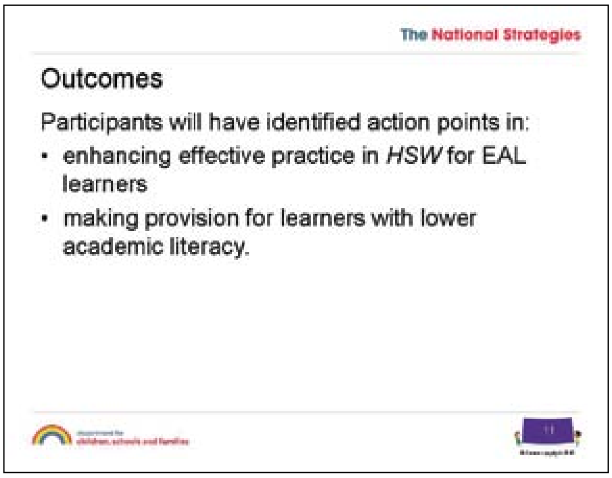
Task 2

- Now look at the materials produced for the area your group considered.
- Identify key features that will support the progress of learners with low academic literacy.
- Prepare to share the three most significant of these with the rest of the group



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Outcomes

Participants will have identified action points in:

- enhancing effective practice in *HSW* for EAL learners
- making provision for learners with lower academic literacy.

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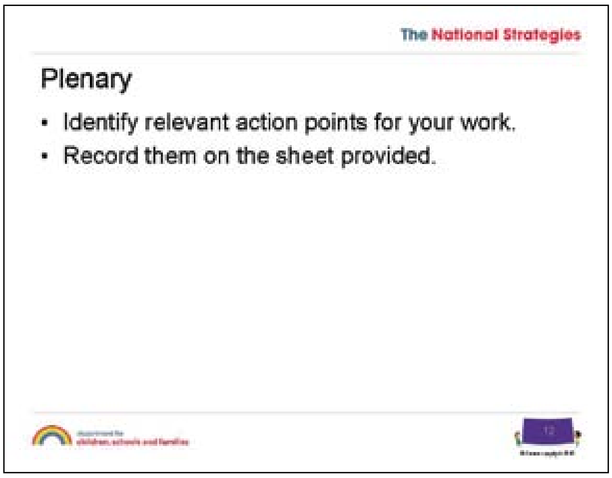

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Plenary

- Identify relevant action points for your work.
- Record them on the sheet provided.

Using data to analyse pupils' attainment and progress in science

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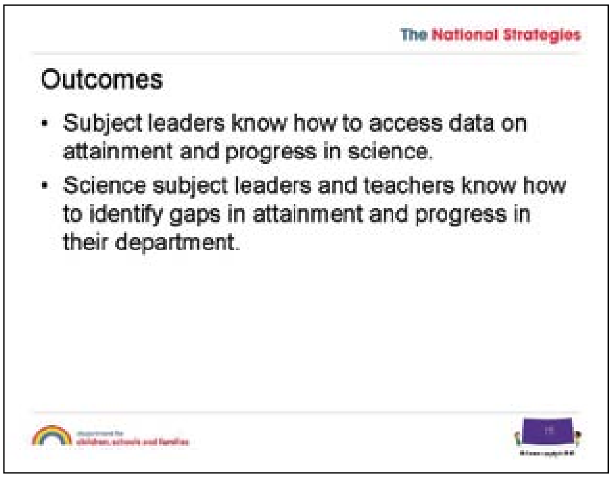
Objective

- To support the process of identifying underperforming groups and individuals in science.



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Outcomes

- Subject leaders know how to access data on attainment and progress in science.
- Science subject leaders and teachers know how to identify gaps in attainment and progress in their department.

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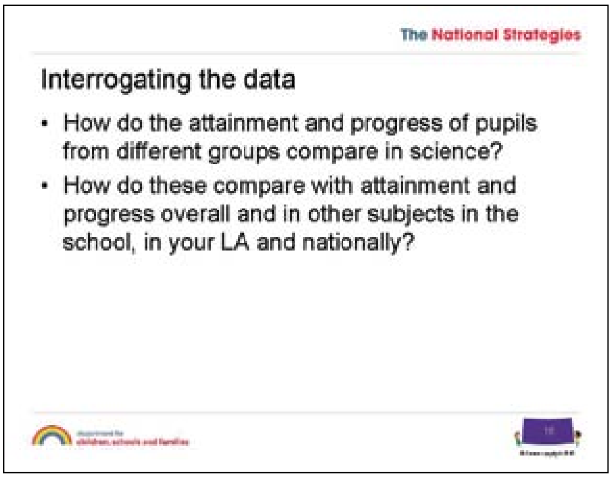

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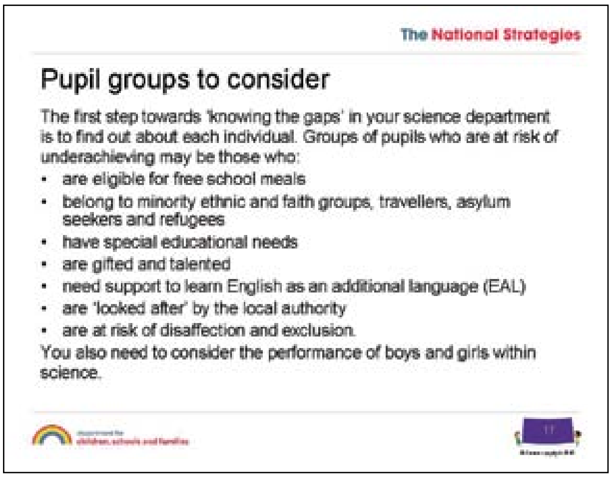
Interrogating the data

- How do the attainment and progress of pupils from different groups compare in science?
- How do these compare with attainment and progress overall and in other subjects in the school, in your LA and nationally?



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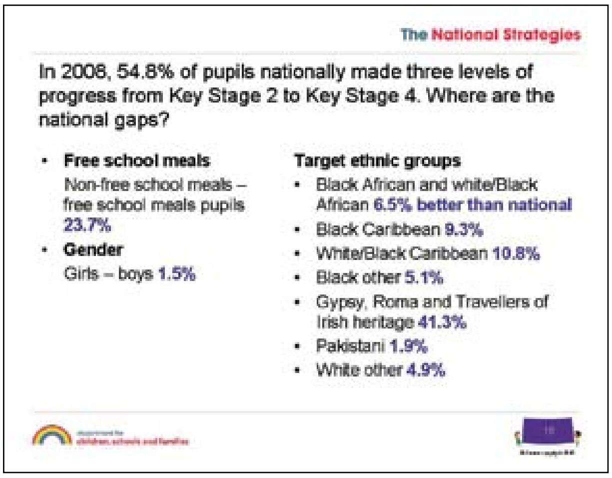
Pupil groups to consider

The first step towards 'knowing the gaps' in your science department is to find out about each individual. Groups of pupils who are at risk of underachieving may be those who:

- are eligible for free school meals
- belong to minority ethnic and faith groups, travellers, asylum seekers and refugees
- have special educational needs
- are gifted and talented
- need support to learn English as an additional language (EAL)
- are 'looked after' by the local authority
- are at risk of disaffection and exclusion.

You also need to consider the performance of boys and girls within science.



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In 2008, 54.8% of pupils nationally made three levels of progress from Key Stage 2 to Key Stage 4. Where are the national gaps?

- **Free school meals**
  Non-free school meals – free school meals pupils **23.7%**
- **Gender**
  Girls – boys **1.5%**

Target ethnic groups

- Black African and white/Black African **6.5% better than national**
- Black Caribbean **9.3%**
- White/Black Caribbean **10.8%**
- Black other **5.1%**
- Gypsy, Roma and Travellers of Irish heritage **41.3%**
- Pakistani **1.9%**
- White other **4.9%**

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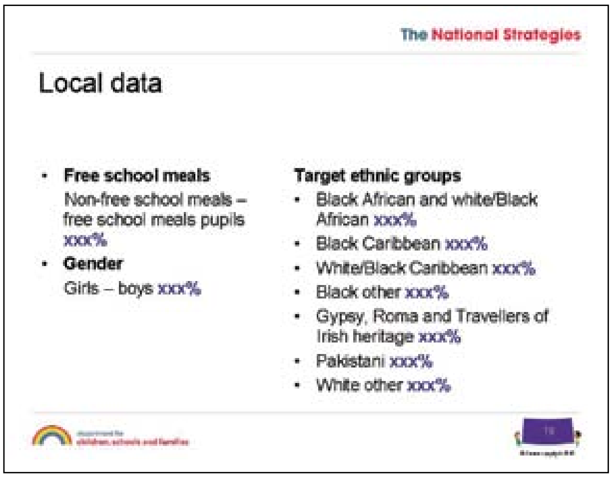

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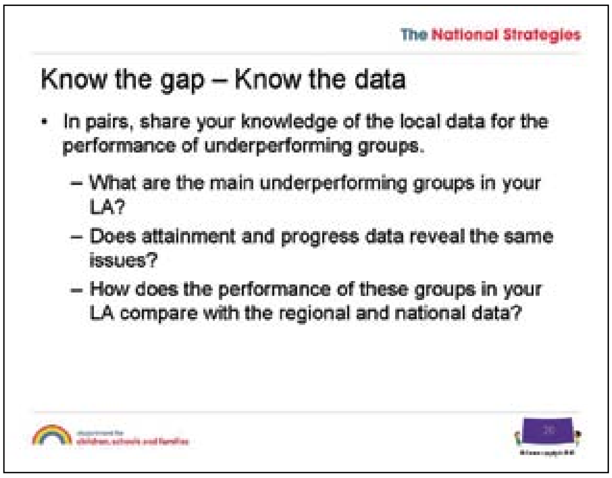
Local data

- **Free school meals**
  Non-free school meals – free school meals pupils xxx%
- **Gender**
  Girls – boys xxx%

Target ethnic groups

- Black African and white/Black African xxx%
- Black Caribbean xxx%
- White/Black Caribbean xxx%
- Black other xxx%
- Gypsy, Roma and Travellers of Irish heritage xxx%
- Pakistani xxx%
- White other xxx%



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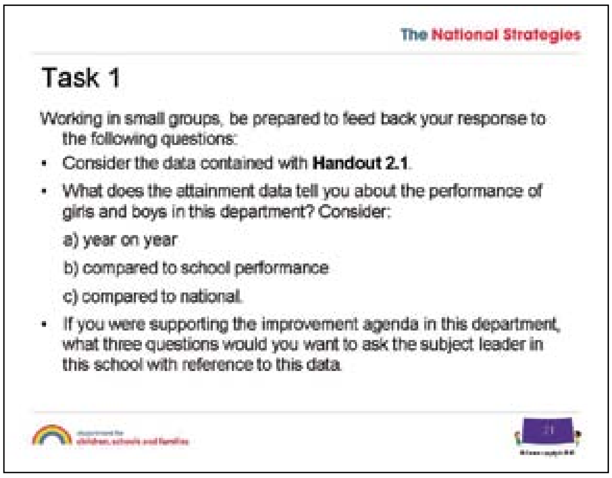
Know the gap – Know the data

- In pairs, share your knowledge of the local data for the performance of underperforming groups.
  - What are the main underperforming groups in your LA?
  - Does attainment and progress data reveal the same issues?
  - How does the performance of these groups in your LA compare with the regional and national data?



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Task 1

Working in small groups, be prepared to feed back your response to the following questions:

- Consider the data contained with **Handout 2.1**.
- What does the attainment data tell you about the performance of girls and boys in this department? Consider:
  a) year on year
  b) compared to school performance
  c) compared to national.
- If you were supporting the improvement agenda in this department, what three questions would you want to ask the subject leader in this school with reference to this data.

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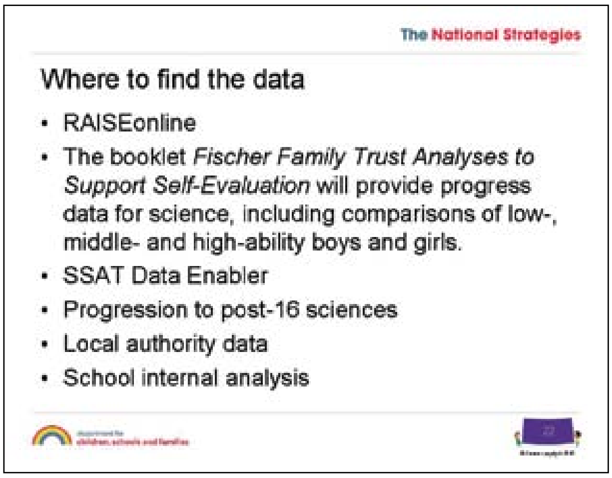

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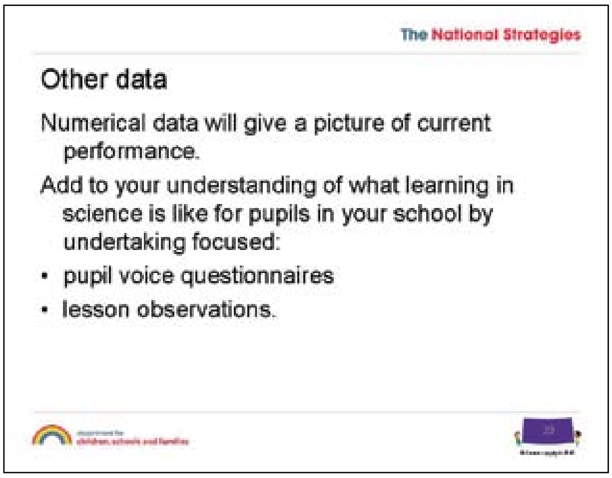
Where to find the data

- RAISEonline
- The booklet *Fischer Family Trust Analyses to Support Self-Evaluation* will provide progress data for science, including comparisons of low-, middle- and high-ability boys and girls.
- SSAT Data Enabler
- Progression to post-16 sciences
- Local authority data
- School internal analysis



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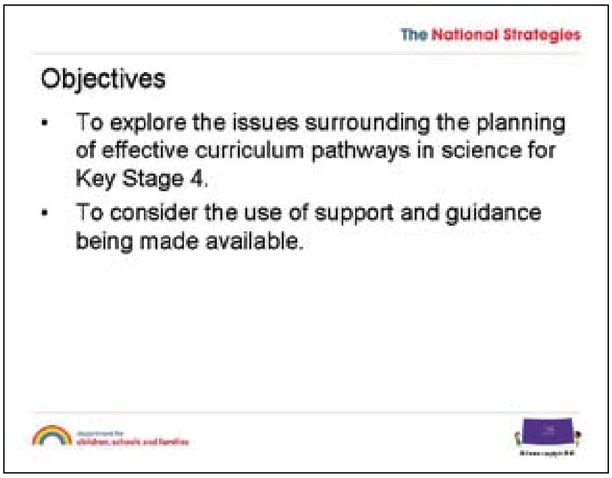
Other data

Numerical data will give a picture of current performance.

Add to your understanding of what learning in science is like for pupils in your school by undertaking focused:

- pupil voice questionnaires
- lesson observations.

Curriculum models



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Objectives

- To explore the issues surrounding the planning of effective curriculum pathways in science for Key Stage 4.
- To consider the use of support and guidance being made available.

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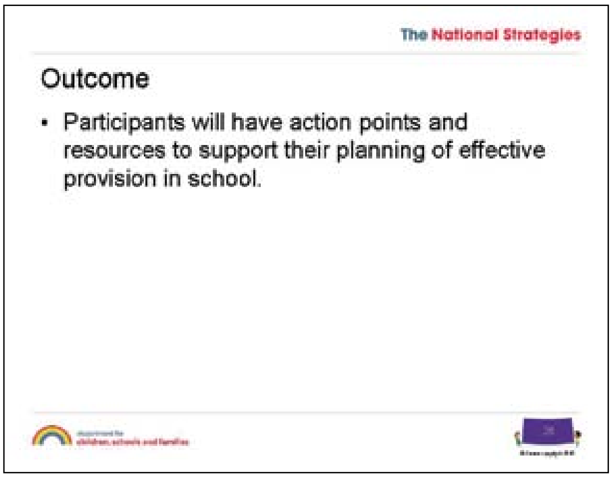

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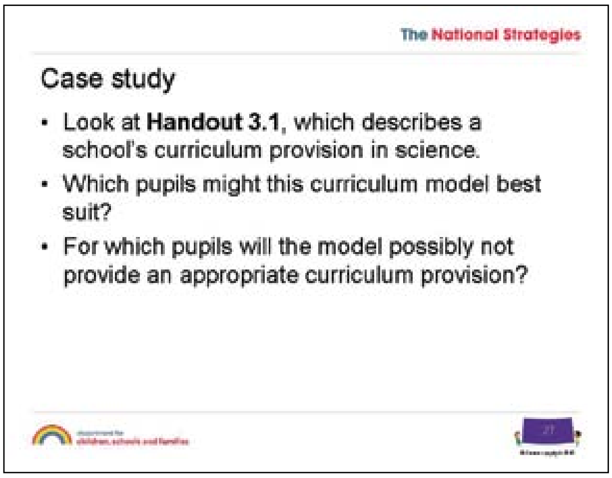
Outcome

- Participants will have action points and resources to support their planning of effective provision in school.



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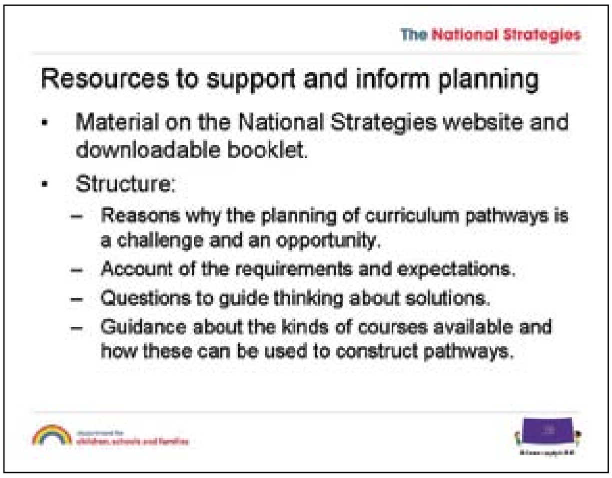
Case study

- Look at **Handout 3.1**, which describes a school's curriculum provision in science.
- Which pupils might this curriculum model best suit?
- For which pupils will the model possibly not provide an appropriate curriculum provision?



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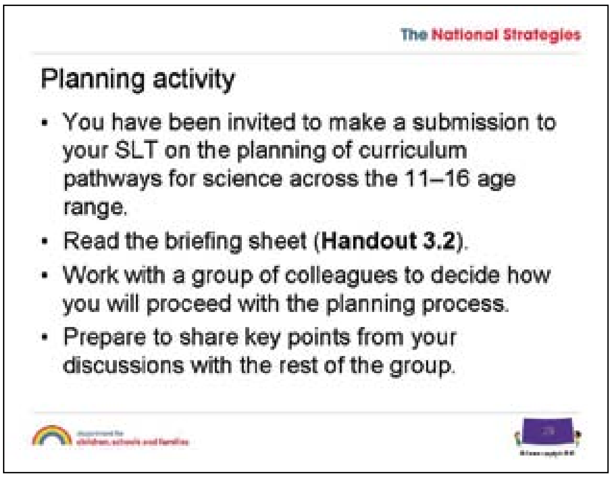
Resources to support and inform planning

- Material on the National Strategies website and downloadable booklet.
- Structure:
  - Reasons why the planning of curriculum pathways is a challenge and an opportunity.
  - Account of the requirements and expectations.
  - Questions to guide thinking about solutions.
  - Guidance about the kinds of courses available and how these can be used to construct pathways.



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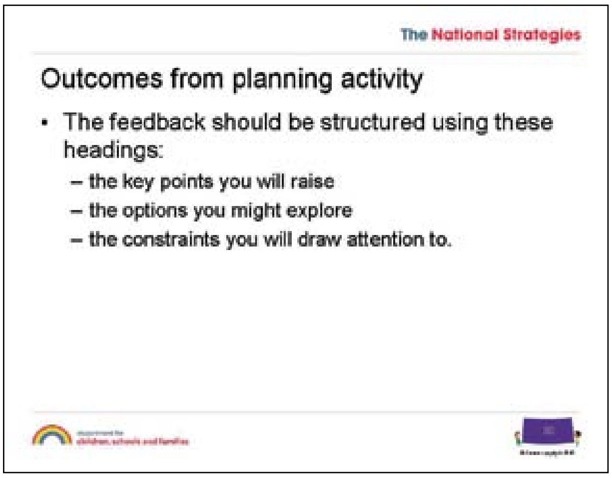
Planning activity

- You have been invited to make a submission to your SLT on the planning of curriculum pathways for science across the 11–16 age range.
- Read the briefing sheet (**Handout 3.2**).
- Work with a group of colleagues to decide how you will proceed with the planning process.
- Prepare to share key points from your discussions with the rest of the group.



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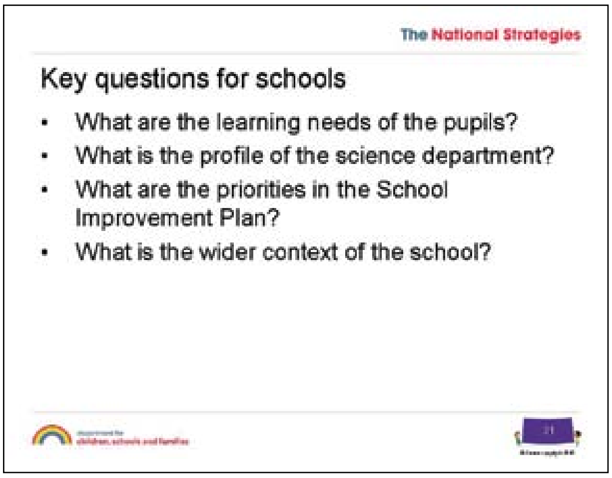
Outcomes from planning activity

- The feedback should be structured using these headings:
  - the key points you will raise
  - the options you might explore
  - the constraints you will draw attention to.



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Key questions for schools

- What are the learning needs of the pupils?
- What is the profile of the science department?
- What are the priorities in the School Improvement Plan?
- What is the wider context of the school?

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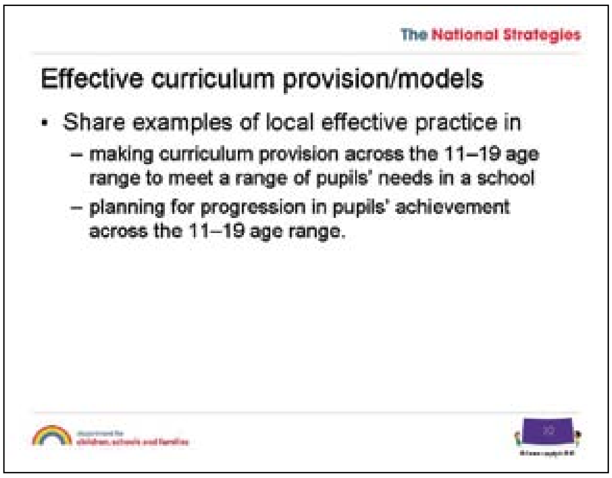

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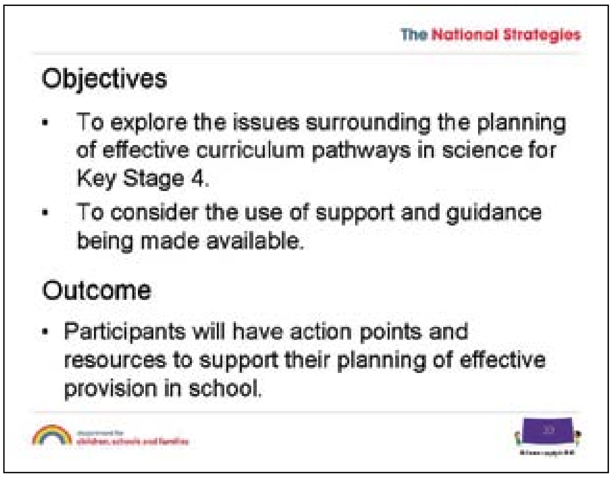
Effective curriculum provision/models

- Share examples of local effective practice in
  - making curriculum provision across the 11–19 age range to meet a range of pupils' needs in a school
  - planning for progression in pupils' achievement across the 11–19 age range.



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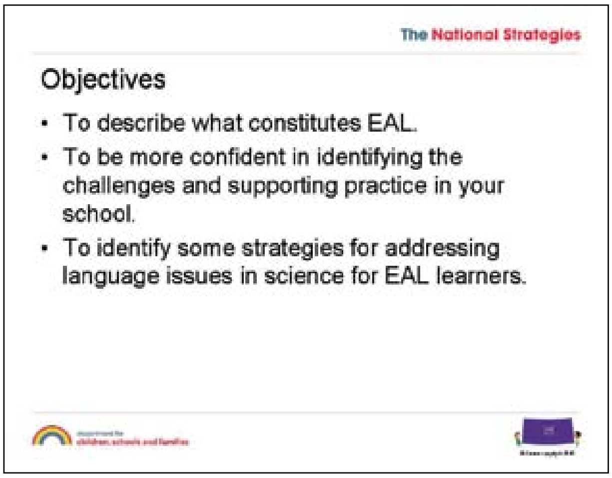
Objectives

- To explore the issues surrounding the planning of effective curriculum pathways in science for Key Stage 4.
- To consider the use of support and guidance being made available.

Outcome

- Participants will have action points and resources to support their planning of effective provision in school.

Supporting EAL pupils



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Objectives

- To describe what constitutes EAL.
- To be more confident in identifying the challenges and supporting practice in your school.
- To identify some strategies for addressing language issues in science for EAL learners.

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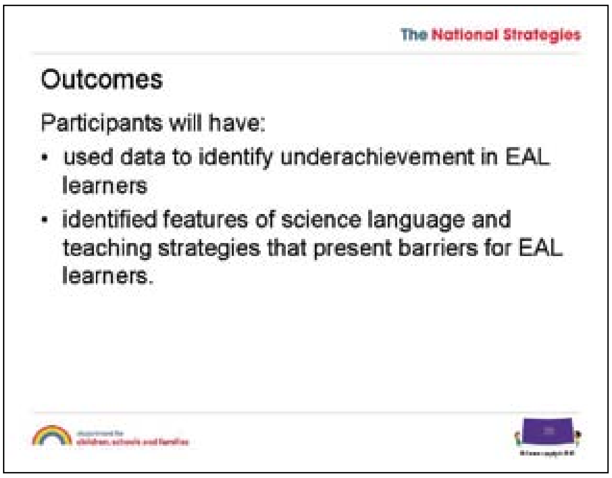

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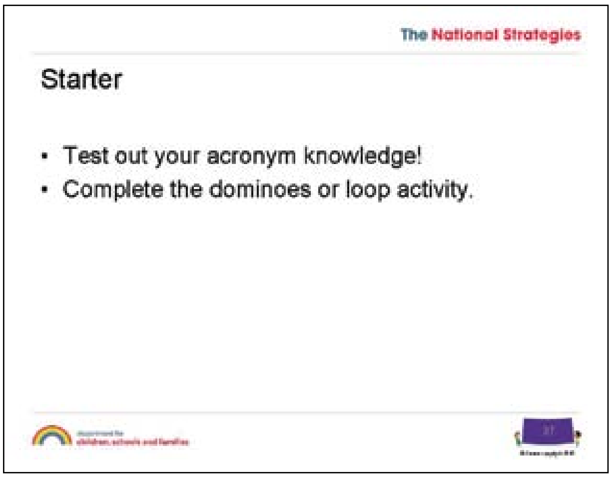
Outcomes

Participants will have:

- used data to identify underachievement in EAL learners
- identified features of science language and teaching strategies that present barriers for EAL learners.



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Starter

- Test out your acronym knowledge!
- Complete the dominoes or loop activity.

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What do you know?

Task 1

Discuss in pairs how your school supports EAL pupils or pupils with low-level academic language skills.

Identify from your table one aspect of effective practice.

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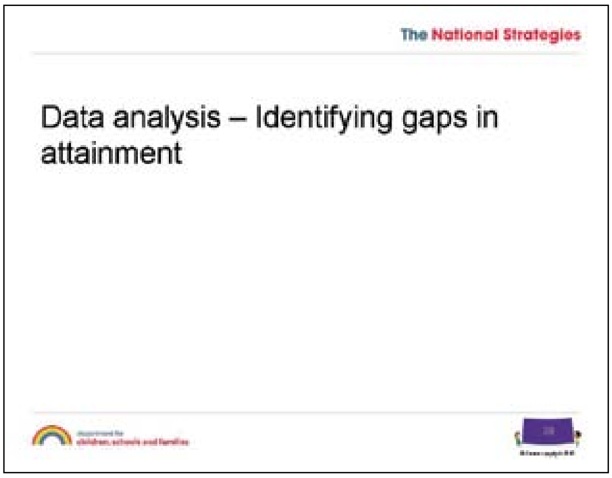
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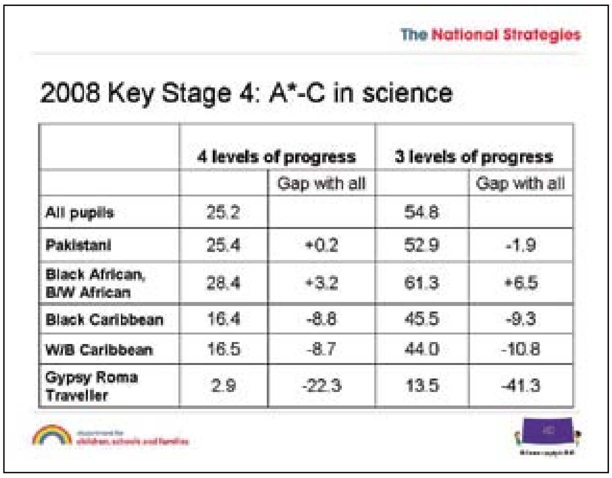
Data analysis – Identifying gaps in attainment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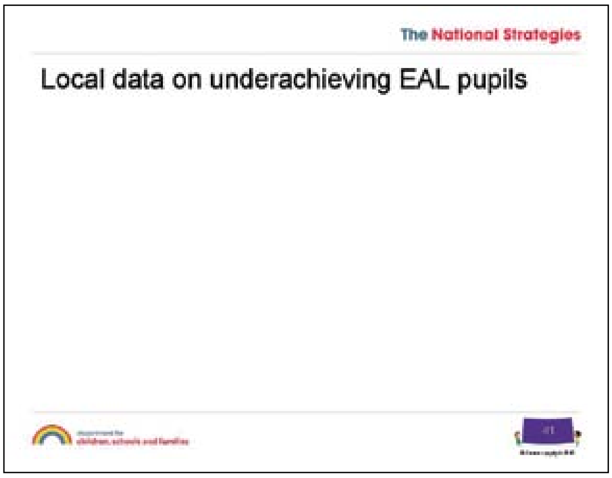
2008 Key Stage 4: A*-C in science

	4 levels of progress		3 levels of progress	
		Gap with all		Gap with all
All pupils	25.2		54.8	
Pakistani	25.4	+0.2	52.9	-1.9
Black African, B/W African	28.4	+3.2	61.3	+6.5
Black Caribbean	16.4	-8.8	45.5	-9.3
W/B Caribbean	16.5	-8.7	44.0	-10.8
Gypsy Roma Traveller	2.9	-22.3	13.5	-41.3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Local data on underachieving EAL pupils

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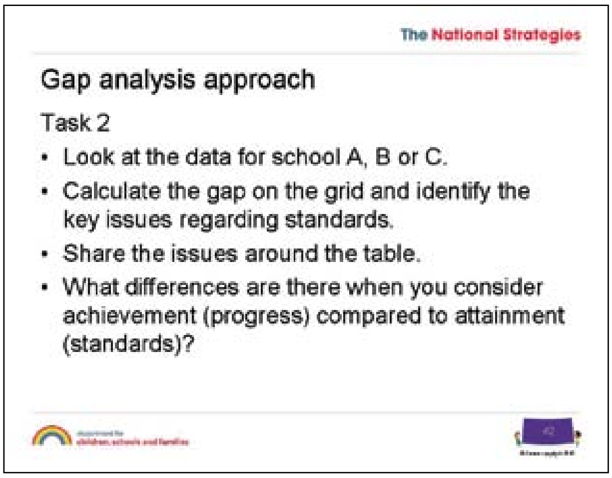

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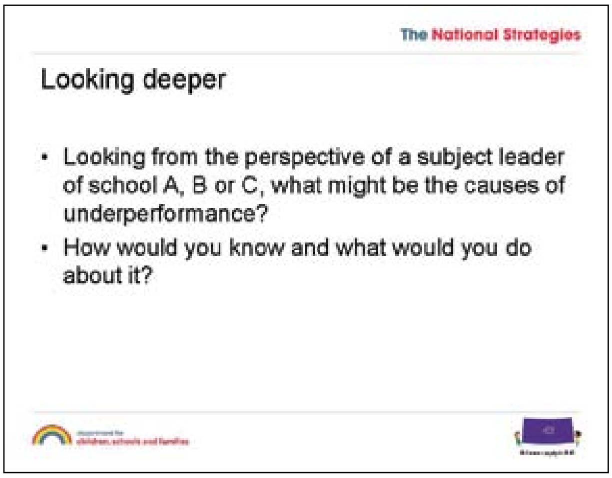
Gap analysis approach

Task 2

- Look at the data for school A, B or C.
- Calculate the gap on the grid and identify the key issues regarding standards.
- Share the issues around the table.
- What differences are there when you consider achievement (progress) compared to attainment (standards)?



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Looking deeper

- Looking from the perspective of a subject leader of school A, B or C, what might be the causes of underperformance?
- How would you know and what would you do about it?

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Challenging practice

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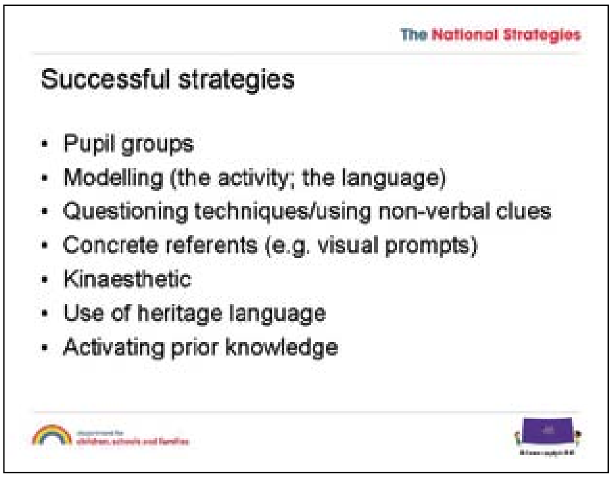
Is it good practice?

Task 3

- Place the cards on the continuum using 'gut instinct'.
- Use reusable adhesive to attach the cards.
- Compare your answers across the table and provide peer support.



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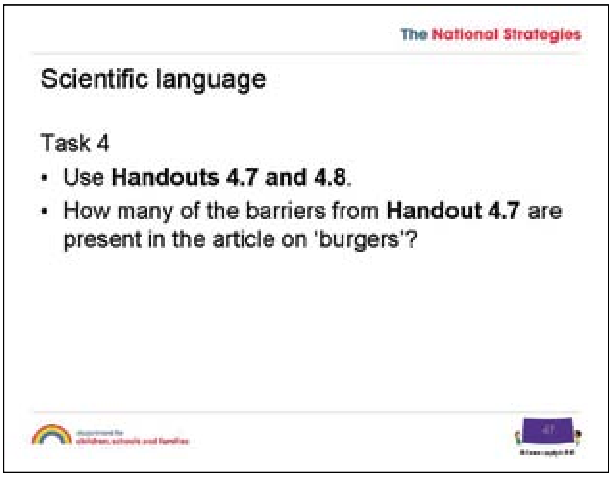
Successful strategies

- Pupil groups
- Modelling (the activity; the language)
- Questioning techniques/using non-verbal clues
- Concrete referents (e.g. visual prompts)
- Kinaesthetic
- Use of heritage language
- Activating prior knowledge



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Scientific language

Task 4

- Use **Handouts 4.7 and 4.8**.
- How many of the barriers from **Handout 4.7** are present in the article on 'burgers'?

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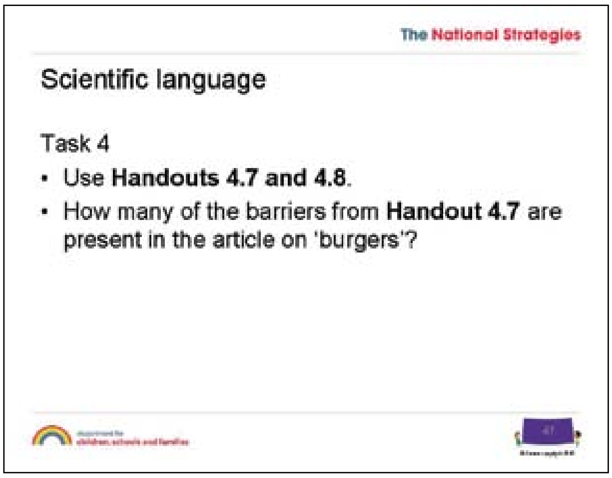

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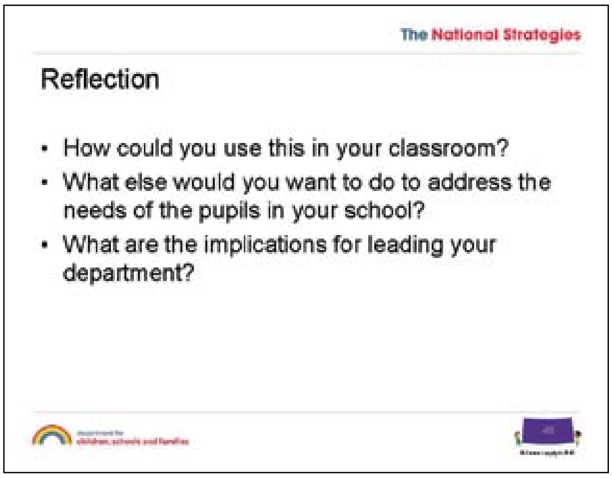
Scientific language

Task 4

- Use **Handouts 4.7 and 4.8**.
- How many of the barriers from **Handout 4.7** are present in the article on 'burgers'?



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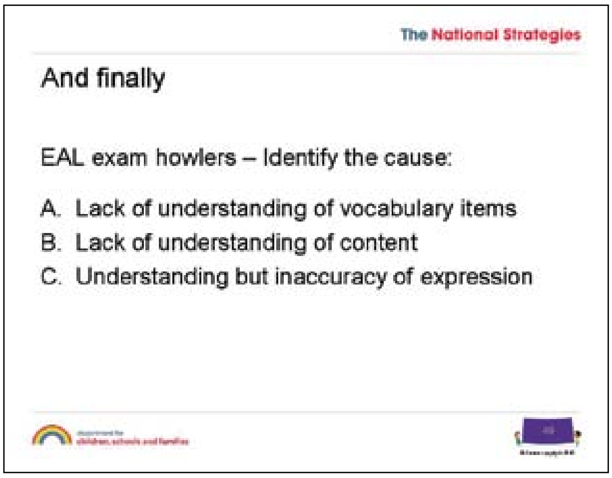
Reflection

- How could you use this in your classroom?
- What else would you want to do to address the needs of the pupils in your school?
- What are the implications for leading your department?



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And finally

EAL exam howlers – Identify the cause:

A. Lack of understanding of vocabulary items
B. Lack of understanding of content
C. Understanding but inaccuracy of expression

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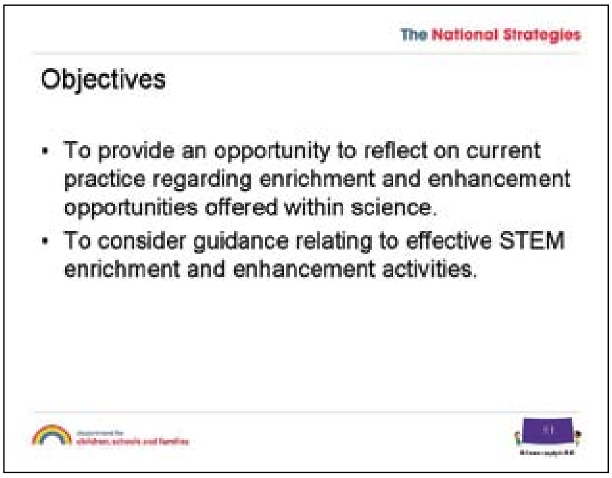
Effective enrichment and enhancement in science (as part of STEM)



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Objectives

- To provide an opportunity to reflect on current practice regarding enrichment and enhancement opportunities offered within science.
- To consider guidance relating to effective STEM enrichment and enhancement activities.

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Outcomes

Participants will have:

- considered the effectiveness and clarity of purpose of current enrichment and enhancement provision in science
- explored how the impact of enrichment and enhancement activities could be increased.

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What is enrichment and enhancement?

- What is it?
- What does this look like in science?
- Why do we need it? (Why is it important?)
- What makes it effective?
- Who is it for?
- Where and when does it happen now?
- Who does it involve?
- Who provides enrichment and enhancement?
- Who can support specific activities?

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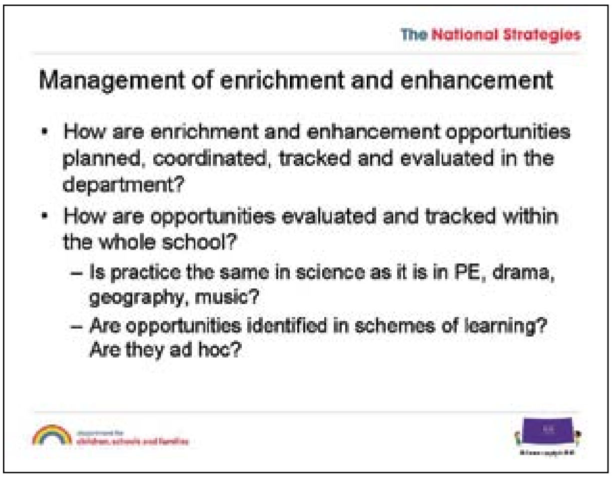
Range of enrichment and enhancement

- What enrichment and enhancement activities do you currently provide for your students?
  - Which of these take place outside the classroom?
  - Which are an integral part of lessons in science? (How do you know?)
  - Which do not fit into either of these categories? (Where do they fit?)
- How are these activities related to pupils' learning:
  - By all the teachers in the department?
  - By the pupils involved?
  - By pupils' parents?
  - By the school leadership team?



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Management of enrichment and enhancement

- How are enrichment and enhancement opportunities planned, coordinated, tracked and evaluated in the department?
- How are opportunities evaluated and tracked within the whole school?
  - Is practice the same in science as it is in PE, drama, geography, music?
  - Are opportunities identified in schemes of learning? Are they ad hoc?

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Management of enrichment and enhancement

- How are external contributions supported by the science team? (Who briefs visitors, pupils, caretakers, other teachers and ensures the event goes smoothly?)
- How are opportunities within science lessons supported? (TAs, technicians, team teaching, parents?)

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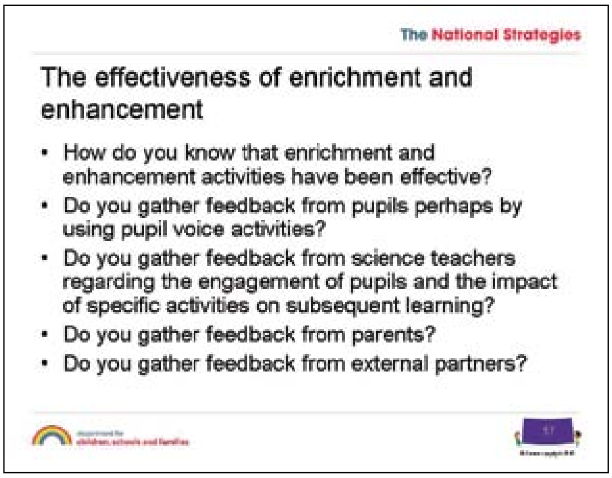

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The effectiveness of enrichment and enhancement

- How do you know that enrichment and enhancement activities have been effective?
- Do you gather feedback from pupils perhaps by using pupil voice activities?
- Do you gather feedback from science teachers regarding the engagement of pupils and the impact of specific activities on subsequent learning?
- Do you gather feedback from parents?
- Do you gather feedback from external partners?

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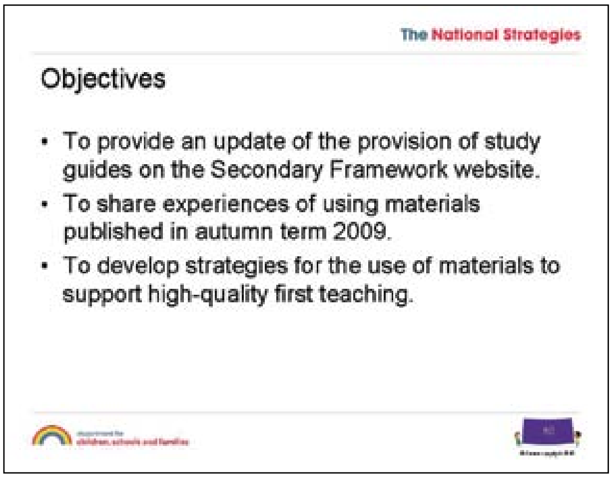
Next steps

- Reflect on the discussions that have taken place today and the resources you have seen.
- How could you change the way in which enrichment and enhancement is approached in your school to make it more effective and to increase the impact on pupils' learning and engagement with science?

Using study guides to support high-quality first teaching



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Objectives

- To provide an update of the provision of study guides on the Secondary Framework website.
- To share experiences of using materials published in autumn term 2009.
- To develop strategies for the use of materials to support high-quality first teaching.

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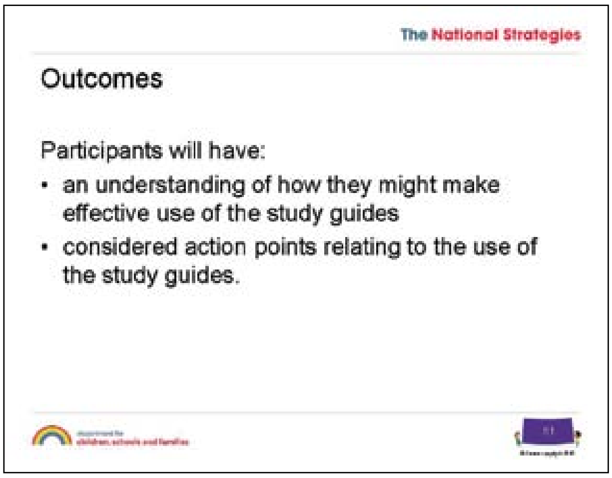

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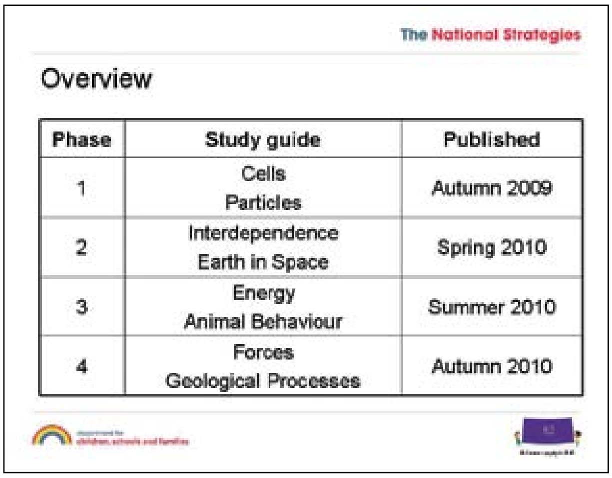
Outcomes

Participants will have:

- an understanding of how they might make effective use of the study guides
- considered action points relating to the use of the study guides.



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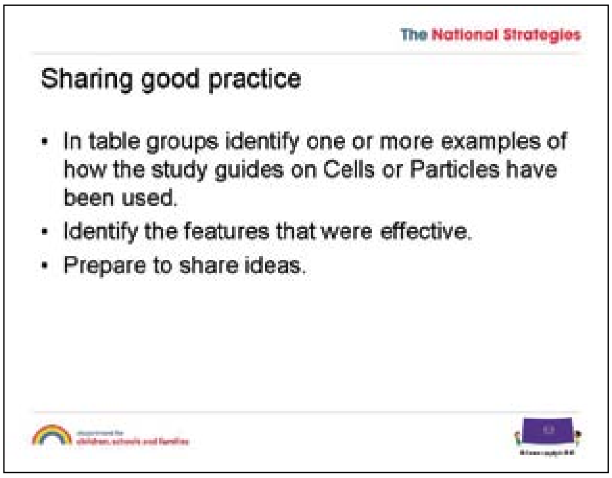
Overview

Phase	Study guide	Published
1	Cells Particles	Autumn 2009
2	Interdependence Earth in Space	Spring 2010
3	Energy Animal Behaviour	Summer 2010
4	Forces Geological Processes	Autumn 2010



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Sharing good practice

- In table groups identify one or more examples of how the study guides on Cells or Particles have been used.
- Identify the features that were effective.
- Prepare to share ideas.

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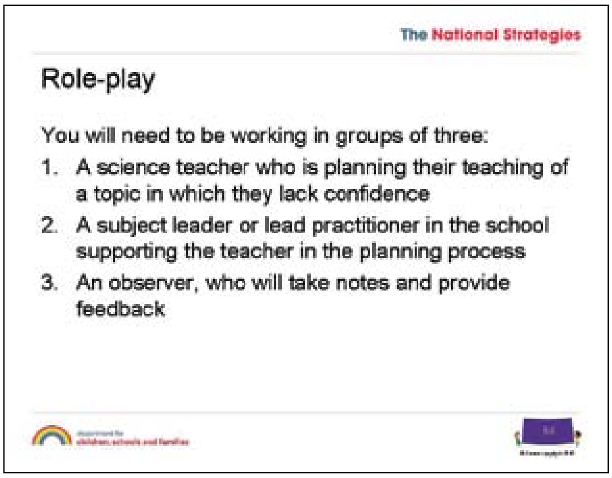

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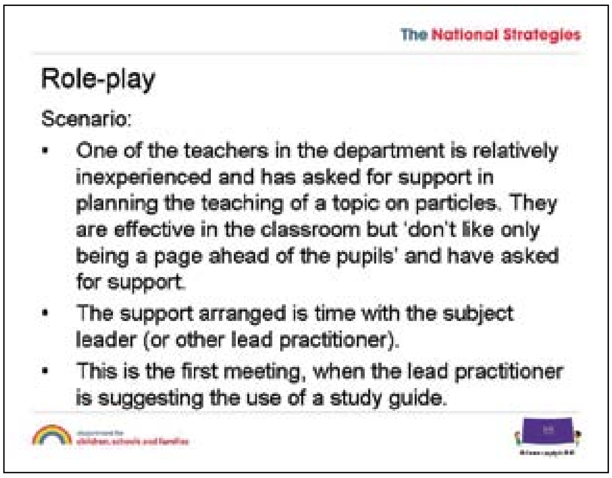
Role-play

You will need to be working in groups of three:

1. A science teacher who is planning their teaching of a topic in which they lack confidence
2. A subject leader or lead practitioner in the school supporting the teacher in the planning process
3. An observer, who will take notes and provide feedback



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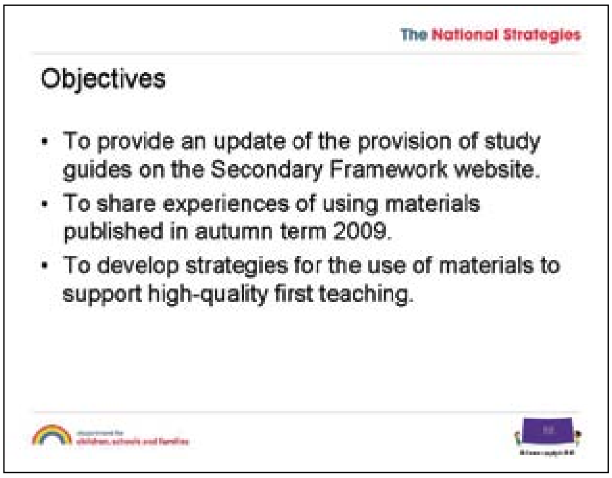
Role-play

Scenario:

- One of the teachers in the department is relatively inexperienced and has asked for support in planning the teaching of a topic on particles. They are effective in the classroom but 'don't like only being a page ahead of the pupils' and have asked for support.
- The support arranged is time with the subject leader (or other lead practitioner).
- This is the first meeting, when the lead practitioner is suggesting the use of a study guide.



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Objectives

- To provide an update of the provision of study guides on the Secondary Framework website.
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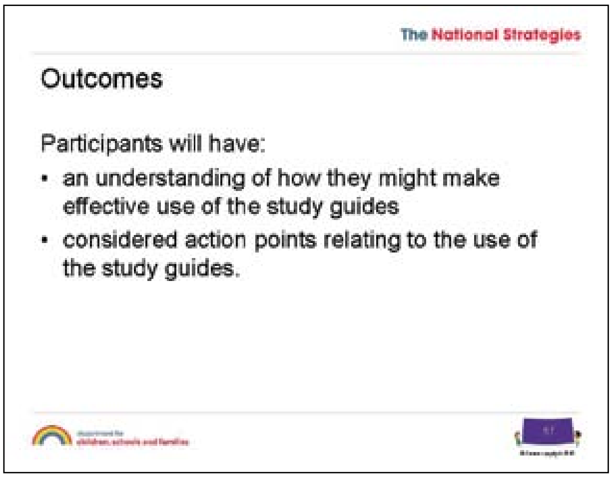

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Outcomes

Participants will have:

- an understanding of how they might make effective use of the study guides
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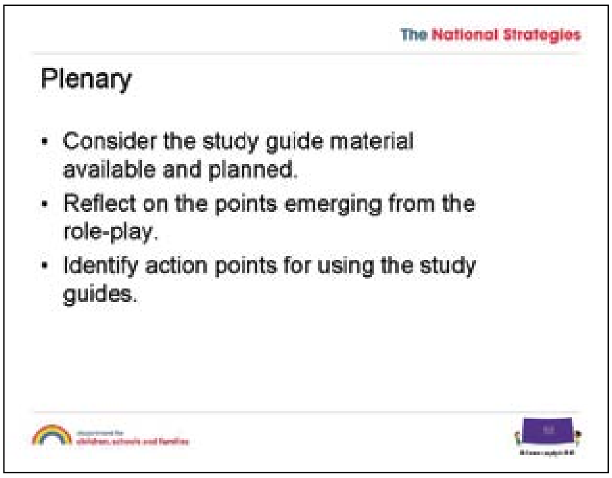

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Plenary

- Consider the study guide material available and planned.
- Reflect on the points emerging from the role-play.
- Identify action points for using the study guides.

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Handout 1.1: Aspects of *How science works* (*HSW*) – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about helping pupils to develop some of the more challenging aspects of the practical *HSW* skills. While many pupils can draw graphs well, fewer understand how to interpret the graphs and the principle of the 'line of best fit'. Variables can remain a mystery to many as they do not understand the interplay between the different types, nor how the choice and range can influence the results of an experiment. How often have pupils written 'I could of done it better' [sic] or 'I needed to do more readings' [sic] as their evaluation? Pupils need to be able to identify and explain sources of experimental error and to take account of these in their additional design.[1]

Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils can:

- present work or data as a graph although the scales may be incorrect;
- identify the pattern shown by the graph and possible anomalous results;
- identify the key factors to be considered and generally assign sensible values to them;
- measure a variety of quantities with precision;
- draw conclusions consistent with the evidence and generally analyse data qualitatively;
- explain how their planning and implementation could be improved.

Step 2 – pupil characteristics

Pupils can:

- choose an appropriate type of graph and scale(s) to display the data effectively;
- explain what the shape of the graph represents and interpret graphs with a negative scale on one axis;
- identify relevant independent and dependent variables;
- choose an appropriate range, number and value for each variable;
- make enough measurements, observations and comparisons for the task;
- draw conclusions consistent with evidence and use scientific knowledge and understanding to explain them;
- explain how planning and implementation could be improved and how this could help overcome experimental error.

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[1] Two useful publications are Watson, R. et al. (2000) *Getting to Grips with Graphs*, Association for Science Education and Goldsworthy, A. et al. (2002) Aksis Investigations: Developing Understanding, Association for Science Education.

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Strategies to ensure progression from step 1 to step 2

Graphical skills

A) Model how to:

- **Assign appropriate scales.**
- **Read a graph.**
- **Describe what a graph is showing, that is, increase, decrease, no change.**
  - Explain to pupils that a graph is not the end point of an investigation. Make it clear that a graph is another way of presenting data, in a way that can make it easier to identify a pattern. Compare tables and graphs for the ease of looking for patterns.
  - Give pupils copies of graphs from past papers or textbooks and ask them first to identify the variables and units and then to give the graph a title.
  - Minibooster 4: Progressing to level 6+ and beyond, activities 1, 2 and 3.

Describing what a graph is showing (bullet 3, above) will be problematic for many pupils and could present a particular difficulty for EAL (English as an additional language) learners. Pupils will need to be taught the conventions of an explanation text and most particularly how to express the relationship between the independent and dependent variables. In order to generate a sentence such as 'the higher the concentration of acid, the faster the magnesium reacts', pupils will need to be taught:

- how the independent variable affects the dependent variable;
- how to use comparatives (adjective + 'er' or 'more' + adjective) to express the relationship;
- how to use superlatives (adjective + 'est' or 'most' + adjective) in comparing more than two independent variables.

B) Demonstrate how to break line graphs up into discrete sections, read each section and then sequence them to build up the whole story of the graph.

- Collective memory task.[2]

  Prepare a graph but keep it concealed from view. The pupils work in small groups to replicate the graph. Pupils come up in turn and have 10 seconds to view the graph followed by 10 seconds to reproduce it, from memory, for the rest of the group. This is repeated until all members of the group have visited the graph. Pupils compare their own graphs with the original.

  This is a good way to encourage pupils to look carefully at the component parts of an image and to consider the strategies they have used to commit them to memory.
- Minibooster 4: activity 5.
- Minibooster 4: Progressing to level 6+ and beyond, activity 3.

C) Create opportunities to interpret a range of graphs including those with simple negative scales on one axis, for example, change of mass.

- Present pupils with a number of less common graphs – that is, not straight lines that begin at or near the origin and slope upwards to the right and ask them to produce a results table from which the graph could have been drawn.
- Minibooster 4: Progressing to level 6+ and beyond, activities 2 and 4.
- Minibooster 4: Progressing to level 6+ and beyond, activity 9.

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[2] *Leading in learning: Developing thinking skills at Key Stage 3*, available at **www.publications.teachernet.gov.uk**. Search using the ref: DfES 0034-2005 G.

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Variables, reliability and accuracy

A) Support pupils in using the correct language when talking about variables.

- Minibooster 5: Progressing to level 6+ and beyond, activity 1.
- Minibooster 6: Progressing to level 6+ and beyond, activity 1.

B) Demonstrate how the choice and range of variables might affect the quality of the investigation, for example, pupils carry out the same investigation using different ranges and numbers of variables and compare results.

- Minibooster 3: activity 1.
- Minibooster 6: activities 2 and 3.

Analysis and evaluation

For EAL pupils, analysis and evaluation, whether in spoken or written form, are text types which will need to be taught explicitly. The main features of these text types may be found in 'Resources for scientific writing', section B.

A) Explain the use of a table as an organiser within the experimental plan as well as a way of presenting data in a report.

- Discuss with pupils how tables can be used as an important part of the planning of an investigation and that they may construct suitable tables before carrying out the work. They may use other tables to summarise data after an investigation or from research.
- Minibooster 4: activity 4.
- Minibooster 5: activity 3.
- Minibooster 4: Progressing to level 6+ and beyond, activity 6.

B) Create the opportunities for pupils to:

- **Compare the relative advantages and disadvantages of presenting results as tables or graphs.**
- **Predict the design of an experiment from the table or graph.**
- **Organise data into different tables and compare them.**
- Make it explicit to pupils why the numeric independent variable should change in equal steps. They can compare it to looking for patterns in tables where the independent variables change in equal and unequal steps.
- Minibooster 5: activities 5 and 6.

C) Model how to interpret patterns in graphs and tables and to be aware of the limitations of the data.

- Minibooster 2: activity 1.
- Minibooster 5: activity 2.
- Use PowerPoint™ 'Pattern' or not?

D) Model how to identify possible sources of experimental error in the planning and implementation.

- Minibooster 2: activities 2 and 4.
- Minibooster 7: activities 1, 2 and 3.
- Minibooster 2: Progressing to level 6+ and beyond, activities 3 and 4.

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Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils can:

- choose an appropriate type of graph and scale(s) to display the data effectively;
- explain what the shape of the graph represents and interpret graphs with a negative scale on one axis;
- identify relevant independent and dependent variables;
- choose an appropriate range, number and value for each variable;
- make enough measurements, observations and comparisons for the task;
- draw conclusions consistent with evidence and use scientific knowledge and understanding to explain them;
- explain how planning and implementation could be improved and how this could help overcome experimental error.

Step 3 – pupil characteristics

Pupils can:

- use lines of best fit appropriately;
- make allowances for anomalous results in their graphs;
- explain what the shape of the graph represents and interpret this correctly;
- manipulate and transform data to represent negative changes, for example, osmosis, exothermic or endothermic reactions;
- identify and manipulate relevant independent and dependent variables and recognise that some cannot be controlled;
- plan for accuracy through the choice of equipment and technique;
- consider whether the data they have collected is sufficient for conclusions to be drawn;
- explain how they have made a numerical prediction based on the trend or pattern in results;
- evaluate their planning and implementation and explain how this could account for errors and anomalies.

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Strategies to ensure progression from step 2 to step 3

Graphical skills

A) Model how incorrect plotting or inappropriate scales can change or distort the pattern of the graph.

- Give pupils a copy of a graph without the labels on the *y*-axis; for example, use a graph showing the growth of a plant over a number of weeks. Then secretly give each group of pupils a set of different scales to add to the graph, such as 0–20 g, 0–100 g, 0–4 kg. Ask them to use the graph to answer questions such as: 'How much mass did the plant gain in the first three weeks?' Ask pupils to work out why the answers are different and why labelling the axis, with the correct scale, is important.
- Use activity 'Problems with scales' from *Getting to grips with graphs* which shows the same set of results plotted on axes marked with different scales and the effect on the pattern presented.
- Minibooster 6: Progressing to level 6+ and beyond, activity 3.

B) Create a number of opportunities to represent data through a range of complex graphs. This should include drawing graphs with negative scales.

- Pupils work in pairs. Each pupil is given a different graph and five minutes to write down all the important information from it. They swap information and then use this to recreate each other's graphs.
- Minibooster 4: Progressing to level 6+ and beyond, activities 1 to 10.

C) Model how to decide whether a line of best fit is needed and how to draw it correctly and whether it should go through the origin. Help pupils to realise that any point on a graph is only ever an approximation.

- Discuss and establish some rules about lines of best fit, for example, they do not always go through all the points; they are not always straight lines; they do not have to go through the origin and there may be more than one possible line of best fit on the same graph.
- Pupils work in pairs using a table of results that has three repeat readings and an average value of all three, that is, four columns of results. One of the pair plots a graph using the mean values only and the other pupil plots all three readings (omitting the means) on the same graph. Pupils compare their lines and discuss why they are different and whether a point on a graph is exact or approximate.
- Present pupils with some graphs with pre-drawn lines of best fit that go through the origin. Check that they are clear about what the origin represents. Ask them to discuss and explain if it makes sense for the line to go through the origin.
- Minibooster 4: Progressing to level 6+ and beyond, activity 5.

D) Create experimental opportunities to calculate negative values, for example, mass before and after; temperature change during reactions.

Variables, reliability and accuracy

A) Create opportunities for pupils to identify the key variables in scientific newspaper articles or adverts.

- Minibooster 1: Progressing to level 6+ and beyond, activity 1.
- Minibooster 4: Progressing to level 6+ and beyond, activity 1.

B) Demonstrate how accuracy can be affected by the choice of equipment or technique, for example, pupils carry out the same investigation using different equipment and compare results.

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- Minibooster 1: activities 1 and 2.
- Minibooster 2: activity 3.
- Minibooster 1: Progressing to level 6+ and beyond, activity 1.
- Minibooster 2: Progressing to level 6+ and beyond, activity 1.
- Minibooster 2: Progressing to level 6+ and beyond, activity 7.
- Minibooster 6: Progressing to level 6+ and beyond, activity 1.
- Ask pupils to justify why they chose to use a particular measuring instrument.

C) Explain the differences between categoric, ordered and continuous variables and require pupils to assign the correct classification to different investigations. Explain to pupils that independent, dependent and control variables all have values but the values might be:

- **categoric** (for example, type of metal) or;
- **ordered** (for example, small, medium, large, very large) or;
- **continuous** – which are numeric.

This could give nine possible combinations. Either present a number of tables of results for pupils to practise deciding the type of variable or ask them to think of examples for each space in the following table.

Independent	Dependent		
	Categoric	Ordered	Continuous
Categoric			
Ordered			
Continuous			

- Minibooster 3: Progressing to level 6+ and beyond, activity 1.

Analysis and evaluation

A) Create opportunities for pupils to:

- identify mathematical trends or patterns and use these to make a prediction;
- devise criteria to decide whether the evidence is valid.

B) Create opportunities for pupils to assess each other's experimental designs and explain where they see possible sources of error.

- Minibooster 3: activity 1.
- Minibooster 2: Progressing to level 6+ and beyond, activity 5.
- Minibooster 7: Progressing to level 6+ and beyond, activity 3.

C) Discuss with pupils the range of errors associated with taking measurements.

- Minibooster 2: Progressing to level 6+ and beyond, activity 2.

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Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils can:

- use lines of best fit appropriately;
- make allowances for anomalous results in their graphs;
- explain what the shape of the graph represents and interpret this correctly;
- manipulate and transform data to represent negative changes, for example, osmosis, exothermic/endothermic reactions;
- identify and manipulate relevant independent and dependent variables and recognise that some cannot be controlled;
- plan for accuracy through the choice of equipment and technique;
- consider whether the data they have collected is sufficient for conclusions to be drawn;
- explain how they have made a numerical prediction based on the trend or pattern in results;
- evaluate their planning and implementation and explain how this could account for errors and anomalies.

Step 4 – pupil characteristics

Pupils can:

- interpolate and extrapolate with accuracy;
- explain and suggest reasons for anomalous results in their graphs;
- identify key factors in complex contexts and in contexts where variables are not easily controlled;
- plan for reliability through trial runs, repeat readings and accurate practical techniques;
- identify and suggest reasons for anomalous results and allow for these when drawing graphs;
- explain how the selective presentation of data can bias the conclusion drawn;
- evaluate their planning and implementation and explain how this could account for errors and anomalies and the subsequent impact on the conclusion drawn.

Strategies to ensure progression from step 3 to step 4

Graphical skills

A) Create opportunities for pupils to explain how they have made numerical predictions from the interpolation or extrapolation of graphical readings.

- Model this process for pupils, making the steps in your thinking explicit.
- Ask some groups of pupils to make predictions from the table of results and others to make predictions from the graph and to discuss and compare their answers.

B) Demonstrate the effect of insufficient readings and/or anomalous results on the graphical representation of data.

- Minibooster 4: Progressing to level 6+ and beyond, activity 7.

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Variables, reliability and accuracy

A) Discuss with pupils investigations where not all variables can be controlled and ask pupils to explain how to account for this in their experimental design.

- Minibooster 6: Progressing to level 6+ and beyond, activities 4, 5, 6 and 7.

B) Demonstrate how to increase reliability through repeat readings, use of a control and trial runs; create opportunities for pupils to develop these techniques.

- Minibooster 1: activities 4 and 5.
- Give pupils the opportunity to carry out some short trial runs of simple investigations to generate some preliminary data that they could use to make decisions about appropriate range, degree of accuracy and number of repeats.
- Ask pupils to justify why they chose a particular number of repeat readings or the use of a control group.
- Minibooster 2: Progressing to level 6+ and beyond, activity 6.

Analysis and evaluation

A) Discuss with pupils how and why bias in the evaluation of evidence might arise.

- Use the table 'Recognising the pitfalls' from *Developing critical and creative thinking* to alert pupils to possible sources of bias and look for examples of this in newspaper articles or on internet sites.
- Minibooster 3: activities 3 and 4.
- Minibooster 3: Progressing to level 6+ and beyond, activities 3 and 4.

B) Model for pupils how a change in experimental parameters can alter the validity of the data.

- Minibooster 7: Progressing to level 6+ and beyond, activities 1 and 6.

C) Create opportunities for pupils to assess each other's experimental designs and conclusions to identify and explain inconsistencies between the two.

- Minibooster 7: Progressing to level 6+ and beyond, activity 4.

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Handout 1.2: Effective group talk steps table – adapted for EAL learners

This strand is about developing productive talk to refine thinking and adjust ideas. Pupils need to have a shared understanding of the behaviour that will produce effective group talk and develop strategies to overcome potential barriers. Pupils need to move from an initial position of unplanned discussions in a lesson to become reflective, independent thinkers, who can analyse information, formulate opinion and argument, incorporate new ideas and critically evaluate a range of opinions. Many of the ideas in this strand underpin pupil progress in the other strands, including pupil use of modelling, research and scientific writing.

Step 1 **pupil characteristics**	**Strategies to ensure progression**	**Step 2** **pupil characteristics**	**Strategies to ensure progression**	**Step 3** **pupil characteristics**	**Strategies to ensure progression**	**Step 4** **pupil characteristics**
Pupils: ● work effectively in a pair to share and develop their ideas; ● make limited contributions to a larger group discussion and debate.	A) Establish rules for group talk. B) Plan short, structured discussions with clear outcomes based on challenging questions. C) Prepare pupils for the discussion by activating prior knowledge and establishing context and key scientific terms. D) Model register – language appropriate to task, audience and purpose.	Pupils: ● can share responsibility in a larger group; ● ask questions, listen to others and make contributions that are responsive to the views of others; ● can explain the value of working as a group.	A) Plan longer structured discussions with clear outcomes based on increasingly challenging questions. B) Require pupils to use a range of strategies to activate prior knowledge and key scientific terms. C) Require pupils to use DARTs and graphic organisers/note-making formats appropriately.	Pupils can: ● make valid contributions to discussions using talk as a tool for clarifying ideas, asking questions and providing extended responses and/or explanations to group questions; ● reflect on the progress made by the group and identify the strategies they used that were effective.	A) Plan substantial discussion or debate of contemporary or controversial scientific issues. B) Prepare pupils for the discussion by providing appropriate material and signposting other sources. C) Use collaborative group/pair talk to develop viewpoints, arguments and justifications.	Pupils can: ● take different roles effectively during discussion and debate and make different contributions; ● ask and respond to questions, and make contributions that clarify understanding, refine ideas and incorporate the ideas of others into their thinking; ● critically evaluate the work of the group.

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	E) Use DARTs (Directed Activities Related to Texts) and graphic organisers/note-making formats to inform discussion and formalise the outcomes. F) Intervene in group discussion as appropriate to: ● refocus discussion ● introduce new elements of cognitive conflict ● correct and model talk. G) Organise formal feedback to whole class on outcomes. H) Support pupils in reflecting on group dynamics and the quality of the thinking (metacognition).		D) Continue to intervene in group discussion as appropriate. E) Establish success criteria for formal feedback/group presentation/class debate. F) Require pupils to use register appropriate to task, audience and purpose. G) Facilitate collaboration to prepare and rehearse the formal feedback/class debate/group presentation. H) Model feedback against success criteria prior to peer assessment.		D) Intervene in group discussion to introduce new ideas or challenge current thinking. E) After the debate/discussion, provide opportunities for pupils to reflect on the quality of the debate/discussion, on the quality of their thinking and the development of their learning.	

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Handout 1.3: Research skills steps table – adapted for EAL learners

This strand is about helping pupils to develop information-processing skills so that they can use and interpret a wide selection of information. Pupils need to be able to:

- undertake some experimental or preliminary research;
- plan how to identify and select the most appropriate or valid sources of information or data;
- transform information into the most appropriate form for the task and audience;
- use criteria to decide on appropriate information to support a conclusion or argument;
- critically evaluate both the pieces of information used and the process for selecting the evidence;
- appreciate that their conclusion is a 'best fit' and be able to consider the validity of alternative explanations;
- develop a range of skills allowing them to transform information into the most appropriate format.

Step 1 pupil characteristics	**Strategies to ensure progression**	**Step 2 pupil characteristics**	**Strategies to ensure progression**	**Step 3 pupil characteristics**	**Strategies to ensure progression**	**Step 4 pupil characteristics**
Pupils: ● can identify a few data items or evidence linked, but not always relevant, to a task;	A) Create opportunities for pupils to classify information based on concrete and then, if appropriate, abstract categories using a range of, for example, mysteries, odd-one-out and relational diagrams.	Pupils can: ● link the selected data items or evidence to reach a suitable conclusion;	A) Model how to use criteria to decide if particular pieces of evidence are appropriate and to what extent they support or negate the hypothesis. B) Expose pupils to a range of sources of scientific information (e.g. magazines, newspapers, blogs).	Pupils can: ● use criteria to judge the relevance and validity of data items or evidence and use this to support or negate an argument;	A) Create opportunities for pupils to evaluate the appropriateness of a piece of research, theory or other pupils' work and to make valid comments about the conclusion the research or work came to.	Pupils: ● evaluate the reliability and validity of others' research, hypotheses and conclusions;

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● have limited note-taking skills that do not identify the main ideas; they struggle to translate the original language into their own words; ● recognise that sources of information and data exist in several forms, for example, graphical as well as textual.	B) Model how to change information from one form to another, e.g. DARTS (Directed Activities Related to Texts); turning scientific development into a time line. C) Support pupils in using different thinking grids and organisers to make links between pieces of information. D) Teach pupils explicitly the difference between fact and opinion and how to recognise them. E) Teach pupils how to use internet search engines and how to read the results summaries.	● produce notes that identify the main ideas and have a clear purpose but do not question the authority of written texts; ● plan to collect relevant information and data from a variety of sources, both primary and secondary.	Explore with pupils the features which make these texts suitable for their audience and purpose. Support pupils in making a judgement as to their validity as sources of scientific evidence. C) Explore with pupils effective ways to make notes from different sources of information. D) Model for pupils the questions to ask which might detect bias in a text (e.g. Who wrote the text? Who funded the research? Is there scientific evidence? What is the political affiliation of the publication? Is the evidence primary or secondary?) E) Teach pupils how to narrow the parameters of their searches using search engines and how to select from the results.	● adopt the most appropriate format for note-taking to represent the information for specific purposes; ● recognise the potential for bias within sources of information and data.	B) Model the part of the scientific process where data is used to develop theories and then build pupils' confidence in being able to adapt or change conclusions in light of new evidence. C) Transform the same piece of information into various forms and evaluate purpose and effectiveness of each.	● transform information into textual, visual and diagrammatic notes that have clarity of purpose and demonstrate critical reflection of ideas; ● explain why they selected or discarded sources of information or data.

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Handout 1.4: Effective group talk – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about developing productive talk to refine thinking and adjust ideas. Pupils need to have a shared understanding of the behaviour that will produce effective group talk and develop strategies to overcome potential barriers. Pupils need to move from an initial position of unplanned discussions in a lesson to become reflective, independent thinkers, who can analyse information, formulate opinion and argument, incorporate new ideas and critically evaluate a range of opinions.

Broadly speaking, talk may be divided into two types: exploratory talk and formal talk.

Exploratory talk[1]

- Partners engage critically but constructively with each other's ideas.
- Relevant information is offered for joint consideration.
- Alternative ideas are proposed and reasons are given when ideas are challenged.
- Agreement is sought as a basis for progress.
- Reasoning underpins and is visible in the talk.

Formal talk

- Is closer to a performance.
- Needs to be rehearsed initially.
- Has structures which resemble those in writing.
- Can be used as a scaffold for writing.

Many of the ideas in this strand underpin pupil progress in the other strands, including pupil use of modelling, research and scientific writing.

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[1] Adapted from Mercer, N. (2000) *Words and Minds*, London: Routledge

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A sequence for supporting pupils

Below are two sequences for supporting pupil talk: the first shows a possible progression in organising and supporting exploratory talk, the second a possible progression for formal talk. It is important to note that the sequences do not have to be followed in their entirety on every occasion as teachers will wish to adapt to their context and pupils will need less scaffolding as their skills improve.

Sequence for exploratory talk

Establish rules for talk
Assign roles in a group

Set challenging questions and tasks with clear outcomes (cognitive conflict)

Prepare pupils by activating prior knowledge and establishing context and key scientific terms

Model register (task, audience, purpose)

Use DARTs, graphic organisers and note-making formats to inform discussion and formalise the outcomes

Intervene in group discussion to refocus discussion, introduce new elements of cognitive conflict and to correct and model talk

Organise formal feedback to whole class on outcomes

Support pupils' reflection on group dynamics and quality of thinking (metacognition)

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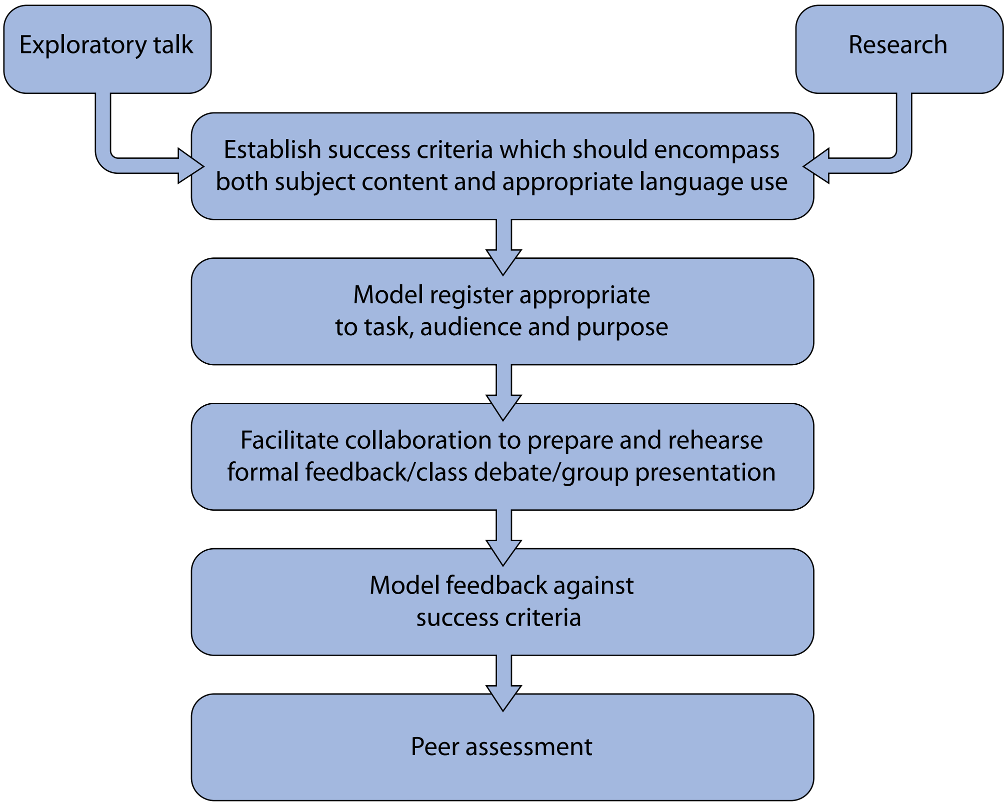
Sequence for formal talk



Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- work effectively in a pair to share and develop their ideas;
- make limited contributions to a larger group discussion and debate.

Step 2 – pupil characteristics

Pupils:

- can share responsibility in a larger group;
- ask questions, listen to others and make contributions that are responsive to the views of others;
- explain the value of working as a group.

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Strategies to ensure progression from step 1 to step 2

Literacy across the curriculum, 2001(DfEE 0235-2001), *Pedagogy and Practice: Teaching and learning in secondary schools* – Unit 10: Group work (DfES 0433-2004 G) and *Strengthening teaching and learning in science through using different pedagogies* – Unit 1: Using group talk and argument (DfES 0702-2004 G) contain many resources to support effective group talk.

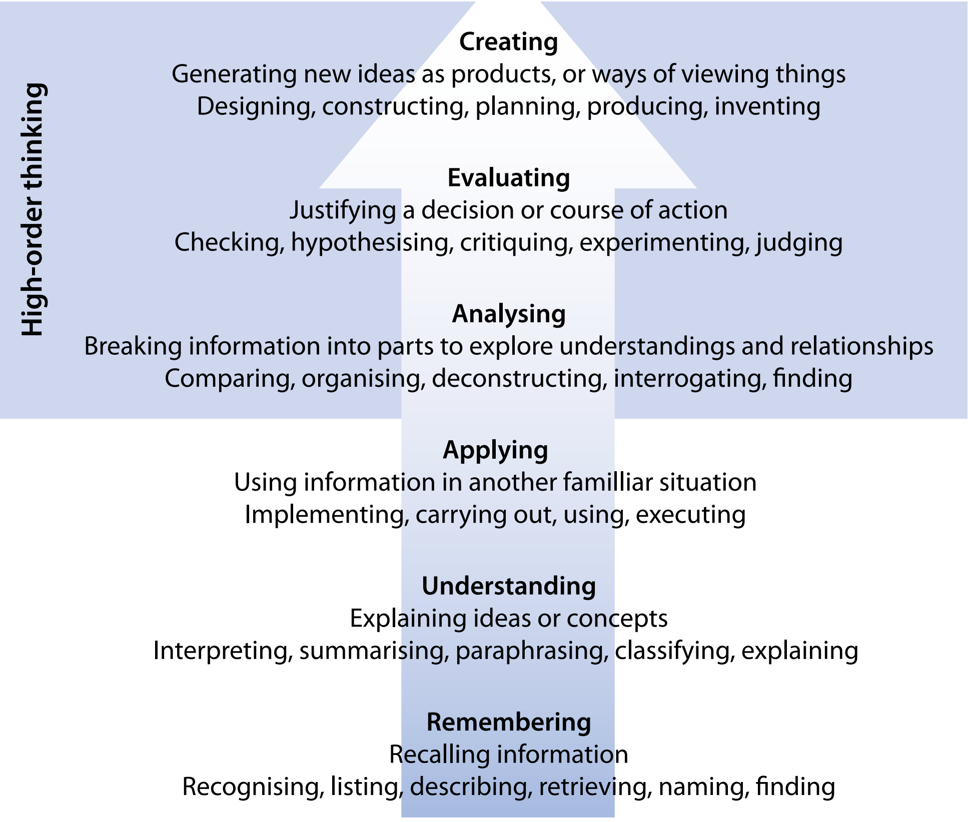
A) Establish rules for group talk

- Discuss and agree ground rules for group discussion.
- Discuss the advantages of assigning roles during group discussions.
- Consider and use a range of strategies for organising group talk, e.g. Rainbow groups; pair talk; small groups; whole class.

B) Plan short, structured discussions with clear outcomes based on challenging questions

- Plan questions which require pupils to use higher-order thinking skills.
- Use the Rich Questions from the science Framework as a focus for discussion.

Bloom's Revised Taxonomy



Creating
Generating new ideas as products, or ways of viewing things
Designing, constructing, planning, producing, inventing

Evaluating
Justifying a decision or course of action
Checking, hypothesising, critiquing, experimenting, judging

Analysing
Breaking information into parts to explore understandings and relationships
Comparing, organising, deconstructing, interrogating, finding

Applying
Using information in another familliar situation
Implementing, carrying out, using, executing

Understanding
Explaining ideas or concepts
Interpreting, summarising, paraphrasing, classifying, explaining

Remembering
Recalling information
Recognising, listing, describing, retrieving, naming, finding

Bloom's Revised Taxonomy by Kurwongbah State School, Australia

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C) Prepare pupils by activating prior knowledge and establishing context and key scientific terms

- Use KWL grids, concept maps, concept cartoons, appropriate visuals and objects which introduce the content and context.
- Use 'reveal tool' on IWB to encourage pupils to speculate with partial knowledge.
- Use 'talking tins' or other audio devices to introduce vocabulary and encourage pupils to make links and predictions.

D) Model register – language appropriate to the task, audience and purpose

- Show pupils how to disagree without offending others, e.g. 'that's an interesting idea, but…' or 'I'm not sure you're right when you say…because…'.
- Show pupils how to take turns without being aggressive, e.g. 'Might I just add…?'
- Show pupils how to signpost a change of topic, e.g. 'Another way to look at this might be…'.
- Show pupils how the use of modal expressions and modal verbs can soften the impact on a listener, e.g. compare 'You are mistaken!' with 'Could you be mistaken?'
- Show pupils how to use modal expressions and modal verbs to express certainty, probability, possibility and intention, e.g. compare 'You must consider', 'You ought to consider', 'You might consider'.

E) Use DARTs, graphic organisers and note-making formats to inform discussion and formalise the outcomes

- Use a range of graphic organisers to help pupils to organise their thoughts during different points in the discussions. Ask pupils to consider which type of organiser they found most beneficial.
- Model for pupils a range of DARTs activities – some for completion and some for analysis.

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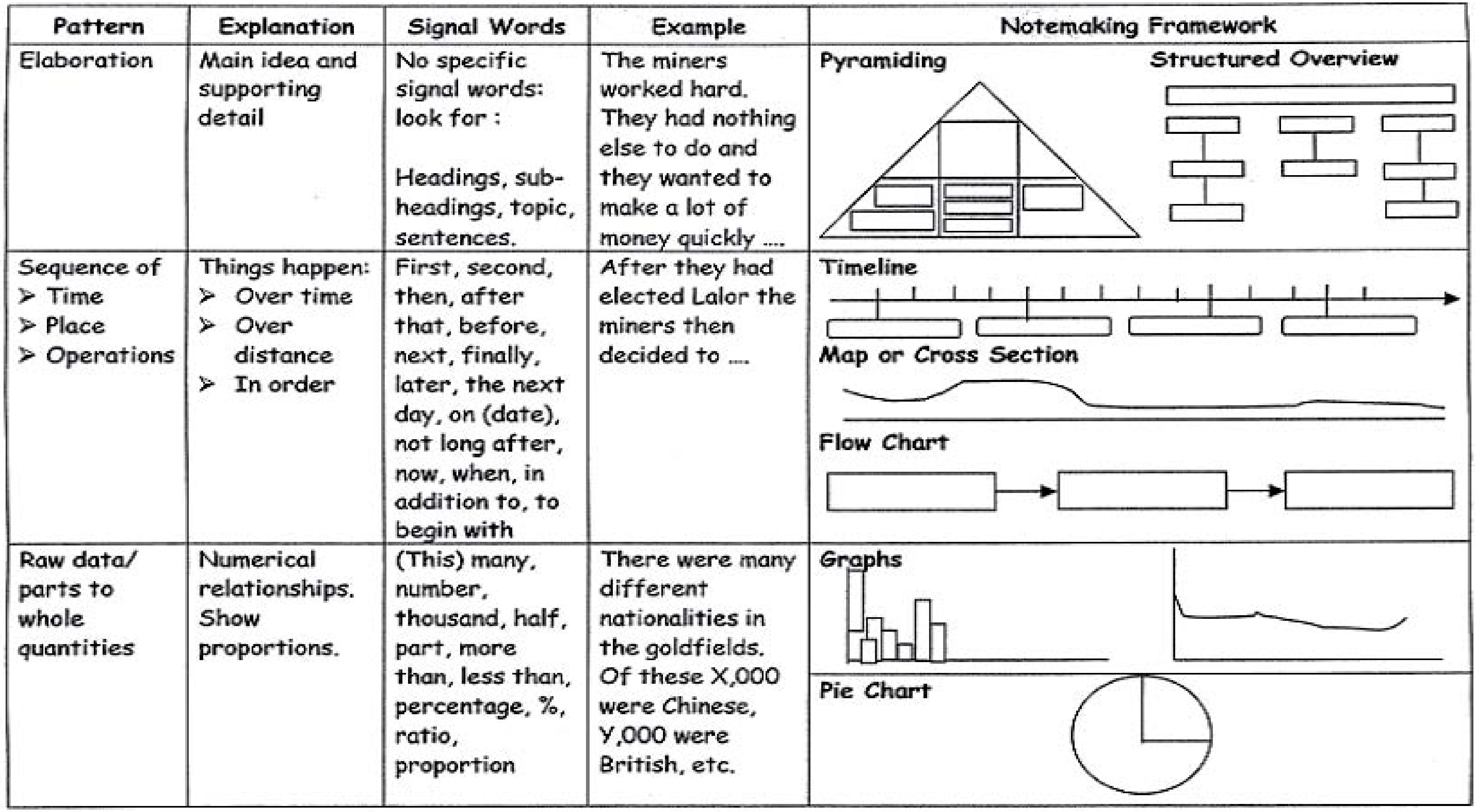
Examples of DARTs activities



Pattern	Explanation	Signal Words	Example	Notemaking Framework
Elaboration	Main idea and supporting detail	No specific signal words: look for : Headings, sub-headings, topic, sentences.	The miners worked hard. They had nothing else to do and they wanted to make a lot of money quickly	Pyramiding Structured Overview
Sequence of ➢ Time ➢ Place ➢ Operations	Things happen: ➢ Over time ➢ Over distance ➢ In order	First, second, then, after that, before, next, finally, later, the next day, on (date), not long after, now, when, in addition to, to begin with	After they had elected Lalor the miners then decided to	Timeline Map or Cross Section Flow Chart
Raw data/ parts to whole quantities	Numerical relationships. Show proportions.	(This) many, number, thousand, half, part, more than, less than, percentage, %, ratio, proportion	There were many different nationalities in the goldfields. Of these X,000 were Chinese, Y,000 were British, etc.	Graphs Pie Chart

The table is adapted by Meredith Lane-Richardson from that appearing in Top-level Structure Written in Low-level Language by D Klarwein. It also appears in the Stepping Out Program (Education Department of Western Australia, 2001) and in Stepping Out: Reading Strategies for Success (Heinemann (UK), 2001).

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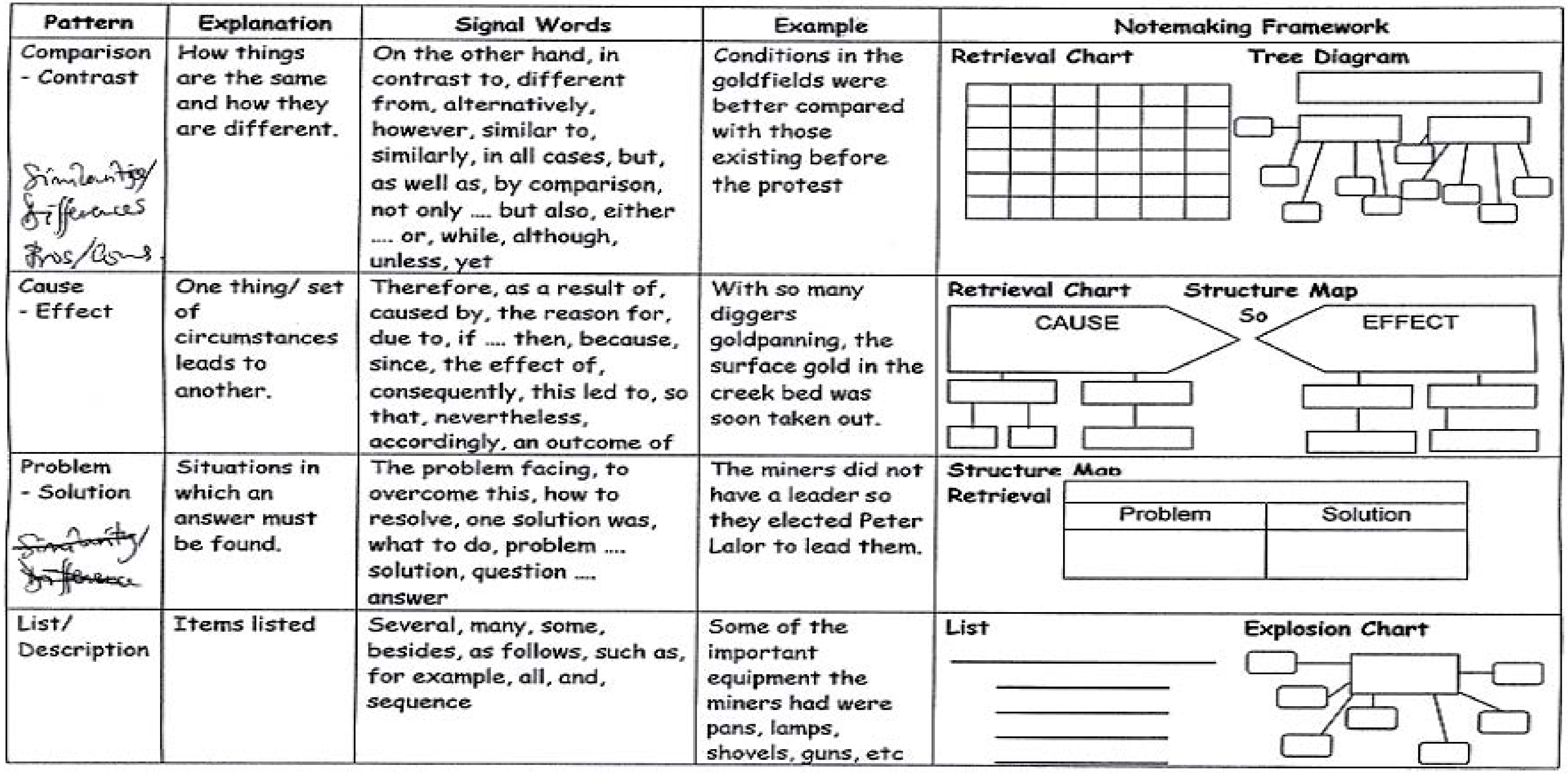

Pattern	Explanation	Signal Words	Example	Notemaking Framework
Comparison - Contrast Similarity/ Differences Pros/Cons	How things are the same and how they are different.	On the other hand, in contrast to, different from, alternatively, however, similar to, similarly, in all cases, but, as well as, by comparison, not only .... but also, either .... or, while, although, unless, yet	Conditions in the goldfields were better compared with those existing before the protest	Retrieval Chart Tree Diagram
Cause - Effect	One thing/ set of circumstances leads to another.	Therefore, as a result of, caused by, the reason for, due to, if .... then, because, since, the effect of, consequently, this led to, so that, nevertheless, accordingly, an outcome of	With so many diggers goldpanning, the surface gold in the creek bed was soon taken out.	Retrieval Chart Structure Map CAUSE So EFFECT
Problem - Solution ~~Similarity/ Difference~~	Situations in which an answer must be found.	The problem facing, to overcome this, how to resolve, one solution was, what to do, problem .... solution, question .... answer	The miners did not have a leader so they elected Peter Lalor to lead them.	Structure Map Retrieval Problem Solution
List/ Description	Items listed	Several, many, some, besides, as follows, such as, for example, all, and, sequence	Some of the important equipment the miners had were pans, lamps, shovels, guns, etc	List Explosion Chart

The table is adapted by Meredith Lane-Richardson from that appearing in Top-level Structure Written in Low-level Language by D Klarwein. It also appears in the Stepping Out Program (Education Department of Western Australia, 2001) and in Stepping Out: Reading Strategies for Success (Heinemann (UK), 2001).

F) Intervene in group talk to refocus discussion, introduce new elements of cognitive conflict and to correct and model talk

- Refocus discussion: 'How does that fit with our objectives and outcomes?' 'How realistic do you think that is?' 'How relevant do you think that evidence is?'
- Introduce new elements: 'What if I told you that…?', 'Group A has discussed…what do you think?'
- Model talk: 'Is there a better word for that?', 'Can you think of another way of saying that?'

G) Organise formal feedback to whole class on outcomes

- Refer pupils to objectives and outcomes and discuss what success will look like.
- Model the appropriate language to use in feedback.
- Provide sentence stems (e.g. 'During our discussions, we…', 'Initially we thought that…however, once we had considered….', 'For our group the key piece of evidence was…', 'In summary, our group concluded that…').
- Prepare pupils for listening with active listening tasks (e.g. 'Did the feedback meet the objectives of the lesson?', 'Did they link their ideas effectively? How?', 'Were arguments backed up with evidence? [Note down examples] 'Note down any subject-specific language used').

H) Support pupils' reflection on group dynamics and quality of thinking (metacognition)

- Refer pupils to the agreed rules for talk and ask if they were observed.
- Refer to roles of pupils during discussions and ask for two positive aspects and one area for development.
- Ask pupils to consider the benefits and limitations of groups of different sizes and compositions.

Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils:

- can share responsibility in a larger group;
- ask questions, listen to others and make contributions that are responsive to the views of others;
- explain the value of working as a group.

Step 3 – pupil characteristics

Pupils can:

- make valid contributions to discussions using talk as a tool for clarifying ideas, asking questions and providing extended responses/explanations to group questions;
- reflect on the progress made by the group and identify the strategies they used that were effective.

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Strategies to ensure progression from step 2 to step 3

A) Plan longer, structured discussions with clear outcomes based on increasingly challenging questions

- Plan questions which require pupils to use higher-order thinking skills.
- Plan whole-class structured discussion and argument. Suggested materials to inform the discussion can be found at UPD8 (**www.upd8.org.uk**).
- In *Strengthening teaching and learning of interdependence*: Session 3 Hedgehogs in Uist handouts 3.6–3.8 and Plants mop up metal pollution handouts 3.9–3.11.

See Bloom's Revised Taxonomy on page four of this document.

B) Require pupils to use a range of strategies to activate prior knowledge and key scientific terms

- Provide pupils with tools like KWL grids, concept maps, concept cartoons, appropriate visuals and objects from which they can select to help activate their thinking.
- Ask pupils to discuss how they look for clues when the 'reveal tool' on IWB is used to encourage speculation.
- Ask pupils to use 'talking tins' or other audio devices for pupils to introduce vocabulary and ideas to other pupils in the class.

C) Require pupils to use DARTs, graphic organisers and note-making formats appropriately to inform discussion and formalise the outcomes

- Provide pupils with a range of graphic organisers to select from to help them to organise their thoughts and ideas.
- Discuss the benefits of making notes.
- Explore with pupils some of the aspects of making notes they find difficult, e.g. difficulty in selecting what to include in case a crucial bit is omitted.

See examples of Darts activities on pages six and seven of this document.

D) Continue to intervene in group talk to refocus discussion, introduce new elements of cognitive conflict and to correct and model talk

- Refocus discussion: 'How does that fit with our objectives and outcomes?' 'How realistic do you think that is?' 'How relevant do you think that evidence is?'
- Introduce new elements: 'What if I told you that…?', 'Group A has discussed…what do you think?'
- Model talk: 'Is there a better word for that?', 'Can you think of another way of saying that?'

E) Establish success criteria for formal feedback/group presentation/class debate

- Model positive and negative types of contribution before small-group or whole-class discussion. This could be a role play set up in advance and involve the teacher and two pupils, or you could provide behaviour cards, for example:

  Person 1: You continually interrupt.

  Person 2: You are very inattentive.

  Person 3: You are divergent, always going off in interesting but irrelevant directions.

  Person 4: You understand the task and want to complete it properly.
- Ask pupils to assess the effectiveness of the group using simple self- or peer-assessment strategies, for example, Do or dice group presentation; Evaluating group practical work and 'How did I do?' sheets.

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F) Require pupils to use register-language appropriate to the task, audience and purpose

- Draw out the conventions of language and content appropriate to the task, audience and purpose.
- Use tables similar to the one below to agree 3–5 success criteria for the feedback/presentation/debate taking account of the audience.
- Ask pupils to discuss and deduce the audience and purpose of a science article.

Explanation texts	
Purpose	To explain the causes and effects of drought
Text level	● General statement to introduce topic ● Sections organised from the most important cause of drought and its effect to the least important ● Concluding section is a summary of the points made
Sentence level	● Third person ● Present tense ● Each section begins with a topic sentence which introduces what the section will be about ● Points within each section work from the most important to the least important ● Connectives like *since, because, so, as, therefore* and connective phrases such as *as a result of which* are important to show cause and effect
Word level	● Subject-specific vocabulary, e.g. *precipitation, drought,* make clear that the context is science

G) Facilitate collaboration to prepare and rehearse the formal feedback/group presentation/class debate

- Remind pupils of success criteria as a basis for planning in their groups.
- Provide pupils with a range of vocabulary to use, e.g. opinion, agreement, relevant, argument, assertion, alternatives, challenge, reason, critical, respect, information, dialogue, thinking together, idea, justify, propose, summarise, support, oppose, explanation, suggestion, evaluate, synthesise, consider, contribute.

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H) Model feedback against success criteria prior to peer assessment

- Teacher models filling in feedback grid after the first presentation.

Success criterion	Evidence	Achieved (Yes/No/Partially)
Effective opening section	General statement introduced topic Good use of connectives – therefore, as a result Good use of scientific vocabulary	Y

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils can:

- make valid contributions to discussions using talk as a tool for clarifying ideas, asking questions and providing extended responses/explanations to group questions;
- reflect on the progress made by the group and identify the strategies they used that were effective.

Step 4 – pupil characteristics

Pupils can:

- take different roles effectively during discussion and debate and make different contributions;
- ask and respond to questions, and make contributions that clarify understanding, refine ideas and incorporate the ideas of others into their thinking;
- critically evaluate the work of the group.

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Strategies to ensure progression from step 3 to step 4

A) Plan substantial discussion or debate of contemporary or controversial scientific issues

- Use Bloom's Revised Taxonomy to frame discussions or debates which require the use of higher-order thinking skills (analysing, evaluating, creating).
- Use the 'Democs' resources to structure a whole-class discussion. **www.neweconomics.org/gen/democsdownload.aspx**
- Give pupils opportunities to role-play a range of viewpoints and challenge the viewpoints of others. For example, use topics such as 'Should people be made to pay for hip replacements?' or 'No cars should be allowed in city centres'. Ask pupils to review and perhaps modify their viewpoint at regular intervals as you present them with new information. Use the group talk cards in the resource folder to help to structure the discussion.
- Plan a class discussion on a controversial subject. As a starter pupils position themselves on a continuum. Use prompt or fact cards to aid the discussion, culminating in every pupil group developing a statement of opinion to share with the class.

B) Prepare pupils for the discussion by providing appropriate material and signposting other sources

- Provide a range of appropriate materials covering a wide range of theories or viewpoints
- Initiate discussion around the usefulness and reliability of source material (refer to Research skills – teacher guidance and with additional notes for EAL learners).
- Provide pupils with a range of information on a current issue; they discuss and share the risks, benefits and consequences (moral, ethical, social, cultural or political) of this issue for future generations.

C) Use collaborative group/pair talk to develop viewpoints, arguments and justifications

- Use activities such as Six Thinking Hats or playing Devil's Advocate.
- Use the Market place activity in which groups of pupils have to gather information from other groups.
- Ask groups of pupils to participate in collective memory activities: Group talk steps 3–4 fishbone organiser and Group organisers.
- Organise class discussions using 'big' questions such as 'What would happen if plant cells did not have a cell wall?' Groups use a fishbone organiser or group outcomes grid to record the main points. They share this with another group and justify the structure of their fishbone or grid.

D) Intervene in group discussion to introduce new ideas or challenge current thinking

- Focus interventions on reliability of evidence, research methodology, range of sources and synthesis of information and ideas (e.g. 'Why have you based your argument so much on Source X?' 'Did you include any primary sources within your research?' 'What are the counter-arguments and how would you rebut them?' 'Are sources B&C mutually exclusive or can you take ideas from both?'

E) After the debate/discussion, provide opportunities for pupils to reflect on the quality of the debate/discussion, on the quality of their thinking and the development of their learning

- Refer pupils to the objectives, outcomes and success criteria as the basis for their reflections
- Pupils use the thinking words and phrases from the bookmarks to reflect on how the debate or discussion has helped their learning.

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- Ask pupils to think about what they should do when the group or members of the group face the following problems:
  - One or two pupils are not contributing.
  - The group is stuck or runs out of steam.
  - The group stops talking when the teacher is near.
  - One person dominates the discussion.
  - Everyone wants to talk and no one wants to listen.
  - No one wants to feed back to the rest of the class.

Handout 1.5: Research skills – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about helping pupils to develop information-processing skills so that they can use and interpret a wide selection of information. Pupils need to be able to:

- undertake some experimental or preliminary research;
- plan how to identify and select the most appropriate or valid sources of information or data;
- transform information into the most appropriate form for the task and audience;
- use criteria to decide on appropriate information to support a conclusion or argument;
- critically evaluate both the pieces of information used and the process for selecting the evidence;
- appreciate that their conclusion is a 'best fit' and be able to consider the validity of alternative explanations;
- develop a range of skills allowing them to transform information into the most appropriate format.

Information-processing skills

These enable pupils to locate and collect relevant information, to sort, classify, sequence, compare and contrast and to analyse partial or whole relationships.

In science pupils need to be able to access, use and interpret a wide selection of information and data; sort, select and prioritise information that is relevant; group and classify observations and findings to determine patterns. This is an essential aspect that underpins pupils' understanding about the ways in which scientists work and being a scientist. Using these skills can be an important early stage in developing language for learning in science.

Pupils learning EAL (English as an additional language) might encounter various barriers to their understanding of information and data, particularly when using texts. These barriers might occur at:

- text level
- sentence level
- word level.

Potential barriers at text level

- **Level of formality** – it may seem counter-intuitive, but many EAL learners, particularly those who have experience of schooling overseas, will find more formal language easier to access than a less formal register. It is important, therefore, not to 'dumb down' text, but to teach pupils strategies for accessing texts with a more formal style.

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- **Cultural context** – each culture has shared understandings of ideas and the way they are presented and organised (see *Access and engagement in science*, DfES 0610-2002).
- **Tone of a text** – for example, an EAL learner might not detect irony in a text and so read it literally (e.g. see articles written by Ben Goldacre[1]).
- **Length of a text** – many inexperienced readers become disengaged when faced with a long text. Pupils need to understand the different ways in which we read long texts – skimming in order to understand the gist of a text and scanning to find particular categories of information. When close reading is required, teachers might wish to use paired reading or guided reading to scaffold access to the texts.
- **Layout of the text** – pupils need to understand how different parts of a text – particularly features such as diagrams, graphs and models – contribute to the overall meaning.

Potential barriers at sentence level

- **Use of the passive voice** – EAL learners will have to be taught that they will often need to use skills of deduction in order to work out who is the agent of an action in a sentence such as 'the epidemic was contained'.
- **Collocation and idiom** – these are commonly used expressions such as 'GM foods are a political *hot potato*' (idiom) and words that frequently appear together such as '*high probability*' (collocation). Teachers should be aware of these in texts and, whenever they are encountered, challenge pupils not only to explain, but to think of alternatives.
- **Degrees of comparison** – in a sentence such as 'The higher the temperature, the faster the reaction', EAL learners will need to be taught that this is showing a dynamic relationship between the temperature and the reaction.
- **Pronouns** – words such as 'he', 'she', 'it', 'they', 'this', 'that', which all refer to a noun elsewhere in the text. In guided or shared reading sessions, teachers should ask pupils to identify the nouns to which the pronouns refer.
- **Modal verbs** – these express doubt, certainty, possibility, probability, obligation or permission and EAL learners might not understand the subtle distinctions between them, for example, 'the results might indicate that…' and 'the results must indicate that…'. How certain is the writer in each case?

Potential barriers at word level

- **Delexical verbs** – these are common verbs (such as 'do', 'make', 'put' and 'get') that can be used in many different contexts. In order to encourage pupils to use more subject-specific verbs, teachers should draw attention to the use of words and phrases such as 'emit' (delexical: give out), 'increases in temperature' (gets hotter) or 'decreases' (goes down).
- **Specialist use of everyday language** – teachers should draw attention to the specialist use of words such as 'cell', 'tissue', 'mass' and 'volume', which can have different meanings in everyday contexts.

In science teachers should plan for pupils to:

- locate and collect relevant information – for example, researching the nature of planets in the solar system, or using a habitat, such as the school playing field or local pond, to collect biotic and abiotic information using both dataloggers and observation notes;

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[1] Goldacre, B. (2008) *Bad Science*, Harper Press.

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- sort, classify and sequence – for example, ordering the planets in the solar system in relation to their relative sizes, or identifying organisms and classifying them and/or using them to construct possible food chains and webs;
- compare and contrast – for example, comparing the sizes and gravitational forces on the different planets, comparing the various invertebrates in terms of movement, nutrition and reproduction;
- analyse partial or whole relationships – for example, predicting how the mass of the planet will affect the relative size of the gravitational force on it, or identifying producers and consumers and recognising their role in the maintenance of the ecosystem of the pond.

Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- can identify a few data items or evidence linked, but not always relevant, to a task;
- have limited note-taking skills that do not include identifying the main ideas; they struggle to translate the original language into their own words;
- recognise that sources of information and data exist in several forms, for example, graphical as well as textual.

Step 2 – pupil characteristics

Pupils can:

- link the selected data items or evidence to reach a suitable conclusion;
- produce notes that identify the main ideas and have a clear purpose but do not question the 'authority' of written texts;
- plan how to collect relevant information and data from a variety of sources, both primary and secondary.

Strategies to ensure progression from step 1 to step 2

A) Create opportunities for pupils to classify information based on concrete and then, if appropriate, abstract categories using a range of, for example, mysteries, odd-one-out and relational diagrams.

Use the mystery 'Why did the dinosaurs die out?' to help pupils make links between pieces of information that may seem disparate and unconnected.

- Pupils may have to read between the lines (supported by teacher modelling or inductive questioning) and decide whether the information is relevant or not. Help pupils differentiate between inductive and deductive approaches. The pupils' thinking is physically evident as they move slips of paper around. This helps them to share their thinking and allows the teacher a unique opportunity for diagnostic assessment. It also gives much opportunity for the development of creative thinking as pupils can generate their own hypotheses or suggest alternate explanations.
- When designing mysteries it is important to start with a topic where there is the opportunity for uncertainty and ambiguity. There need to be 15–30 data items, some of which can be red herrings.
- Share the question with the pupils and then say that they will be given a set of cards with information on them, which they can sort to help them decide on an answer. You may choose to tell them that some of the cards are red herrings, or you might like to leave it up to them to decide. Alternatively, you might decide to use it as a prompt question during the activity, if appropriate.

- After 15–30 minutes stop the task and explain to pupils that they need to come up with an explanation for their answer. Give them a short time to do this and share the responses with the class to see if there is agreement or a range of answers. Then ask the pupils to evaluate how they did the task and the important things that they learnt. Again share these responses with the whole class.
- It may be appropriate to split the work so that pupils begin the mystery in one lesson with time to generate some questions that they then can research for homework. They continue the mystery in the next lesson as above.

Background information

Quite a few possible theories have been suggested at different times as to why dinosaurs died out – often based on rather flimsy evidence. These include:

- Meteors hitting the Earth, increasing levels of dust, radiation, pollution and decreasing levels of light.
- Volcanic eruption on a grand scale, increasing levels of dust, radiation, pollution and decreasing levels of light.
- Issues relating to diet, for example, increase in numbers of mammals and competition for food sources.
- Issues relating to reproduction, for example, increased temperature could have resulted in more female dinosaurs because the determination of sex is temperature dependent; some chemicals or pollution can decrease fertility or make egg shells thinner.
- Increased radiation, for example, from solar flares and meteorites, can cause mental problems through a reduction in brain size. As dinosaurs already had small brains this could have affected how well they responded to environmental factors. Increased radiation could also cause cancer, infertility and the death of dinosaur embryos.
- Changes to levels of oxygen in the air, for example, high oxygen levels may have increased the metabolic rate of some animals, leading to an increased demand for food with the result that many of the larger animals could not find enough food to enable them to survive.
- The evolution of plants resulted in more flowering species, many of which contained toxic alkaloids that may have been lethal to animals. This may have been exacerbated if dinosaurs ate large numbers of plants – see point above.

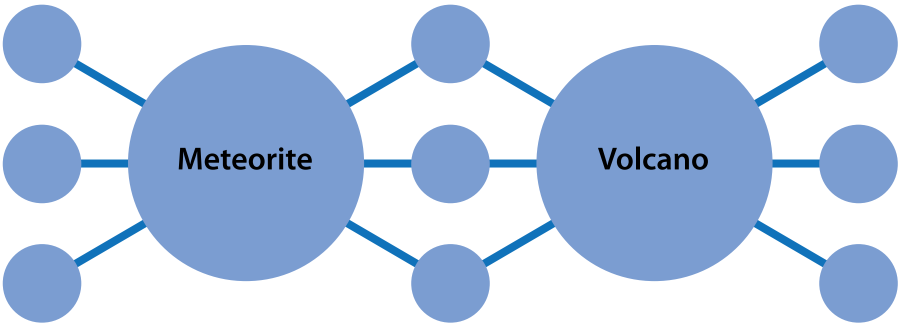
If pupils find this difficult you can use fewer cards or suggest some headings for the cards.

The mystery cards can also be used in different ways:

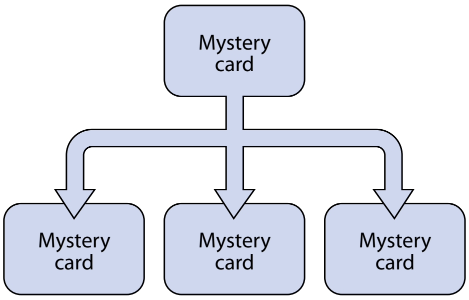
i. Put pupils into groups of three or four. One member of the group mixes up the mystery cards and then deals four cards to each pupil in the group, placing the rest of the cards face-down on the table. The object of the game is for pupils to collect a set of cards that supports only one theory of why the dinosaurs died out, by discarding and picking up cards from the pile in turn. Once they have a complete set they have to explain the link to the others in the group.

ii. Use the cards to construct a graphic organiser diagram. One example is given below in which the circles in the centre will contain points or issues common to both. The circles on either end are for the points that are not similar.

   In both activities it is not the placing of the cards that is important but pupils' ability to articulate their reasons based on scientific knowledge and understanding. Good questioning by the teacher is vital and it is worth planning some key questions before the lesson.



There are a number of different graphic organisers (sometimes thinking maps) that can be used to organise information and two are shown below.



Some suggested questions:

- How did the graphic organiser help you to process, sort or classify the information?
  - Was this a good graphic organiser to use? Why?
  - Could you adapt the organiser to make it more fit for purpose?
  - Could you add some questions to your organiser to clarify or to fill gaps in understanding?
  - Could you add links in a different colour to other information or ideas that you know about?
- Relational diagrams can help pupils understand the similarities and differences between terms. This is a useful link to classification as relational diagrams allow pupils to show whether NONE, SOME or ALL of a particular group of things belong to one category. Pupils can be asked to annotate the boundaries to show what distinguishes one area from another.

In many cases there is a correct version of the diagram, based on the recognised definition of terms that may be restricted by pupils' current level of knowledge. In some cases the task may be divergent and different diagrams could be defended on the basis of the interpretation of terms or opinions, for example, some terms could have everyday meanings that are different to the scientifically-accepted ones. This could be tried with terms such as health, safety, risk, hazard or stem cells, embryo, clone, disease.

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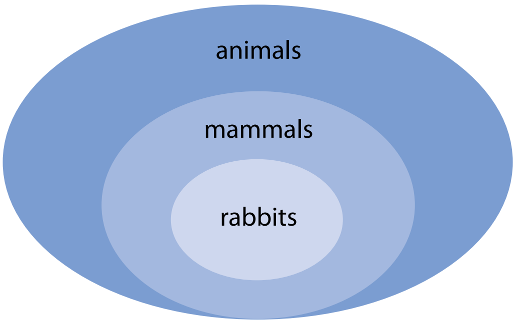
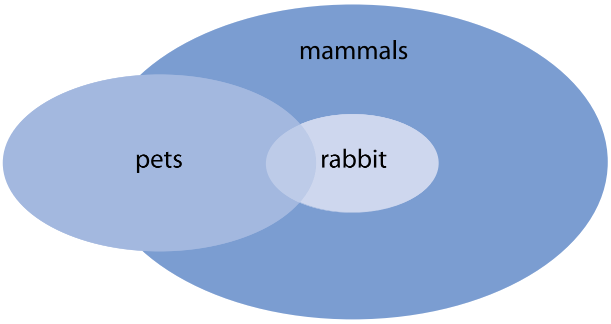
It is important to model the process for pupils using a simple example of animals, mammals and rabbits.



This shows how a diagram can demonstrate simple relationships between groups and subgroups.

This could be extended by using the categories of rabbits, pets and mammals and asking pupils to show the relationship as overlapping/non-overlapping circles. Pupils need to consider the relative sizes of the diagrams.



It is the discussion about the organisation of the diagram that is important, not the diagram itself. Pupils may have used this type of diagram in other subjects, for example, mathematics which could be useful practice to draw on.

i. Use the photosynthesis and respiration cards to construct a relational diagram. One group of pupils presents its diagram to the class and the other groups have a few minutes to discuss it before asking questions; or pupils share their diagram with another group to identify and discuss the reasons for any differences.

ii. Present pupils with a completed diagram and ask them to decide why they agree or not with the placing of the cards or whether they can construct a better diagram.

Some suggested questions

- How did you decide where to put things?
  - Has the drawing helped you sort out the meanings of the terms and their relationships?
  - Is this more helpful than looking words up in a dictionary?
  - Did you need to change your diagram?

B) Model how to change information from one form to another, for example, DARTs (Directed Activities Related to Texts), turning scientific development into a timeline.

- DARTs are a useful way to ensure that pupils engage with text in a way that promotes understanding.

  These activities are **directed** because pupils are told why they are reading and what they should gain from the experience before they start. They are **active** because they make pupils think and make decisions.
- Use the handout 'Supporting the writing of a conclusion', which contains a number of sheets from the 'Literacy in science' unit to support the class or groups of pupils in writing better conclusions.

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C) Support pupils in using different thinking grids and organisers to make links between pieces of information.

There are many examples of concept maps, mind maps and graphic organisers that can be used to help pupils make links between pieces of information. Use some of the examples from the *Developing critical and creative thinking in science* guide.

D) Explain clearly the difference between fact and opinion and teach pupils how to distinguish between them.

- Pupils will need to be taught that there is a grey area between opinion and fact, which could contain:
  - opinion with no supporting evidence
  - opinion based on 'common sense'
  - opinion based on balance of probabilities
  - opinion or hypotheses based on one source of evidence or a range of sources.
- 'The washing line' activity can help pupils order their ideas and justify their choices. Pupils are given a number of cards and have to place them between the two ends of the washing line – one end representing 'fact' and the other 'opinion'. On the cards could be statements such as:
  - the world is round
  - the Earth orbits the Sun
  - the world will end tomorrow
  - global warming is caused partly by the greenhouse effect
  - there will be a new ice age within 50 years.
- Pupils should also be taught that there are certain language features that might signal opinion, such as: 'I think that…', 'it is believed that…', 'some experts say that…'. Where there is evidence to suggest that a statement could be factual, pupils should look for phrases such as 'Evidence/research has shown that…' and 'Experiments suggest that…'.
- Pupils should be taught that there are always other points of view and that, where appropriate, these should be taken into account. The following activities are useful in helping pupils move away from their own points of view.
  - 'Plus, Minus, Interesting' (PMI) grids (see 'Developing critical and creative thinking in science').
  - Six thinking hats.
  - The continuum activity (see Ideas for values continuums in group talk steps 2–3).

E) Teach pupils how to use internet search engines and how to choose results summaries to read.

Pupils should be taught that like any other source of information, internet pages can be inaccurate or untruthful. They should also be taught that in certain search engines:

- the results near the top are sponsored results;
- the suffixes '.com' and '.co.uk' are likely to be published by a commercial company;
- the suffixes '.gov' and '.org' are likely to come from government and official sources;
- the suffix '.ac' comes from an educational organisation.

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Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils can:

- link the selected data items or evidence to reach a suitable conclusion;
- produce notes that identify the main ideas and have a clear purpose but do not question the 'authority' of written texts;
- plan to collect relevant information and data from a variety of sources, both primary and secondary.

Step 3 – pupil characteristics

Pupils can:

- use criteria to judge the relevance and validity of data items or evidence and use this to support or negate an argument;
- adopt the most appropriate format for note-taking to represent the information for specific purposes;
- recognise the potential for bias within sources of information and data.

Strategies to ensure progression from step 2 to step 3

A) Model how to use criteria to decide if particular pieces of evidence are appropriate and to what extent they support or negate the hypothesis.

- Use the dark sucker theory (**www.myteacherpages.com/webpages/LAlewine/files/Dark%20 Suckers.doc**) to model for pupils how to use the 'Evidence decision maker' sheet to make choices about whether a piece of evidence is appropriate to the question being asked in terms of reliability and validity. Then pupils use the 'Evidence decision maker' to assess a range of conclusions, for example, pupils' own investigations, newspaper articles, internet sites, television reports, to decide if these are valid conclusions.
- Use the 'Plate tectonics card sort' which is arranged into three groups for this task. The statements may be printed onto different coloured cards. The activity can also be used as a further mystery. Ask pupils to select nine cards at random from the 15 red plate tectonic cards. Then they rank these cards as a diamond nine and draft a suitable conclusion, based on the evidence they have in front of them. Pupils should then have access to each other's work and should discuss why the evidence card at the top of the diamond is where it is, giving some justification for their choice. This could be with another group or to the whole class. It is important that pupils appreciate that the same evidence-base may lead people to form different conclusions.

B) Expose pupils to a range of sources of scientific information (e.g. magazines, newspapers, blogs). Explore with pupils the features which make these texts suitable for their audience and purpose. Support pupils in making a judgement about their validity as sources of scientific evidence.

Writing in science can be effective when the writing expectations and purposes are made clear at the start. By considering audience and purpose pupils can become more imaginative in writing about science and develop persuasive, interpretive and argumentative writing.

- Liaise with the English department to see what skills pupils already have in writing for different audiences and purposes.
- Discuss with pupils what constitutes an audience, for example, people of a particular age, from a particular group, or with common interests and what constitutes a purpose, for example, to entertain, inform, explain, persuade and serve a practical need or decorative function.

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- Use some of the examples below for pupils to discuss and:
  - agree the criteria for designing a leaflet for parents about why they should stop smoking and use agreed criteria to evaluate the leaflets;
  - review the appropriateness of different graphs for presenting different data sets, for example, line graph, bar chart, histogram, pie chart, scattergraph;
  - match different diets to different people, for example, diabetic, coeliac, pregnant woman, long distance runner, body builder, or energy resources to particular environments and justify the choice;
  - identify the key features of an explanation for a younger pupil on how to carry out a procedure or investigation;
  - decide which of a set of given scientific poems is most suitable as an explanation, for example, explaining to a class of six-year-olds how to care for the environment;
  - compare how advertisements about a given issue would be different, for example, to persuade people to buy less salty foods if it were aimed respectively at pensioners, parents of young children, teenagers and people with a history of heart disease in the family;
  - present both sides of an argument, for example, to a group of mothers with young babies about whether they should use the MMR vaccine or to a supermarket chain about whether they should sell genetically-modified food.

C) Explore with pupils effective ways to make notes from different sources of information.

- Use the handout on 'Note-taking strategies' and ask pupils to identify where they have already used some of the techniques in other subjects and how useful the technique was, using a RAG (red, amber, green) rating.
- Model any techniques that pupils have not tried and give them opportunities to try and evaluate these for themselves during lessons.

D) Model for pupils some questions they could ask to try to detect bias in a text.

- Provide pupils with a research aide-memoire containing questions to assist them in identifying bias , for example:
  - Who wrote the text?
  - Who funded the research?
  - What is the scientific evidence in the text?
  - Is the publication running a campaign on this issue?
  - Did your personal opinion affect your judgement as to the reliability of the source?
- Discuss with pupils the kind of language which might indicate bias, for example:
  - assertions
  - exaggeration
  - use of passive voice to lend authority and hide the agent of an action.
- Use an activity such as a 'Newsbug'. The pupils are given a cut-out six-legged bug. For each piece of evidence they have to decide if it is strong evidence (leg remains), the evidence has some merit (appropriate proportion of the leg is removed) or the evidence is very weak (whole leg is removed). At the end the pupils see if the bug will stand up.

E) Teach pupils how to narrow the parameters of their internet searches using search engines and how to select from the results.

- Show pupils how to use the 'Advanced search' features of a search engine.
- Discuss with pupils the best words to use for a search and why.

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils can:

- use criteria to judge the relevance and validity of data items or evidence and use their findings to support or negate an argument;
- adopt the most appropriate format for note-taking to represent the information for specific purposes;
- recognise the potential for bias within sources of information and data.

Step 4 – pupil characteristics

Pupils:

- evaluate the reliability and validity of others' research, hypotheses and conclusions;
- transform information into textual, visual and diagrammatic notes that have clarity of purpose and demonstrate critical reflection of ideas;
- explain why they selected or discarded sources of information or data.

Strategies to ensure progression from step 3 to step 4

A) Create opportunities for pupils to evaluate the appropriateness of a piece of research, theory or other pupils' work and to make valid comments about the conclusion the research or work came to.

- Allow pupils, working in small groups, to decide on three appropriate criteria for evaluating a piece of work or theory. Let them share these with another group and agree three final criteria to share with the class. Agree a class set of criteria to use with some samples of work.
- Present pupils with a number of alternative theories and a short summary about each. Ask them to support or refute the theory using information sources to construct their argument. Possible alternative theories could include:
    - spontaneous generation
    - phlogiston theory
    - the flat Earth
    - the Earth is the centre of the Universe
    - the Lamarck theory of the inheritance of acquired characteristics
    - we see because light rays travel from our eyes to the objects.

  All the class could work on the same theory or each group could be given a different theory.

B) Model the part of the scientific process where data is used to develop theories and then build pupils' confidence in being able to adapt or change conclusions in light of new evidence.

- Use the plate tectonic cards. Give pupils the red tectonic plate cards and ask them to draw a conclusion based on that evidence. They may want to use the 'Evidence decision maker'. Now introduce the amber cards and ask whether they need to amend or change the conclusion and if so in what way. Now give them the green cards and repeat the process.

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Alternatively, give groups different sets of cards (pupils do not know this at this stage) and ask them to draw a conclusion. Ask groups with different cards to join up and share their conclusions. Ask them to discuss why they have different conclusions and then to use all available evidence to reach a consensus.

- Use the PowerPoint™ presentation 'Drawing conclusions from graphs' as a model to explain to pupils how new evidence can change the shape and therefore the 'story' of the graph. Ask pupils to discuss where this is a good analogy and where it has weaknesses.
- **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;
  - the importance of testing explanations by using them to make predictions;
  - checking if evidence matches the predictions.

  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, for example, 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 pectinase that '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 some pieces cut from a whole pineapple. The pieces should be on the same large dish (so as not to give away any clues to the pupils) although the two varieties should be kept 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

In 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 include:

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- 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 were not 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 did set because the tinning process uses chemicals;
- the fresh pineapple jellies did not set because there is bacteria or germs on fresh pineapple that stop the setting process.

Stage 4

After about five 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. Use a whole-class discussion about the range of explanations and tests to model 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 involves 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.

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Stage 6

If there is time, pupils set up their tests; alternatively 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.
- Several explanations are suggested based on knowledge and theories.
- Some explanations can be dismissed as further knowledge (evidence) which 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.

C) Transform the same piece of information into various forms and evaluate the purpose and effectiveness of each.

- Use articles from newspapers, text books or produced by pupils and ask different groups of pupils to transform the same piece of information into another suitable form such as:
  - a table
  - a flow chart
  - a spider diagram
  - a picture diagram
  - a cartoon
  - a poem.

Pupils present their information, in revised form, to the class and then collectively discuss and evaluate which forms are most effective for which purpose.

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Handout 1.6: Scientific writing steps table – adapted for EAL learners

This strand is about developing pupils' skills in writing using correct scientific terminology and drawing on evidence. It is important to realise that thinking and talking are important precursors of writing. Pupils also need to learn to construct extended pieces of writing and understand the implications of context, audience and purpose.

Step 1 pupil characteristics	Strategies to ensure progression	Step 2 pupil characteristics	Strategies to ensure progression	Step 3 pupil characteristics	Strategies to ensure progression	Step 4 pupil characteristics
Pupils: ● use key scientific words intermittently in oral and written work including explanations and evaluations; ● lack confidence in using scientific terminology correctly;	A) Make vocabulary a focus for starters or plenaries differentiating between everyday and subject vocabulary. B) Use talk to model and practise complex sentences and use more sophisticated connectives like 'because', 'if'… 'then', 'when'. C) Use collaborative talk activities for organising ideas, for example, card sorts or graphic organisers.	Pupils: ● use a range of key scientific words in oral and written work including explanations and evaluations; ● produce longer written responses using more sophisticated connectives like 'because', 'if'…'then', 'when' to link and organise ideas within paragraphs, and connectives like 'firstly' and 'next' between paragraphs;	A) Use more complex technical vocabulary as a focus for starters and plenaries. B) Discuss the use of more complex scientific vocabulary when reading texts. C) Explain the use of more complex scientific vocabulary when modelling writing. D) Identify shades of meaning (possibility, probability, certainty) or relationships between ideas, for example distinguishing between opinion or hypothesis and fact when exploring texts.	Pupils: ● mostly use appropriate scientific terminology and conventions in explanations and evaluations written in standard English; ● organise their ideas to produce independent written work to communicate science in a clear, logical way appropriate for audience and purpose;	A) Create opportunities to construct sophisticated hypotheses based on a wide range of evidence. B) Create opportunities for individual or group project-type work based on research and selection of appropriate information and evidence.	Pupils: ● use a wide range of scientific terminology and conventions drawing on abstract ideas and models in explanations and evaluations; ● select and synthesise relevant information and evidence and then choose the most appropriate form to communicate these to a wide range of audiences or to support an argument.

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● produce brief written responses using mainly simple sentences and common connectives like ‘and’, ‘then’, ‘but’; ● make some limited attempts to organise ideas, e.g. sequencing, not always successfully; ● are not clear about the purpose of the writing, e.g. explanation or evaluation.	D) Model types of writing, e.g. using a writing frame for planning, explaining, evaluating.	● understand the purpose of writing and are beginning to use the appropriate style, for example, using cause and effect appropriately in explanations.	E) Model the development of a simple discursive argument based on evidence using point, evidence, explanation. F) Use peer assessment with clear criteria for specific types of writing, e.g. explanations, evaluations or persuasive writing.	● can identify shades of meaning and relationships between ideas and organise evidence appropriately to produce a written response; ● can use success criteria to assess both the form and content of scientific writing.	C) Create opportunities to write for a different audience, for example, newspaper articles, teaching material for younger pupils, instruction manuals for technical equipment and science fiction that has some basis in fact, such as a script for a TV show.	

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Handout 1.7: Scientific writing – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about developing pupils' skills in writing using correct scientific terminology and drawing on evidence. It is important to realise that thinking and talking are important precursors of writing. Pupils also need to learn to construct extended pieces of writing, and understand the implications of context, audience and purpose.

Effective writing in science requires the use of correct vocabulary and terminology and the development of increased sophistication in written responses. The activities included in these materials allow opportunities for pupils to move from brief, written responses to lengthy pieces of well-constructed argument based on evidence that takes account of context, audience and purpose.

Pupils need to develop their skills from ordering and vocalising their own thoughts into producing a piece of discursive writing (an opinion clearly backed by evidence), then to a persuasive argument designed for a particular audience to change the reader's point of view. This then enables pupils to contribute to the development of a group argument.

In science, teachers should plan for pupils to:

- build on their own experience of different styles of writing developed in the primary school;
- develop their use of scientific terminology by making increasingly complex terminology the focus for starters and plenaries;
- produce independent written work that communicates science in a clear, logical way;
- distinguish between opinion and fact to demonstrate understanding of the role of evidence in scientific ideas.

The ability to write coherently and clearly is a fundamental aspect of the scientific process. For Key Stage 3 pupils this is an essential precursor to the skills of synthesis and analysis in extended written work, which is now a feature of Key Stage 4 science. *Ten steps to better writing in science*[1] is a useful resource.

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[1] Available at **www.publications.teachernet.gov.uk**. Search using the ref: DfES 0179-2005

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Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- use key scientific words intermittently in oral and written work including explanations and evaluations;
- lack confidence in using scientific terminology correctly;
- produce brief written responses using mainly simple sentences and common connectives such as 'and', 'then', 'but';
- make some limited attempts to organise ideas, e.g. sequencing, not always successfully;
- are not clear about the purpose of the writing, e.g. explanation or evaluation.

Step 2 – pupil characteristics

Pupils can:

- use a range of scientific words in oral and written work including explanations and evaluations;
- produce longer written responses using more sophisticated connectives such as 'because', 'if… then', 'when', to link and organise ideas within paragraphs, and connectives like 'firstly' and 'next' between paragraphs;
- understand the purpose of writing and are beginning to use the appropriate style, for example using cause and effect appropriately in explanations.

Strategies to ensure progression from step 1 to step 2

Resources for scientific writing, Section A, which is to be used alongside this guidance, contains a wide range of activities taken from existing Secondary National Strategy materials and is referred to throughout the rest of this document.

A) Make vocabulary a focus for starters and plenaries, differentiating between everyday and subject vocabulary.

- Use word games such as:

  Word splat – Pupils devise questions that can be answered by one of a dozen or so scientific words or terms that are written on the board. The class is divided into two groups. One member of each group is invited to stand close to the board. The teacher chooses a pupil to ask a question. The pupil from the opposite team who is by the board must say the word and place a hand on it. Any pupil who answers incorrectly chooses another member of the group to replace them at the board.

  Drawing the word – Pupils can either draw the word for other pupils to guess or could draw a simple picture to make a link that is pertinent to them, for example, to remember the job of the nucleus, a pupil might draw a book, computer or steering wheel.

- A wide variety of simple activities that require minimal preparation can be used here. Refer to section A from *Resources for scientific writing*. Some examples from this list are:

  Definition cards – Prepare two sets of cards, one with key words and another with definitions. Either individually or in groups, pupils match each word with its definition.

  Alternatively they can be used as **flash cards**. Pupils each have a set of words and the teacher reads out a definition. Pupils hold up what they think is the correct word. This also enables quick assessment of pupils' understanding.

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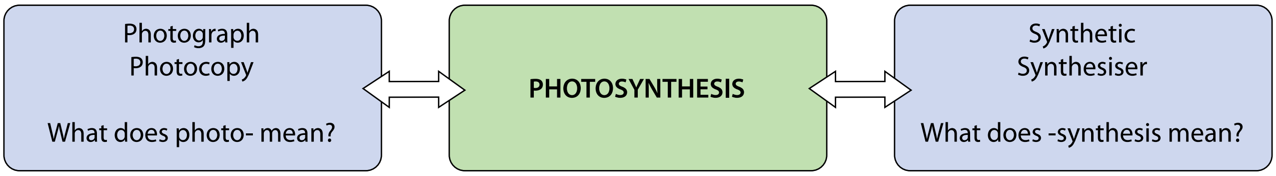
Use **word-webs** to help pupils look at words that have something in common. For example:

What does the word 'photosynthesis' mean? How do you know?



Photograph
Photocopy

What does photo- mean?

PHOTOSYNTHESIS

Synthetic
Synthesiser

What does -synthesis mean?

B) Use talk to model and practise complex sentences and use more sophisticated connectives such as 'if… then', 'when'.

- Play card games with connectives on coloured cards to make sentences using a range of connectives for different purposes.
- Give pupils examples of connectives that they have to use in oral and written work.

Cause and Effect	**Summary**	**Emphasising/ Qualifying**	**Adding**
because therefore consequently when eventually accordingly consequently as so effectively thus as a result therefore until because inevitably	in brief in conclusion overall to sum up in short throughout summarising/ in summary on the whole	in particular certainly explicitly definitely above all specifically in fact more importantly as long as apart from yet nevertheless although	as well as too also and and then in addition furthermore what is more
Conclusion	**Compare/ Contrast**	**Sequencing**	**Illustrating**
finally to sum up to conclude after all in the end ultimately in conclusion	compared with like similarly in contrast to balance this equally as with comparatively however still whereas alternatively otherwise instead (of) nevertheless	to begin with in the first place firstly/ secondly lastly next then finally eventually meanwhile after	for example for instance in other words such as in the case of/ to take the case of to show that

C) Use collaborative talk activities for organising ideas. For example, card sorts or graphic organisers.

- Use a range of sequencing activities, mystery activities and diamond nine activities to identify and prioritise important information; justifying choices.

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- Use the key ideas sentences, as in the example below. Pupils construct a number of sentences and use these to write a paragraph about a topic or idea.

Particles

Make 10 correct sentences by choosing a word or phrase from each column.

Solids Liquids Gases	cannot can spread have take melt evaporate condense solidify	a fixed shape the shape of the container high density be squashed when heated low density a fixed volume be poured to fill the space available	because the particles	gain energy and move further apart. cannot move around, only vibrate. move around but stay close together. gain energy and move around more. are close together. lose energy and move around less. lose energy and move closer together. are far apart. move around freely, at high speed.

- Use the 'Explanations' tables as in the example for *How science works* below. Pupils, working in pairs, choose the best explanation for each statement. Groups can compare their answers to identify and discuss those where they have different answers.

How science works

Choose the best explanation for each statement. Some of the explanations match more than one statement.

Statement	Because	Explanation
Scientists repeat measurements In an enquiry scientists change one thing while keeping everything else the same Scientists make sure they have enough readings Scientists draw graphs of their results When collecting results scientists measure things carefully Scientists often make a prediction Scientists use scientific ideas Scientists often do a control experiment where they keep everything the same	because	it makes it easier to spot patterns in their results. it helps them decide what to investigate. they want to be sure of their conclusions. they need to make sure the effect is not just something that would have happened anyway. they need to make their results as accurate as possible. they often have an idea of what will happen before they do the experiment. they want to make it a fair test. they want to make sure their results are reliable.

- Use 'Loop card games' with pupils. Each card has a word on one side and a definition on the other although the two do not match. One pupil reads out a word from the front of their card, then the pupil with the correct definition on the back of their card reads it out, then reads out the word on the front of the card. If all goes well, the loop should finish back at the person who started the game, who will have the final definition.

D) Model types of writing, e.g. using a writing frame for planning, explaining, evaluating.

- Use the sequence below explicitly with pupils to support writing.

Step	Example	Possible resources
1. Establish clear aims	The purpose of the writing is made clear to pupils, e.g. the purpose of writing a conclusion is to summarise findings and the explanation of the science underpinning them.	See handout 3.4 at the end of this guidance.
2. Provide example(s)	Teachers provide an exemplar piece of writing or alternatively a good and a weak example for comparison; exemplars of other text types should also be available.	See handout 3.20 at the end of this guidance.
3. Explore the features of the text **4.** Define the conventions	Use good questioning to identify the conventions/features at: ● text level (e.g. paragraphing: introduction, main development and conclusion); ● sentence level (e.g. use of cause and effect connectives to enhance complex sentences); ● word level (e.g. accurate use of vocabulary).	See handout 3.12 at the end of this guidance.
5. Demonstrate the writing process	Teacher makes thinking process of writing a conclusion explicit to pupils while demonstrating the writing process, e.g. 'I am going to use an "er/–er" sentence to describe the relationship between two variables'.	
6. Compose together **7.** Scaffold the first attempts	Pupils have an opportunity to practise the teacher's model collaboratively.	
8. Develop independent writing	In subsequent scientific enquiries pupils will move towards independent writing of a conclusion.	
9. Draw out the key learning outcomes **10.** Review	Pupils are required to make their thinking about the writing process explicit, reinforcing learning.	

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Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils:

- use a range of scientific words in oral and written work including explanations and evaluations;
- produce longer written responses using more sophisticated connectives like 'because', 'if'…'then', 'when' to link and organise ideas within paragraphs, and connectives like 'firstly' and 'next' between paragraphs;
- understand the purpose of writing and are beginning to use the appropriate style, for example, using cause and effect appropriately in explanations.

Step 3 – pupil characteristics

Pupils can:

- mostly use appropriate terminology and conventions in explanations and evaluations written in standard English;
- organise their ideas to produce independent written work to communicate science in a clear, logical way appropriate for audience and purpose;
- can identify shades of meaning and relationships between ideas and organise evidence appropriately to produce a written response;
- can use success criteria to assess both the form and content of scientific writing.

Strategies to ensure progression from step 2 to step 3

Resources for scientific writing, Section B, which is to be used alongside this guidance, contains a wide range of activities taken from existing Secondary National Strategy materials and is referred to throughout the rest of this document.

A) Use more complex technical vocabulary as a focus for starters and plenaries.

Similar activities to those in 'Moving from step 1 to 2' above can be used if the level of complexity of the vocabulary is increased.

- Use prefixes and suffixes to help pupils see connections between words.
- Recognise that pupils need to use higher-order thinking skills to understand abstract concepts like photosynthesis, gravity and particle theory and use strategies like:
  - Loop card games
  - Concept maps
  - Converting text into diagrammatic representation, e.g. as for photosynthesis below.

Photosynthesis: Carbon dioxide + water $\xrightarrow{\text{Light + Chlorophyll}}$ **Glucose + oxygen**

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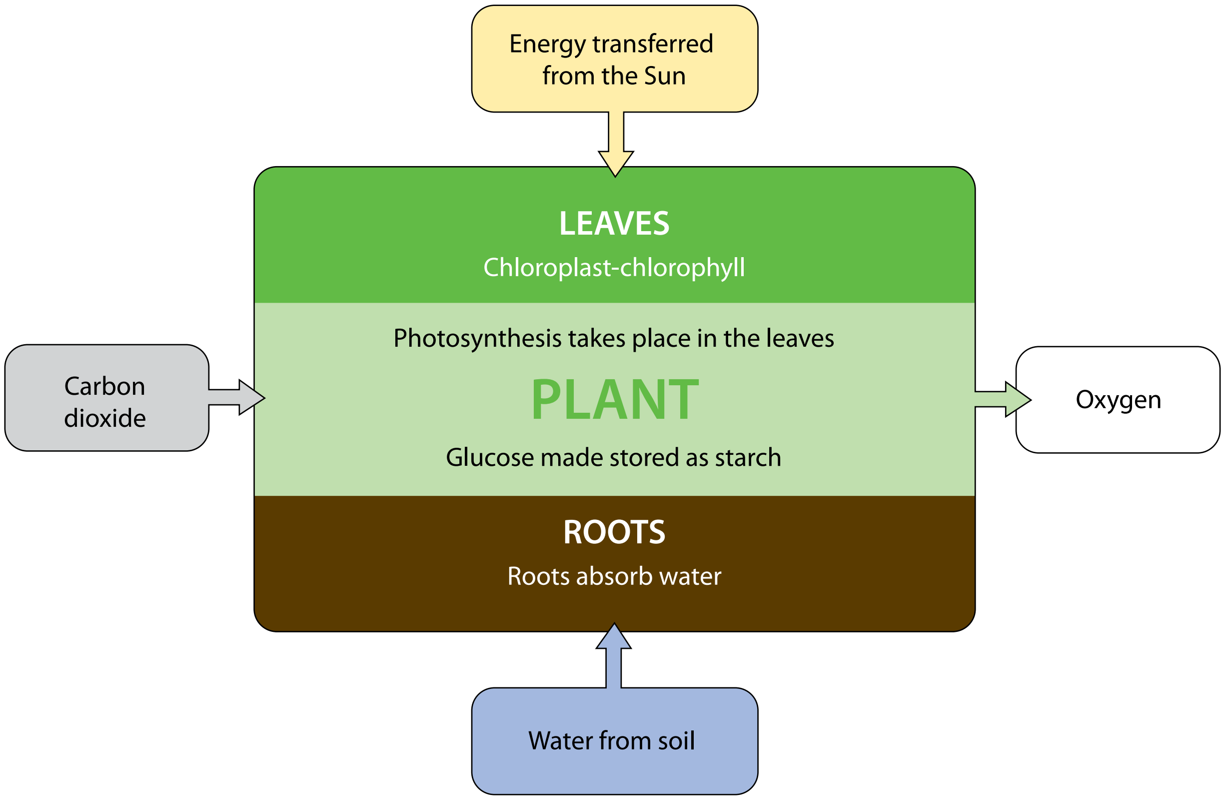

B) Discuss the use of more complex scientific vocabulary when reading texts.

- Use DARTs-type activities to help pupils identify complex scientific words or phrases.
- Explore with pupils scientific words that might have other everyday meanings that could lead to confusion, e.g. material and power, or could be misused even in text books, e.g. theory, energy.

C) Explain the use of more complex scientific vocabulary when modelling writing.

- Model talk: 'Is there a better word for that?', 'Can you think of another way of saying that?'
- Draw out conventions of writing in science, for example using the table below. Other examples can be found in *Resources for scientific writing*, Section B.

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Explanation texts	
Purpose	**To explain the causes and effects of drought**
Text level	- general statement to introduce topic - sections organised from the most important causes and effects of drought to the least important - concluding section is a summary of the points made
Sentence level	- third person - present tense - each section begins with a topic sentence which introduces what the section will be about - points within each section work from the most important to the least important - connectives such as 'since', 'because', 'so', 'as', 'therefore' and connective phrases such as 'as a result of', which are important to show cause and effect
Word level	- subject-specific vocabulary, e.g. 'precipitation', 'drought', make clear that the context is science

D) Identify shades of meaning (possibility, probability, certainty) or relationships between ideas, for example distinguishing between opinion or hypothesis and fact when exploring texts.

- Model how to distinguish between fact and opinion. Identify how the use of particular words can suggest a certainty that doesn't actually exist. Give pupils newspaper and magazine articles to identify examples of where opinion has been presented as factual evidence. Peer review can be used to evaluate their decisions.
- Model how to write a conclusion and ask pupils to compare 'good' and 'less good' conclusions to identify what makes the difference.

E) Model the development of a simple discursive argument based on evidence using point, evidence, explanation.

- Give pupils the text on the dark sucker theory (www.myteacherpages.com/webpages/LAlewine/files/Dark%20Suckers.doc). Ask pupils to assess the text, using the 'Evidence decision maker', and to decide how valuable the evidence is and therefore whether the theory can be believed. Ask them to write a discursive piece of text of their own, setting out why they do or do not support this theory on the basis of what they have read.
- Use resource 8 from *Resources for scientific writing* to provide some questions for pupils to discuss and decide how they will go about finding the answer in order to construct their argument.
- Use the 'Evidence sorting cards' to decide if the information presented can be defined as evidence. Pupils could construct a similar activity for homework, which could be used as part of the next lesson.
- Provide pupils with examples of connectives to use in their arguments.
- Use resource 10 in *Resources for scientific writing* to develop pupils' skills in writing explanations. In these activities pupils have to assess the level at which they think particular explanations are and justify their reasoning.
- Use these activities to trial the sample lesson.

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F) Use peer assessment with clear criteria for specific types of writing, e.g. explanations, evaluations or persuasive writing.

- Discuss and agree criteria for judging a good explanation, evaluation or persuasive writing.
- Provide opportunities for pupils to peer assess the different types of writing.
- Provide opportunities for pupils to peer assess the different types of writing and how it could be improved.

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils:

- **mostly** use appropriate terminology and conventions in explanations and evaluations written in standard English;
- organise their ideas to produce independent written work to communicate science in a clear, logical way appropriate for audience and purpose;
- can identify shades of meaning and relationships between ideas and organise evidence appropriately to produce a written response;
- can use success criteria to assess both the form and content of scientific writing.

Step 4 – pupil characteristics

Pupils can:

- use a wide range of scientific terminology and conventions drawing on abstract ideas and models in explanations and evaluations;
- select and synthesise relevant information and evidence and then choose the most appropriate form to communicate these to a wide range of audiences or to support an argument.

Strategies to ensure progression from step 3 to step 4

Resources for scientific writing, Section C, which is to be used alongside this guidance, contains a wide range of activities taken from existing Secondary National Strategy materials and is referred to throughout the rest of this document.

The UPD8 website (**www.upd8.org.uk**) has an ever-changing set of resources for teaching contemporary science and teaching ideas for Key Stage 3 as well as Key Stage 4.

Acclaim (**www.acclaimscientists.org.uk**) has a variety of resources based on the theme of science in the news. *Science Newswise*[2] (ISBN 0 85389 883 9) has a number of teaching strategies for teachers to use with pupils.

A) Create opportunities to construct sophisticated hypotheses based on a wide range of evidence.

- Model for pupils how to devise a simple hypothesis from limited evidence and then develop this as more evidence becomes available.
- Provide pupils with examples of other pupils' hypotheses and the evidence they have used to devise it. Assess the quality of the hypothesis.

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[2] Jarman, R. McClune, B., Newsroom Project Team, Science Newswise, Queens University, Belfast

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- Consider the evidence that was used to support conflicting historical hypotheses, e.g. Agassiz's and Lyell's hypotheses for the formation of the Earth's features.

B) Create opportunities for individual or group project-type work, based on research and selection of appropriate information and evidence.

- Pupils could be asked to identify a news story that catches their attention, either in a newspaper or on television. Their task is then to consider the science contained within the news story and to share their understanding of the story with the rest of their group, through a piece of independent writing. Pupils could be asked to consider what the implications of the story might be for themselves, for other people and for the environment.
- Refer to the materials about teaching contemporary science (*Resources for scientific writing,* Section C) and consider the advice and ideas given when planning lessons.
- Use these activities to trial the sample lesson.

C) Create opportunities to write for a different audience, for example, newspaper articles, teaching material for younger pupils, instruction manuals for technical equipment, and science fiction that has some factual basis, such as a script for a television show.

- Pupils discuss how the purpose of different texts is related to its layout, structure, sequencing, voice and viewpoint, for example, first person, tense used, level of the vocabulary and complexity of the sentences.
- Discuss different types of text with pupils and remind them of previous work in primary school and in English lessons. Identify the main types of text and ask pupils to discuss which of them they would use in science and their reasons for their choices. Allow the groups to discuss and share their examples with the whole class.

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Handout 1.8: Understanding misconceptions – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about recognising that pupils come to lessons with ideas about the world around them that can often be different from the accepted scientific ideas. Pupils need to develop some understanding of what these misconceptions are. They should begin to explore the idea that some scientific explanations can be counter-intuitive and how misconceptions or alternative frameworks might arise.

It is important that potential misconceptions are identified in the scheme of work and some suggested activities are provided for teachers to begin to address these. (The word 'misconceptions' as used throughout this document may be taken to mean 'alternative frameworks' or 'alternative conceptions'.) A misconception can be defined as a view that does not fully coincide with the scientific view.

Some features of misconceptions are that they:

- may be linked to everyday use of language;
- are constructed from everyday experience and are usually adequate for everyday life;
- can be personal or shared with others;
- explain how the world works in simple terms;
- are often similar to earlier scientific models (e.g. 'the Earth is flat');
- may be inconsistent with science taught in schools;
- can be resistant to change;
- may inhibit further conceptual development.

It is worth noting that in many cases pupils can hold both the 'misconception' and the scientific idea at the same time and may use different ways of explaining events in different situations. Some misconceptions may persist despite teachers' best efforts. Even when presented with new evidence pupils may modify it to fit into their existing model; for example, some pupils, having been clearly shown that current is not used up in a circuit, responded a few weeks later by saying that the ammeters were not working properly.

It is important that pupils' ideas are challenged in a non-threatening way and they feel reassured and safe when exposing and exploring their ideas. Pupils need to be able to test out their ideas to experience the 'conflict'. It is not enough just to tell pupils their ideas are wrong and this is what they should think.

It is all too easy to underestimate what pupils can achieve in science, simply because they are new learners of the English language. The expectation should be that they progress in their scientific learning at the same rate as other pupils of their age. Addressing misconceptions is essential for all learners; however, for EAL (English as an additional language) learners, the origins of misconceptions might not just be in scientific concepts (which can be addressed in the same way as for other learners) but in their understanding of text.

Such misunderstandings might occur at text, sentence or word level.

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Potential barriers at text level

- **Level of formality** – it may seem counter-intuitive, but many EAL learners, particularly those who have experience of schooling overseas, will find more formal language easier to access than a less formal register. It is important, therefore, not to 'dumb down' text but to teach pupils strategies for accessing texts with a more formal register.
- **Cultural context** – each culture has shared understandings of ideas and the way they are presented and organised which may cause problems if not taken into account. Contexts for learning should be relevant, motivating and culturally inclusive. This can mean that some 'common' metaphors and analogies are not helpful.
- **Tone of a text** – for example, an EAL learner might not detect irony in a text and so read it literally.
- **Layout of the text** – pupils need to understand how different parts of a text – particularly features such as diagrams (cross-sections, 3D and 2D), graphs and models – contribute to the overall meaning.
- **Lexical density of a text** – this refers to the number of content words that are 'packed in' to each clause. Lots of extended noun groups, such as 'lung cancer death rate', make the text harder for EAL pupils to read.

Potential barriers at sentence level

- **Use of the passive voice (who did what to whom?)** – EAL learners will have to be taught that they will often need to use skills of deduction in order to work out 'who did what to whom'.

  In everyday spoken English we tend to talk about what people do. However, when scientists are writing about their work, they are less interested in what individual people do. Scientific writing is usually impersonal. We don't need to know who carried out the action. Compare 'Miss Patel heated the test tube over a bunsen burner' with 'The test tube was heated over a bunsen burner.' The second sentence is more typical of scientific writing – we don't need to know who carried out the experiment. This style of writing is achieved by using the passive voice. For example, 'the embryo is implanted', 'blood is oxygenated', 'rocks are eroded'.
- **Collocation and idiom ('It's just an expression')** – these are commonly used expressions such as 'The issue of GM foods is a political hot potato' (idiom) and words that frequently appear together such as 'high probability' (collocation). Teachers should be aware of these in texts and, whenever they are encountered, challenge pupils not only to explain, but to think of alternatives. Other examples include 'rocket science', 'blind with rage', 'bad blood' and 'by the skin of your teeth'.

  Some idioms can lead to misconceptions, for example, 'looking daggers at you' can make pupils think seeing happens because light comes from the eyes or 'dry as a bone' can make pupils think bones are dead.

  There is also a high probability that some words will appear together in a sentence. 'High probability' is itself an example of this. Other examples are 'do a test', 'strong acid' (rather than 'powerful acid') and 'adverse reaction'. This is called 'collocation'.
- **Degrees of comparison ('the bigger they come the harder they fall')** – in a sentence such as 'The higher the temperature, the faster the reaction' EAL learners will need to be taught that this is showing a dynamic relationship between the temperature and the reaction.

  A crucial aspect of science is identifying relationships between variables. To do this, pupils need to be able to understand and use a particular sentence pattern: 'The …er the X, the …er the Y'. For example, 'The thicker the metal, the longer it takes to dissolve'.

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Remember that often words of three or more syllables take 'more' or 'less' rather than the comparative form of '...er'. For example, 'The more acidic the solution, the less explosive the reaction'.

The expression of degrees of comparison is an important aspect of drawing conclusions from investigations and should be specifically taught through modelling.

- **Using pronouns ('this and that')** – pronouns are words such as 'he', 'she', 'it', 'they', 'this', 'that', which all refer to a noun elsewhere in the text. In guided or shared reading sessions, teachers should ask pupils to identify the nouns to which the pronouns refer.

  As pupils' writing in all subjects develops they learn how to make their writing flow by avoiding repetition. Compare 'John went to the park. John played on the swings' with 'John went to the park. He played on the swings.' 'He' is a pronoun and refers back to 'John'. In scientific writing there are many examples of the use of pronouns such as 'this', 'that', 'these' and 'those'. For example, 'Elements cannot be broken down into anything simpler. When these combine together they make compounds.' 'These' and 'they' are both examples of pronouns and in this sentence refer back to 'elements'. This will not necessarily be obvious to some pupils with EAL. Particular attention needs to be given to pronouns and the words to which they refer.

- **Modal verbs ('should have', 'could have', 'would have')** – these express doubt, certainty, possibility, probability, obligation or permission and EAL learners might not understand the subtle distinctions between them. For example: 'the results might indicate that…' and 'the results show that…' – how certain is the writer in each case?

  At the heart of science is the use of evidence to reach decisions, but science is also about identifying what is doubtful, certain, probable or possible. In investigations and problem-solving activities pupils start off tentatively saying, 'It might be X…it could be Y'. Then after finding appropriate evidence they decide that 'it can't be X because…' or 'it must be Y because…'.

  To do this they need to understand and use modal verbs. These include 'can', 'could', 'might', 'may', 'should', 'ought to' and 'would' and their negative and question forms, as well as different tenses. For example, when looking back at an investigation they might want to consider what 'might have happened' or what 'should have happened' or what 'could not have happened'. Modal verbs should be specifically taught through modelling and through relating them to ideas, hypotheses and conclusions.

Potential barriers at word level

- **Delexical verbs** – these are common verbs such as 'do', 'make', 'give', 'put' and 'get' that can be used in many different contexts. These verbs have different meanings depending on other words they are combined with or the context they are used in; consider 'give out' (emit, break down) or 'put down' (place, humiliate, suppress, write). Verbs such as these are often used incorrectly by pupils with EAL.

  It is preferable to teach pupils the science-specific verbs rather than using the more common delexical verbs which can cause confusion.

- **Specialist use of everyday language** – teachers should draw attention to the specialist use of words such as 'cell', 'tissue', 'mass', 'volume', which can have different meanings in everyday contexts.

  Science has its own subject-specific vocabulary, for example, 'evaporation', 'sodium chloride', 'transpiration', 'oxygenated'. In general, teachers are very good at drawing attention to these words and teaching them explicitly.

  There are also many scientific words which are used in other curriculum areas and in ordinary English with different meanings: 'conductor', 'tissue', 'host', 'property', 'value', 'attract', which can cause problems unless the different meanings are made explicit to pupils.

Apart from subject-specific vocabulary in science texts, there are many other examples of more formal language not normally used in spoken English: 'represent' (show), 'container' (beaker), 'method' (how to do it), 'direction' (way), 'complete' (finish).

Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- use everyday experience to explain scientific ideas;
- show common misconceptions in their written and oral work.

Step 2 – pupil characteristics

Pupils:

- are aware that some scientific explanations are counter-intuitive and that this can be because of differences between everyday and scientific explanations.

Strategies to ensure progression from step 1 to step 2

A) Use Concept Cartoons™ (concept mapping or annotated drawings) with pupils to raise awareness that alternative ideas exist.

- Use a Concept Cartoon™ and give pupils time to discuss any points with which they agree and to justify their decisions, explaining how they know. Share these views with the whole class to explore whether different pupils hold different views. If all pupils think the same then ask them to try to give at least one idea or reason why other characters might think differently.

  The aim of this exercise is to reinforce the idea that there are often seemingly legitimate reasons why people think certain things and hold particular ideas. A Concept Cartoon™ can be used to create some cognitive conflict that will be developed further on.

  The Ideas, Evidence and Argument in Science (IDEAs) project[1] has materials to support the development of argument in the classroom.

- Use concept maps – these may be constructed by pupils or devised by the teacher where some of the links are based on current scientific knowledge and understanding and some are not.

  The aim of this exercise is for pupils to work in small groups to identify links with which they agree and those that they think are wrong. They share their ideas with another group and look for similarities and differences in their ideas. Pupils can use this to produce a list of questions or ideas about which they are less secure. It is important to have a climate for learning that enables pupils to feel safe enough to admit that they do not know.

  Use annotated drawings – these may be ones drawn by pupils in other classes, taken from various science sources or drawn by the pupils. Annotated drawings might be produced in response to:

  - a question, such as: 'What does a plant need to grow?' or: 'How do clothes dry?';
  - a simple practical activity such as placing an ice cube in a metal container and observing the changes, or watching a Cartesian diver.

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[1] The Ideas, Evidence and Argument in Science (IDEAS) project was developed by Jonathan Osborne, Sibel Erduran and Shirley Simon and published by King's College, London (2004)

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Working in small groups, pupils identify any annotations with which they do not agree and make changes in a different colour. These are passed to another group who make further changes in another different colour – these changes might be to the original or amended annotations. The drawings are then returned to the original group for further discussion before the three groups join together to explore any differences in their ideas.

B) Identify some misconceptions held by the pupils and explore with them which of these statements seem counter-intuitive and why.

- Use the true/false/unsure sheet from the 'Misconceptions in science' handout to identify quickly some misconceptions across a range of concepts.

  Or use the card sort activity from the 'Misconceptions in science' handout and ask pupils to sort the cards into those with which they agree, those with which they do not agree and those about which they are not sure. (Note: They are all false!)
- Use the 'Identifying misconceptions questionnaire' with small groups of pupils to explore their understanding.
- Ask pupils which areas of science they find the easiest to understand and see if they can say why.
- Explain the idea of the counter-intuitiveness of science to the pupils. Allocate some misconceptions to groups of pupils and ask them to find out what the scientific explanation is.
- Ask them to decide if this explanation seems counter-intuitive and what makes the misconception more believable.

Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils are:

- aware that some scientific explanations are counter-intuitive and that this can be because of differences between everyday and scientific explanations.

Step 3 – pupil characteristics

Pupils can:

- explain how some common misconceptions might arise;
- recognise that it is possible to have and use conflicting models.

Additional guidance

In some areas of school science, there are big overlaps between everyday and scientific ways of knowing (for example, skeletons) which are the ones pupils generally find the easiest to understand because of the similarity of the explanation. However, in other areas, science offers an alternative to the everyday view – one that pupils may find implausible. For example, most people will describe drinking through a straw as 'sucking'; the scientific explanation is that there is a difference in air pressure inside and outside the straw. You remove some particles of air from the straw, thus reducing the air pressure inside the straw, and the greater air pressure outside pushes the orange juice up into your mouth. The scientific explanation can seem counter-intuitive.

Strategies to ensure progression from step 2 to step 3

A) Use Concept Cartoons™ with pupils to promote the discussion of alternative viewpoints, for example, explaining why they do not agree with certain characters' viewpoints.

- Use a Concept Cartoon™ but this time ask pupils to explain why they do not agree (wholly or partly) with the other characters' ideas or statements.
- Set up a debate with different pupils taking different roles to justify why their view is correct. English and humanities departments often have expertise that can be drawn on to organise this well.
- Use a variety of group work activities to enable pupils to explore different viewpoints. See the handout 'Successful science discussions'.

B) Discuss with pupils how some of the different representations of scientific phenomena can lead to misconceptions, for example, diagrams or models of particles, seasons, gas exchange.

- Ask pupils to look through textbooks to find pictures of:
  - diagrams of particles, for example, in solids, liquids and gases; osmosis; diffusion;
  - gas exchange in leaves and air sacs;
  - day and night; seasons; phases of the Moon;
  - respiration (usually only animals and not plants);
  - elements and compounds;
  - light ray diagrams;
  - the reproductive system.

  Select one of these and explain to pupils how it might cause misconceptions. For example, the diagram showing the seasons generally has a noticeably oval orbit with the Earth much closer to the Sun in autumn and spring.

  Ask them to look at the other diagrams to see if they can identify how any of them could lead to misconceptions.

Additional guidance

Models and analogies are useful to help pupils visualise abstract ideas and objects or processes that are too small to be seen. Different pictures can be used to explain different ideas or aspects of ideas. However, no one model can explain everything and sometimes models break down. Models can be 'good enough' for the particular purpose, for example, a 'billiard ball' model is good enough for solids, liquids and gases but not for chemical reactions. Yet in many books this is what is shown. Pupils need to be made aware of the 'good enough' model and its shortcomings.

C) Create the opportunity for pupils to discuss which of the common misconceptions could arise because of everyday ways of speaking, for example, 'plants get food from the soil'.

- Give pupils some examples of common everyday expressions that could cause misconceptions. For example:
  - 'I'm looking right through you.'
  - 'Turn the switch off and save power.'
  - 'Shut the door and keep the cold out.'
  - 'Come a bit closer – I can't hear you.'
  - 'The ball stopped because it ran out of force.'

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  - 'I've used up all my energy.'
  - 'Astronauts float because there is no gravity in space.'
  - 'Just going to buy some plant food.'

  Ask pupils to discuss how these could lead to misconceptions and if they can they think of any others.

- Give pupils the 'Everyday meanings sheet' to discuss and complete. How do these words lead to misconceptions?
- Ask pupils to search the internet for any old sayings or myths that might lead to misconceptions, for example, the idea of taking flowers out of a hospital ward or bedroom at night. Ask whether they have been told any of these by parents, carers or grandparents.

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils can:

- explain how some common misconceptions might arise;
- recognise that it is possible to have and use conflicting models.

Step 4 – pupil characteristics

Pupils can:

- explain how insight into the ways misconceptions can arise has helped their understanding of science.

Strategies to ensure progression from step 3 to step 4

A) Use Concept Cartoons™ with pupils as a stimulus to enable them to think about why the characters might have those ideas and where they might have come from.

- Pupils are given a Concept Cartoon™. The aim of this exercise is to develop an awareness of how the misconception might have arisen and to extend this to include an explanation of what is fundamentally wrong with the idea. Pupils should have already considered how misconceptions can arise from everyday terminology or expressions and when the scientific explanation feels counter-intuitive. Other reasons may be as a result of:
  - the scale of the topic – either giant scale, for example, the Universe, or tiny scale, atoms, means that it cannot be observed directly;
  - the statement being based on opinion rather than scientifically-accepted fact, or opinions based on atypical observations such as: 'All plants reproduce like the Mexican hat plant, where little plants form round the edge of the leaves, drop off and grow in to another plant';
  - it being an abstract concept;
  - relying on another concept being fully embedded.

  This list may be used as a checklist for pupils or made into a table.

B) Create the opportunity for pupils to compare some of the common misconceptions to the scientifically-accepted explanations and consider what evidence they would need to disprove the misconceptions.

- Pupils could devise their own Concept Cartoons™ to illustrate possible areas of confusion in a topic. Then give this to another group to decide what activities they would ask younger pupils to undertake to begin to challenge some of the misconceptions.

- Pupils identify and discuss examples where they think it would be difficult to challenge the misconception, and explain why.
- Give pupils some examples of how scientists came to a view that was contrary to the beliefs of the time; for example, Galileo, Darwin, Wegener and the role of the scientific community in validating new models.

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Handout 1.9: Using models – teacher guidance with additional notes for EAL learners

The original teacher guidance for this aspect has hyperlinked resources. These materials can be accessed from the bookcase in the 'Local school' or from the Grouped Resources tab.

This strand is about recognising the importance of models in developing scientific understanding. Within the scientific community, models and modelling are an important mechanism for advancing scientific understanding. Models are an excellent tool for illustrating abstract concepts and processes and are highly recommended for EAL (English as an additional language) learners.

Models can help pupils to engage with abstract concepts they encounter in science, and also help to further develop their understanding of how the world works. They should be able to make connections between the model or analogy and the concept or observation presented. Exposure to a range of different analogies and teaching models will enable pupils to develop skills to question how appropriate they are. To make progress towards level 6 and beyond, pupils should begin to evaluate the strengths and weaknesses and modify teaching models to fit new observations and ideas.

Analogies, however, should be selected with care as they might be based on knowledge or cultural assumptions not shared by all the pupils, for example:

> 'An electric circuit is like a race where the electrons flow around the circuit like runners around a track. Components, like light bulbs, slow down the flow of electrons just as the hurdles do in a steeplechase.'
>
> 'The greenhouse effect is one of the causes of global warming.'

Before using an analogy, ask yourself the following questions:

- Are the pupils familiar with the words (e.g. 'steeplechase', 'greenhouse')?
- Are the pupils familiar with the concepts (e.g. how a steeplechase is run, how a greenhouse is used)?
- Is the analogy relevant to the pupils (e.g. an analogy involving the countryside might not be relevant to a pupil who has never left the city)?
- Would a physical or visual model be better?

Scientific researchers and science teachers all use models to help visualise and explain the world. In turn, models and analogies can help pupils to engage with the abstract concepts they encounter in science, and use these to develop their understanding of how the world works further. Teachers can use modelling to help pupils make sense of their observations, findings and abstract ideas through the visualisation of:

- objects that are too big, for example, the solar system or an ecosystem;
- objects that are too small or not seen easily, for example, a cell or the heart;
- processes that cannot easily be seen directly, for example, digestion or erosion;
- abstract ideas, for example, particulate nature of matter or energy transfer.

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Additional guidance

Types and models

The science strand of the National Strategies uses a simple method for classifying models, sufficient to meet the needs of teachers and pupils in this age range.

Models can be grouped into:

- **scientific models** – consensus models agreed by the scientific community. They are often pictorial, such as the arrangement of particles in solids, liquids and gases, although sometimes they are mathematical representations;
- **teaching models** – ways of explaining abstract phenomena. They can be pictorial representations (for example, a diagram of the eye), three-dimensional (for example, molecular models) or computer animations (for example, to illustrate the particulate nature of matter);
- **historical models** – explanations used by scientists in the past, for example, the phlogiston theory. These change as new evidence becomes available.

Analogies are a subset of teaching models and are based on comparisons with familiar objects or processes. They are useful illustrations but often have only superficial parallels with the abstract idea being illustrated. There are many different ways of describing models and analogies across the curriculum. There can be much overlap between the two and teachers of English might argue that they are specific applications of metaphor. It is useful to check what other subjects mean by analogies to be able to clarify this for the pupils.

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Models in Key Stage 3 Science

Models in science teaching can mainly be classified into two groups.

<table>
<tr><th>Scientific model (or consensus model)</th><th colspan="2">Teaching model</th></tr>
<tr><td rowspan="2">This represents the accepted scientific view of a concept or idea.
● It provides a representation or an explanation for a complex process.
● It is a consensus view held by the scientific community.
● It can be a mathematical or a physical representation or an explanatory theory.
● It can help predict the behaviour of systems or events.</td><td colspan="2">This is used to help a learner understand or visualise an idea, a process or a system.
● It is a visual or a physical representation.
● It is a teaching method to help pupils visualise something abstract or invisible.
● It helps explain the abstract idea or invisible structure to the learner.</td></tr>
<tr><td></td><td>Analogies are:
● a subset of teaching models;
● based on an object or process very familiar to pupils;
● often stated as ‘it’s rather like…’;
● based on superficial similarities or parallels to the abstract idea;
● usually illustrative rather than explanatory;
● often stories.</td></tr>
</table>

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Progression in the use of models

Pupils at level 5 are likely to use simple models to explain familiar scientific concepts. They are able to make connections between the model and the concept or observation being explored. Pupils need to be exposed to a range of different analogies and teaching models and be taught to question how appropriate they are. To make progress towards level 6 and beyond, pupils will begin to evaluate the strengths and weaknesses and modify teaching models to fit new observations and ideas.

This progression will now be explained in more detail in a series of four steps. This will include teaching strategies and resources that can be used to help pupils move from one step to the next.

Moving from step 1 to step 2

Step 1 – pupil characteristics

Pupils:

- recognise that everyday models and analogies can help to explain some scientific ideas.

Step 2 – pupil characteristics

Pupils can:

- devise simple models to explain their observations, data or ideas;
- recognise that different models are used in science to explain the same phenomenon.

Strategies to ensure progression from step 1 to step 2

A) Demonstrate how to use and develop simple everyday analogies or models to explain a process or concept.

- Allow pupils to construct a range of cell models and then discuss whether these models helped them to visualise cells that are too small to see.
- Share suitable, familiar, concrete analogies for a process or concept, and ask pupils to discuss how the analogy fits their observations. Some examples to use:
  - **Process or concept**: diffusion of gas particles demonstration;
  - **Concrete analogy**: crowds leaving a tube station or a football match;
  - **Process or concept**: digestion; function of enzymes or observations as pupils chew some food;
  - **Concrete analogy**: a food processor in action;
  - **Process or concept**: composition of different types of rock;
  - **Concrete analogy**: different types of biscuits/cookies.
- Use some of the models and analogies in the table and ask pupils to identify features of the model or analogy. It might be useful to have actual examples available for pupils to look at. Next ask pupils to take each feature in turn and to decide if it helps to explain the process or concept.

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Sc2 Biology	Sc3 Chemistry	Sc4 Physics
squeezing a toothpaste tube to represent peristalsis	representing different sorts of rock by different sorts of biscuits (cookies)	using money or blocks to represent energy as it is transferred
visking tubing to represent the small intestine and how the products of digestion are diffused	using sweets to represent: elements (toffees), mixtures (toffees and mints) and compounds (mint toffees)	coloured balls with fastening strips attached to those of one colour, and a felt screen of that colour to show reflection and absorption of coloured light
anatomical models of the organs of the body	balls connected by springs to represent solids	using limbs to illustrate different types of lever
balloons in a bell jar to show how the lungs inflate	frying eggs to represent a chemical change	explaining how magnets behave: the domain theory
food webs to represent feeding relationships	representing the kinetic theory using 'play pool' balls and a large bed sheet	wave machines and/or the slinky to illustrate longitudinal sound waves
a badminton net and different sized balls to show the action of a semi-permeable membrane	melted butter mixed with popcorn to represent the states of matter: cooled – solid, heated gently – liquid, heated until the popcorn starts to pop – gas	cartoon pictures of runners to represent the flow of charges in an electric current with obstacles to represent resistance
comparing digestive enzymes with scissors		contrasting the eye and the camera

Use the 'Modelling the process of digestion' lesson plan with pupils for them to begin to decide what makes a good model or the 'Modelling the separation process' lesson plan to use models to explain how to separate mixtures.

Act out the model of photosynthesis or play the 'Food web game'.

- Use one of the presentations to illustrate a range of models and analogies used to explain some of the key ideas in science. Ask pupils to identify any better models or analogies.
  - Cells/Models and analogies for Cells.ppt
  - Energy/Models and analogies for energy.ppt
  - Interdependence/Models and analogies for Interdependence.ppt
  - Forces/Models and analogies for Forces.ppt
  - Particles/Models and analogies for particles.ppt.
- Allow pupils to explore some of the differences between using a simple model or a concrete analogy to explain the same process. Some examples to use:
  - **Concrete analogy**: reflection of light can be like a football being bounced off a flat wall;
  - **Simple model:** a ray diagram illustrating the reflection of light from a plane mirror;
  - **Concrete analogy**: reflection of light can be like a table tennis ball being bounced off an egg box;
  - **Simple model:** a ray diagram illustrating the scattering of light from a surface;

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  - **Concrete analogy**: refraction of light is like soldiers marching on concrete then through sand;
  - **Simple model:** a ray diagram illustrating the refraction of light as it passes through a glass block.
- Create opportunities for pupils to identify where and how models and analogies have been used in national test questions.

B) Create opportunities for pupils to select appropriate models or analogies to help to explain a concept or observation.

By selecting a model that would best describe an idea and/or observation, pupils can experience a range of different, unrelated models to begin with and decide which one would be best to describe what they see.

- Provide pupils with four unrelated models or analogies:
  - a 3-D model of a cell without labels;
  - a diagram of a food web;
  - a picture of a central heating system;
  - beads arranged in layers in a transparent plastic box.

  Ask pupils to discuss which concept or process the model could be used for. Extend this activity by asking pupils to list other models they can use for each of these concepts.
- Discuss the 'sweetie' model as a way of explaining elements, compounds and mixtures or different rock types.
- Develop pupils' understanding of enzymes by making apple juice and devising a model to explain what has happened.
- Use the chromosome game as a model to explain inheritance.

Moving from step 2 to step 3

Step 2 – pupil characteristics

Pupils can:

- devise simple models to explain their observations, data or ideas;
- recognise that different models are used in science to explain the same phenomenon.

Step 3 – pupil characteristics

Pupils:

- identify strengths and weaknesses in some of the analogies and scientific models used;
- use criteria to decide if it is a 'good enough' model or if the model needs to be changed.

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Strategies to ensure progression from step 2 to step 3

To move on from step 2, pupils need to be taught explicitly how to evaluate models, to decide how appropriate they are and to recognise that different models or analogies may be used to explain scientific phenomena. Lessons should be planned with this in mind.

A typical lesson objective could be:

- to be able to use a range of models and analogies to explain…

The learning outcomes for the lesson could be that pupils:

- identify or devise some models or analogies to help explain…;
- explain how the model and/or analogy fits the phenomena well and where it breaks down.

This approach would be useful in any lesson where models and analogies can help explain a given abstract idea. The rest of the lesson would then focus on delivering these learning outcomes, either through looking at one concept in detail and the models that can be used to explain it, or by using a range of different concepts in less detail and more episodes to explore the models connected to them.

A) Compare the strengths and weaknesses of using different models and analogies to explain the same phenomenon.

- For any model or analogy, focus on one aspect, and explain to pupils how it fits the idea and where it falls down. Use examples from steps 1 and 2.
- Ask pupils to make their own cells models and analyse the strengths and weaknesses of them. A recording sheet may be used or they could compare their models to the models in the cells presentation.
- This process provides pupils with opportunities to focus on the evaluation side of using models. Using a range of prepared models enables pupils to concentrate on the purpose of different aspects of the model and analyse how appropriate they are. Pupils can use a range of communication methods including debate, tabulation and evaluative writing to present their ideas.
- Show pupils some examples of elements and compounds and give their formulae. Provide pupils with a range of different sweets, including liquorice sweets. Ask pupils to match the sweets to the elements and compounds. Pupils can make up some new models, using other materials, for example, paper clips, Lego® blocks, MolyMods®.
- Pupils discuss how suitable their models are by generating some questions about them, for example, 'Can we make compounds from the different element models?' 'Can we simulate the chemical formulae of the compounds using the model?' Pupils can use these questions to decide on the 'best fit' model.
- Use Task E from the 'Particles' unit and discuss the strengths and limitations of the models.
- Compare different models to explain digestion or energy transfer in the ecosystem.
- Compare the strengths and weaknesses of a number of models used to explain some geological processes, crystal formation in rocks and salt extraction in Cheshire.
- Further examples and resources to support the use of teaching models that can be used in this approach include:
  - evaluating models to show the conservation of matter;
  - looking at different particle models and seeing if they are good enough;
  - comparing different 3-D models of specialised cells;
  - comparing different models and analogies for representing energy transfer;
  - using different models for representing aspects of light and how it travels;

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  - using the particle model, popcorn, role-play for modelling changes of state;
  - using different electricity models to simulate an electric circuit, for example, monopoly, coal trucks being delivered from mine to power station;
  - using different three-dimensional models of organ systems;
  - looking at examples of different models of rocks to represent particular features;
  - looking at a model of subsidence;
  - modelling different processes in the rock cycle: interdependence.
- Several different teaching models used in Key Stage 3 are identified in Mapping models and analogies.

B) Model how to use criteria to help pupils work out which is the preferred 'best fit' model and decide on the rationale for this decision.

- Use handout 2.16 to identify shortcomings of five particle models.
- Present pupils with up to four models for a concept or process. Use these to model how to establish some criteria to judge the model. Make your thinking explicit. Now allow pupils to use these criteria to judge other models and discuss what they find. (This activity can be extended for steps 3 and 4 below by asking pupils to suggest changes to the criteria.)

Moving from step 3 to step 4

Step 3 – pupil characteristics

Pupils:

- identify strengths and weaknesses in some of the analogies and scientific models used;
- use given criteria to decide if it is a 'good enough' model or if the model needs to be changed.

Step 4 – pupil characteristics

Pupils can:

- select and justify the use of a particular model for an explanation;
- think creatively to devise more than one model to explain a scientific phenomenon.

Strategies to ensure progression from step 3 to step 4

A) Model for pupils how to extend their explanation of the strengths and weaknesses and how to manipulate a model to make it more appropriate.

- Use models to explain more abstract concepts in magnetism (domain theory), particles (solubility of different solutes), gravity (feather and hammer falling), and electricity (resistance of a wire). Ask pupils to generate questions to test the model. Pupils can use these to develop success criteria that would apply to the model.
- Remind pupils of how the particle model can be used to represent a simple mixture. Show pupils a range of different mixtures and ask them to discuss how appropriate this model would be to describe the range of mixtures shown. Ask pupils to develop some criteria for judging the teaching model. Pupils can then modify the model to match the different range of mixtures.
- Act out the process of photosynthesis, using the model given. Ask pupils to predict what will happen to the model if the conditions change, for example, the amount of sunlight, water or carbon dioxide changes the rate of photosynthesis. Ask pupils to act out the changes and evaluate how well the model responds. Are there any further changes that need to be made to the model?

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- Use task K to evaluate different models for explaining the conservation of matter.
- Explain how different models have had to be developed to explain different aspects of the behaviour of light.
- Use the Energy cards and ask pupils to discuss and select which of the three models best describes what happens.

B) Create opportunities for pupils to study a range of cases of how real-life examples of the use of models have changed over time as a result of creative thinking.]

- Use historical models and analogies and show how they have changed over time. Introduce a scientific concept through an observation or data. Discuss early ideas about different scientific processes and show the models that were developed to understand these. Show how these models have changed over time and ask pupils to suggest reasons for these changes. Ask pupils to discuss how appropriate the most recent model is, in light of what we already know, and how it may be improved.

  There are a number of examples that can be used to exemplify this. Use the context of the prevention of the spread of disease, beginning with ideas about malaria (bad air) and the miasma theory. These ideas developed as a result of the work of Jenner with smallpox, John Snow with cholera, Louis Pasteur and then finally Alexander Fleming. Pupils can be given summaries of these people's ideas and observations and develop models to explain them. Pupils can then analyse each other's models and come up with the 'best fit' model.
- Other examples where this approach could be used include:
  - early models of the solar system;
  - early models about particles and how they have changed;
  - development of the phlogiston theory and how this has changed.

C) Encourage pupils to extend their use of models to generate other ways of explaining the observation/data that may be at odds with current scientific knowledge and provide a reasoned argument as to why this is also a plausible analogy.

- Pupils can extend their use of models to generate other ways of explaining observations or data that may be at odds with current scientific knowledge and then provide reasoned arguments why this is also a plausible analogy, for example, the dark sucker theory. This could then be extended in to the next lesson where a non-scientist teaches the class and two groups need to convince this teacher which model is most appropriate.
- Use the different digestion models drawn by pupils and ask them to discuss why the models could seem plausible.

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Handout 2.1: Using data

Task

If you do not already know, ask your line manager for pupil information relating to pupil groups. This might include a list of children who:

- are eligible for free school meals (FSM)
- belong to minority ethnic and faith groups, travellers, asylum seekers and refugees
- have special educational needs
- are gifted and talented
- need support to learn English as an additional language (EAL)
- are 'looked after' by the local authority
- are at risk of disaffection and exclusion.

Look at the school level results using one or more of the data sources listed below.

You could also include departmental results from internal tracking including outcomes from periodic assessments using Assessing Pupils' Progress (APP) or external interim assessments.

Calculate the differences between those children who are part of the designated group and those who are not (boys – girls). Compare these differences with other subjects in your school and, if available, against the performance of these groups locally and nationally.

Data sources

- RAISEonline
- The booklet *Fischer Family Trust Analyses to Support Self-Evaluation* will provide progress data for science, including comparisons of low-, middle- and high-ability boys and girls.
- SSAT Data Enabler
- Progression to post-16 sciences
- Local authority data
- School internal analysis

An example of a spreadsheet set up to look at differences between the performance of boys and girls is shown on the next page.

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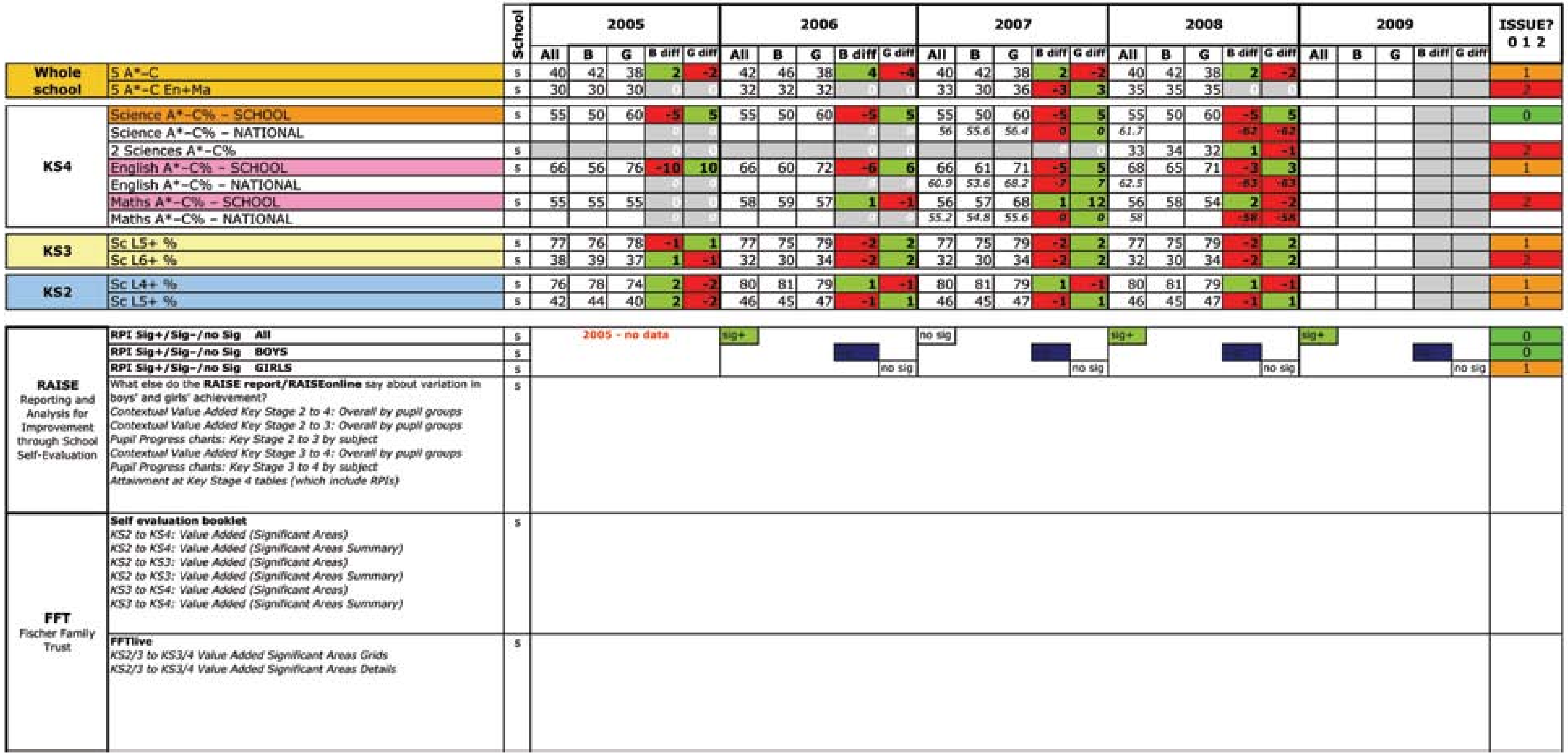
Data analysis boys – girls



		School	2005					2006					2007					2008					2009					ISSUE? 0 1 2
			All	B	G	B diff	G diff	All	B	G	B diff	G diff	All	B	G	B diff	G diff	All	B	G	B diff	G diff	All	B	G	B diff	G diff	
Whole school	5 A*–C	s	40	42	38	2	-2	42	46	38	4	-4	40	42	38	2	-2	40	42	38	2	-2						1
	5 A*–C En+Ma	s	30	30	30	0	0	32	32	32	0	0	33	30	36	-3	3	35	35	35	0	0						2
KS4	Science A*–C% – SCHOOL	s	55	50	60	-5	5	55	50	60	-5	5	55	50	60	-5	5	55	50	60	-5	5						0
	Science A*–C% – NATIONAL					0	0				0	0	*56*	*55.6*	*56.4*	*0*	*0*	*61.7*			-62	-62						
	2 Sciences A*–C%	s				0	0				0	0				0	0	33	34	32	1	-1						2
	English A*–C% – SCHOOL	s	66	56	76	-10	10	66	60	72	-6	6	66	61	71	-5	5	68	65	71	-3	3						1
	English A*–C% – NATIONAL					0	0				0	0	*60.9*	*53.6*	*68.2*	*-7*	*7*	*62.5*			-63	-63						
	Maths A*–C% – SCHOOL	s	55	55	55	0	0	58	59	57	1	-1	56	57	68	1	12	56	58	54	2	-2						2
	Maths A*–C% – NATIONAL					0	0				0	0	*55.2*	*54.8*	*55.6*	*0*	*0*	*58*			-58	-58						
KS3	Sc L5+ %	s	77	76	78	-1	1	77	75	79	-2	2	77	75	79	-2	2	77	75	79	-2	2						1
	Sc L6+ %	s	38	39	37	1	-1	32	30	34	-2	2	32	30	34	-2	2	32	30	34	-2	2						2
KS2	Sc L4+ %	s	76	78	74	2	-2	80	81	79	1	-1	80	81	79	1	-1	80	81	79	1	-1						1
	Sc L5+ %	s	42	44	40	2	-2	46	45	47	-1	1	46	45	47	-1	1	46	45	47	-1	1						1
RAISE Reporting and Analysis for Improvement through School Self-Evaluation	**RPI Sig+/Sig–/no Sig All**	s	2005 – no data					sig+					no sig					sig+					sig+					0
	RPI Sig+/Sig–/no Sig BOYS	s									■					■					■					■		0
	RPI Sig+/Sig–/no Sig GIRLS	s										no sig					no sig					no sig					no sig	1
	What else do the **RAISE report/RAISEonline** say about variation in boys' and girls' achievement? *Contextual Value Added Key Stage 2 to 4: Overall by pupil groups* *Contextual Value Added Key Stage 2 to 3: Overall by pupil groups* *Pupil Progress charts: Key Stage 2 to 3 by subject* *Contextual Value Added Key Stage 3 to 4: Overall by pupil groups* *Pupil Progress charts: Key Stage 3 to 4 by subject* *Attainment at Key Stage 4 tables (which include RPIs)*	s																										
FFT Fischer Family Trust	**Self evaluation booklet** *KS2 to KS4: Value Added (Significant Areas)* *KS2 to KS4: Value Added (Significant Areas Summary)* *KS2 to KS3: Value Added (Significant Areas)* *KS2 to KS3: Value Added (Significant Areas Summary)* *KS3 to KS4: Value Added (Significant Areas)* *KS3 to KS4: Value Added (Significant Areas Summary)*	s																										
	FFTlive *KS2/3 to KS3/4 Value Added Significant Areas Grids* *KS2/3 to KS3/4 Value Added Significant Areas Details*	s																										

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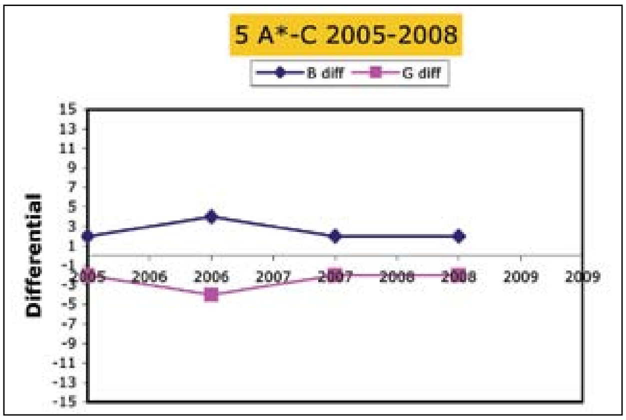

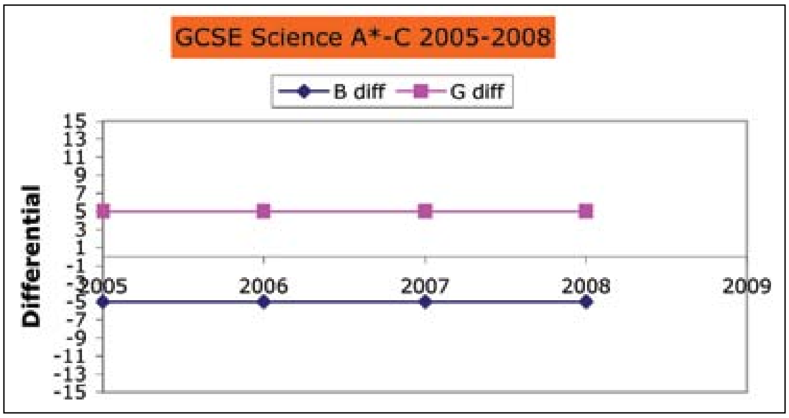

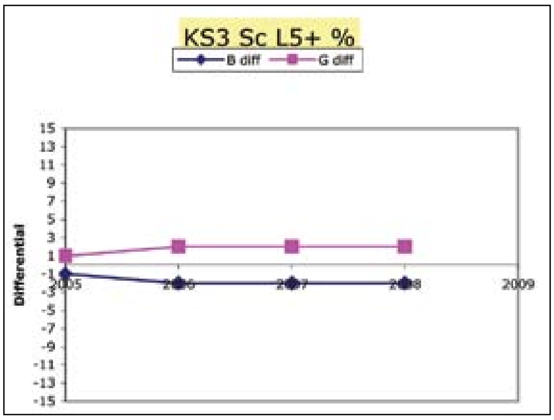

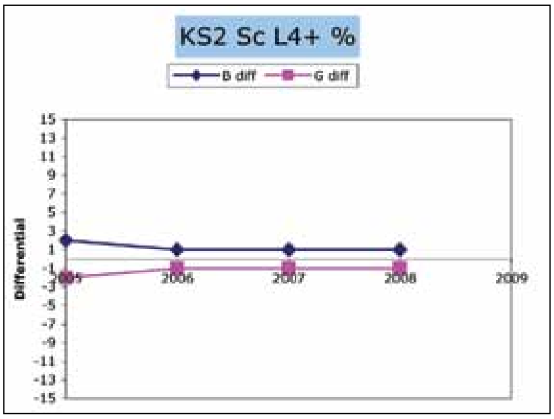

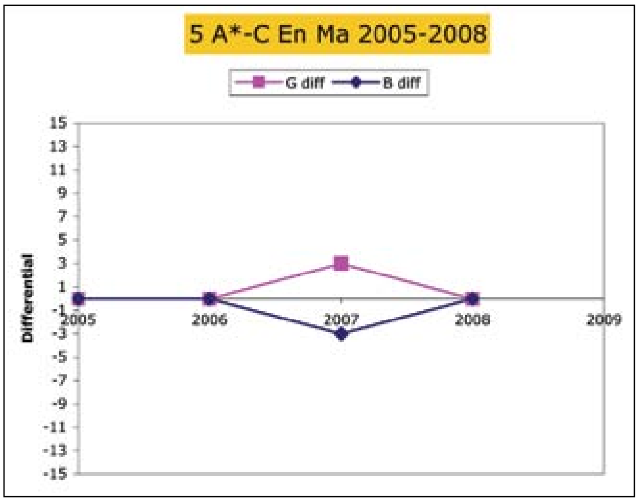

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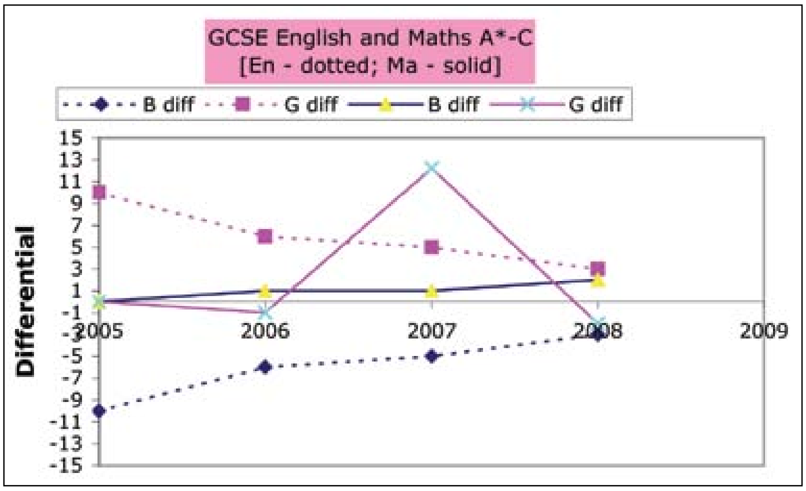

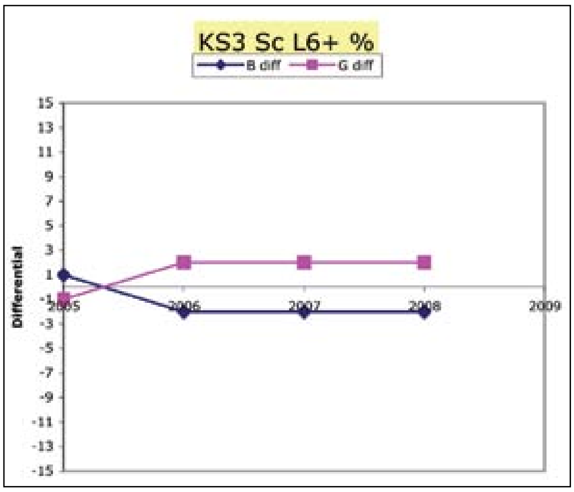

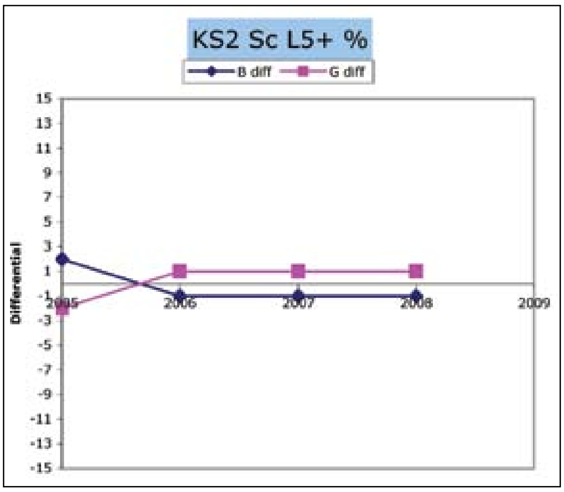

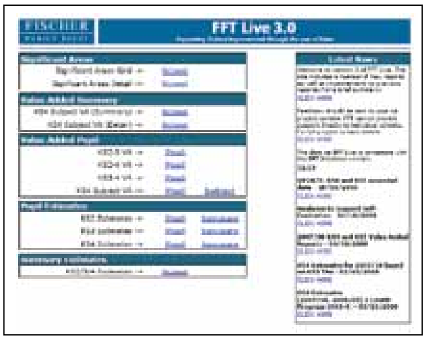

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Handout 2.2: Interrogating the data

Rationale

How do the attainment and progress of boys and girls compare in science? How do these compare with attainment and achievement of boys and girls overall and in other subjects in the school? To answer these questions, a range of data needs to be accessed and compared. Scrutiny of the data may reveal issues and raise further questions. This may lead to further enquiry before solutions can be trialled and evaluated.

Trends over time – for all pupils, girls and boys, school and national

Percentage of pupils gaining:

5 A*–C

5 A*–C En+Ma

2 sciences A*–C

1 science A*–C

Progression to A level sciences

English A*–C

Mathematics A*–C

KS3 – L5/6+

Questions

1. **How does the performance of boys and girls compare across English, mathematics and science in school and national data?**

The purpose of this analysis is to determine if there might be trends across all core subjects. For example, if girls' attainment is lower than national across all subjects, not just science, it may be that the mean ability of girls is lower than that of boys or that girls are underachieving across all three subjects.

Look at trends in boy/girl/both science attainment…	and compare to whole-school boy/girl/both attainment
% 1 A*-C GCSE science % 2 A*-C GCSE sciences triple sciences % A*-C BTEC science any other sciences	5 A*-C 5 A*-C En+Ma A*-C En A*-C Ma

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2. What does value added data tell us?

Do girls or boys appear to have significantly lower achievement across English, mathematics and science?

If so, what are the Contextual Value Added (CVA) values for boys and girls?

(Boys may appear to be underperforming compared to girls, but value added data suggests that boys make good progress. Boys' mean ability is lower than that of girls.)

What does the *FFT Self-evaluation* booklet tell you about the achievement of boys and girls over time? Look at the following sections first:

- KS2 to KS4: Value Added (Significant Areas)
- KS2 to KS4: Value Added (Significant Areas Summary)

3. How does science compare with other subjects in the school?

What does RAISEonline tell you about the relative performance of boys and girls in science over time? (Relative performance indicators (RPI) tell you how the pupils performed in science relative to the other subjects they took.)

Look at the following, which can be found in Home > Reports & Analysis > View All Analyses > Key Stage 4 > Attainment > Thresholds > KS4 Relative Performance Indicators in full GCSE subjects by Subject

RPI Sig+/Sig–/no Sig All

RPI Sig+/Sig–/no Sig BOYS

RPI Sig+/Sig–/no Sig GIRLS

4. Additional data sources (e.g. school, progression to post-16) – do these give you any additional information?

Use your most recent RAISEonline 2008 Full Report, Fischer Family Trust Analyses to Support Self-Evaluation documents and any LA/internal data to determine whether there are significant differences between boys' and girls' performance in general and/or in science.

The following table shows some of the analyses available. Access to RAISEonline and FFTlive will provide further analyses.

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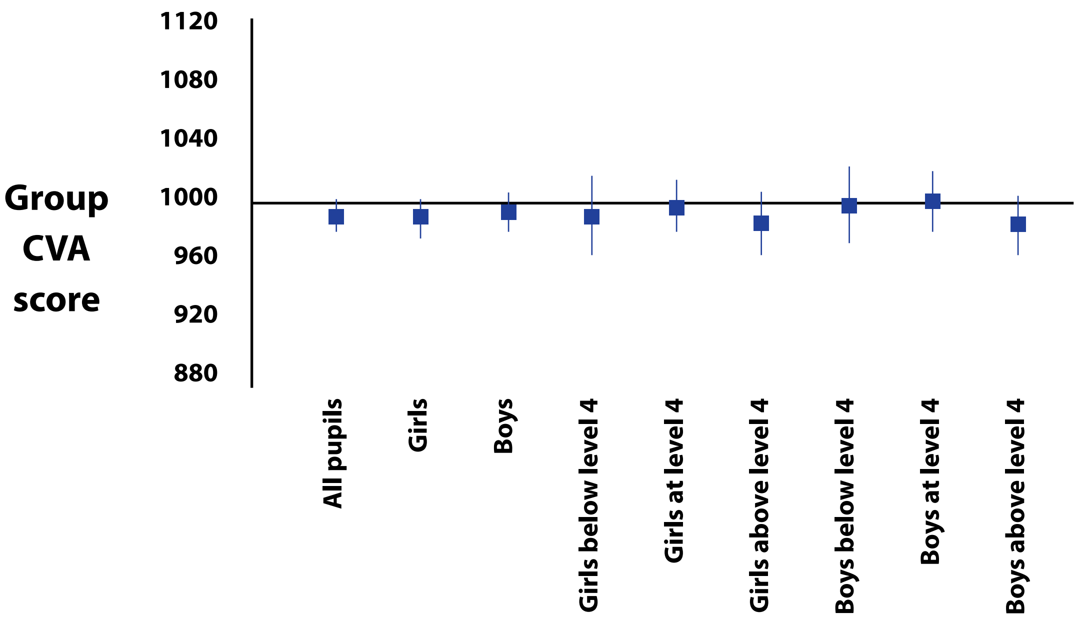
	Analysis	**Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes**
RAISE on line	Contextual Value Added Key Stage 2 to 4 : Overall by pupil groups	

	All pupils	Girls	Boys	Girls < Level4	Girls at Level 4	Girls > Level 4	Boys < Level 4	Boys at Level 4	Boys > Level 4
Cohort for CVA	149	74	75	11	37	26	14	29	32
School score	991.9	991.2	993.6	992.1	997.8	987.3	998.9	1001.6	986.4
95% confidence interval	9.6	13.1	13.1	25.9	17.5	19.9	24.3	19.2	18.5
Significance									

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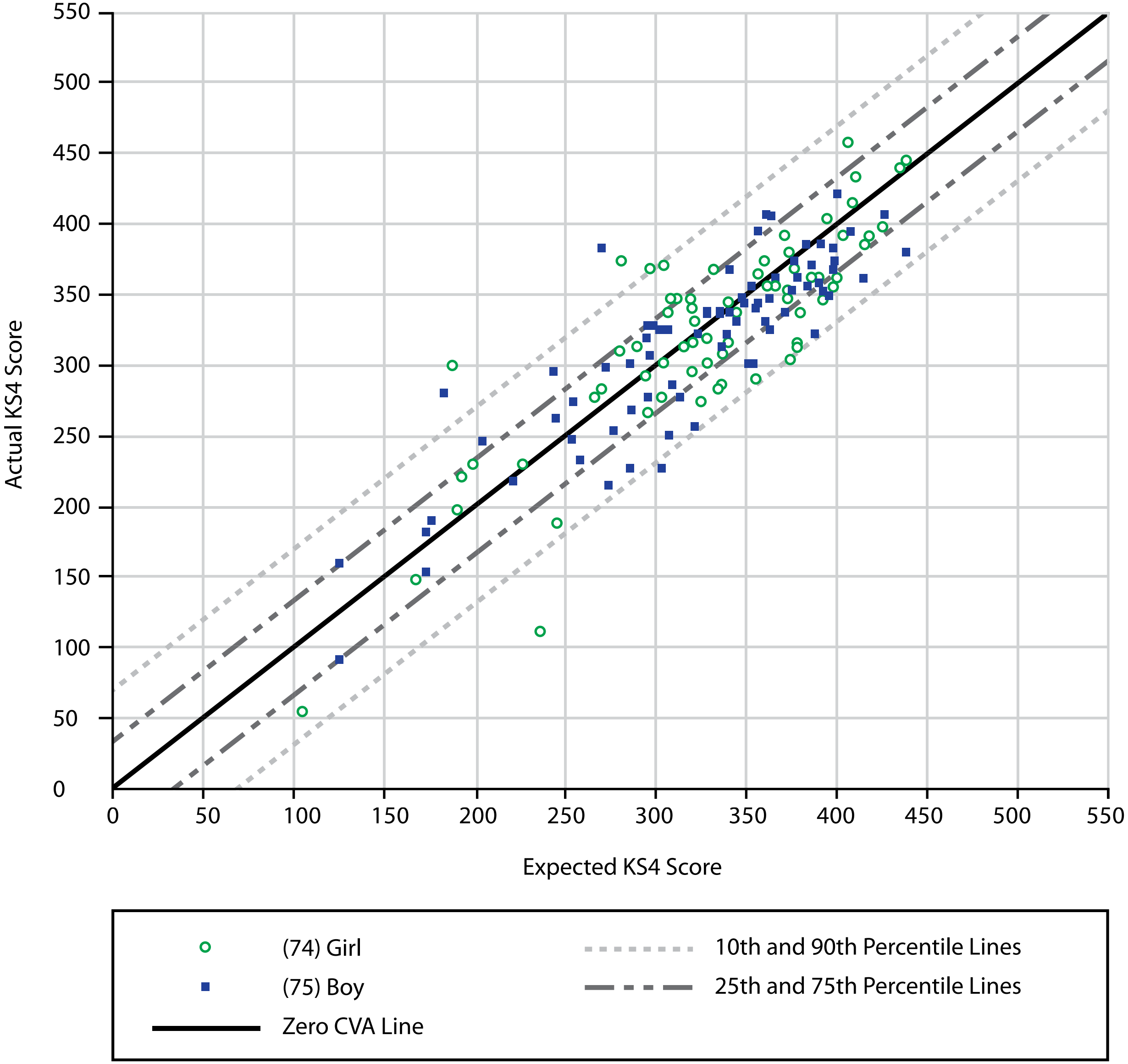
	Analysis	**Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes**
RAISE on line	Contextual Value Added Key Stage 2 to 4: Overall, predicted versus actual for pupils	 >10% of boys or girls above or below the 75th and 25th percentile line is significant

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	Analysis	Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes							
RAISE on line	Contextual Value Added Key Stage 2 to 4: 3 year average			**Contextual Value Added**			**3 Year Average**	**3 Year Average CVA By Subject 2006–2008**	
			Number of Pupils in Latest Year	**2006**	**2007**	**2008**	**2006–2008**	**English**	**Maths**
		All Pupils	149	971.1	982.6	991.9	980.8	998.9	997.9
		Gender							
		Girls	74	970.8	993.5 ↑	991.2	983.1	998.8	998.7
		Boys	75	975.7	975.8	993.6	979.7	999.0	997.3

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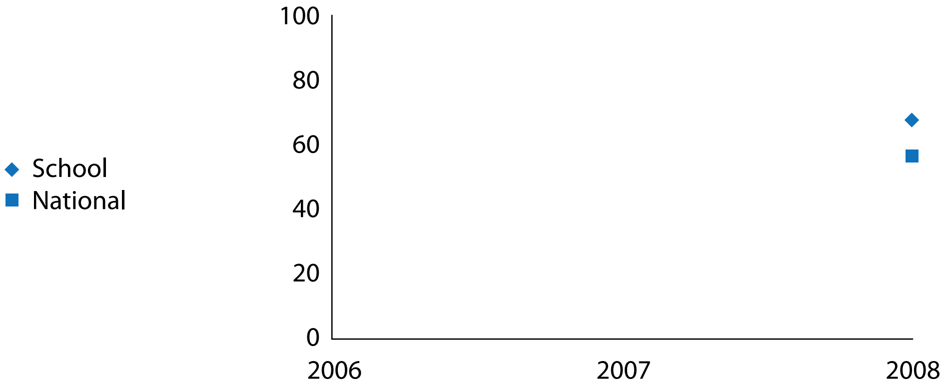
<table>
<tr><th></th><th>Analysis</th><th>Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes</th></tr>
<tr><td>RAISE on line</td><td>Attainment, percentage achieving 2 or more A*–C in science at GCSE</td><td>
Percentage of pupils achieving two or more A*–C in science at GCSE and equivalent



<table>
<tr><th>Sciene A*–C</th><th>2006</th><th>2007</th><th>2008</th></tr>
<tr><td>Cohort</td><td>-</td><td>-</td><td>150</td></tr>
<tr><td>School</td><td>-</td><td>-</td><td>61</td></tr>
<tr><td>National</td><td>-</td><td>-</td><td>50</td></tr>
<tr><td>Difference</td><td>-</td><td>-</td><td>11</td></tr>
<tr><td>Significance</td><td>-</td><td>-</td><td>Sig+</td></tr>
</table>

Note: tables for girls and boys available at RAISEonline
</td></tr>
</table>

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Analysis

Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes

Attainment

Relative Performance Indicators for full GCSEs, all pupils

Subject	Entries	School Average	Average In All Other Subjects	School Difference	National Difference	Relative Performance Indicator
Art & Design	68	37.2	39.6	-2.4	2.3	-4.7
Biology	27	45.8	43.6	2.2	0.3	1.9
Business Studies	49	37.2	42.6	-5.4	-2.2	-3.2
Chemistry	27	44.4	43.7	0.7	0.6	0.1
Communication Studies	1	46.0	44.5	1.5	0.9	0.6
Design & Technology	94	36.7	37.9	-1.2	0.2	-1.4
Drama	47	39.2	40.4	-1.1	1.8	-2.9
English Literature	133	42.6	39.9	2.6	0.5	2.1

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	Analysis	**Examples from an anonymous report 2009 (Production date: 9th February 2009) and notes**
FFT Analyses to Support Self-Evaluation	Key Stage 2 to Key Stage 4: Value Added (Significant Areas)	

Key Stage 2 to Key Stage 4
Value Added (Significant Areas)

2006–2008

Pupil Group	Pupils	Threshold (%)			% including EM		Points		Average Grade #		
	Key Stage 2 Match	5+ A*/A	Level 2 (5+ A*–C)	Level 1 (5+ A*–C)	Level 2 (5+ A*–C)	Level 1 (5+ A*–C)	Total	Capped	English	Maths	Science
ALL PUPILS	597		↓	↑↓	🟩 ↓	🟩 ↓	🟦 ↓	🟩 ↓	🟩 ↓	🟩 ↓	🟩 ↓
Girls	286		↓	🟩	🟩 ↓	🟩	🟦 ↓	↓	🟩 ↓	🟩 ↓	🟩 ↓
Girls–Lower	139		🟦	🟩 ↓		🟩	🟦 ↓	↓		🟩 ↓	↓
Girls–Middle	111				🟩		🟦			🟩	🟩
Girls–Upper	36		↓	↓	🟩		🟦 ↓	↓		🟩	
Boys	311		↓	🟩 ↑↓	↓	🟩 ↑↓	↓	🟩 ↓		🟩 ↓	🟩 ↓
Boys–Lower	149		↓	🟩 ↓		🟩 ↓	↓	🟩 ↓		🟩 ↓	↓
Boys–Middle	102				🟩 ↓	🟩				🟩 ↓	🟩
Boys–Upper	60				↓	↑↓	🟦			🟩 ↓	
Without FSM	449		↓	🟩 ↓	🟩 ↓	🟩 ↓	🟦 ↓	🟩 ↓	🟩	🟩 ↓	🟩 ↓
With FSM	148			🟩		🟩	↓			🟩 ↓	
No SEN	470		↓	🟩 ↓	🟩 ↓	🟩	🟦 ↓	↓	🟩 ↓	🟩 ↓↓	🟩 ↓
SEN Action	81			🟩		🟩				🟩 ↓	
SEN Action Plus	38			🟩		🟩	🟩	🟩		🟩	🟩
SEN Statement	8	*Not shown for small groups of pupils*									
White	577		↓	🟩 ↓	🟩 ↓	🟩 ↓	🟦 ↓	🟩 ↓	🟩 ↓	🟩 ↓	🟩 ↓
Black Caribbean	3	*Not shown for small groups of pupils*									
Pakistani	1	*Not shown for small groups of pupils*									
Bangladeshi	2	*Not shown for small groups of pupils*									
Other Asian	4	*Not shown for small groups of pupils*									
Chinese	2	*Not shown for small groups of pupils*									
Any Other	5	*Not shown for small groups of pupils*									
No Information	3	*Not shown for small groups of pupils*									

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Handout 3.1: Mitchell Media College

The school has a roll of 850 pupils, with a sixth form of 150. It is situated in the suburbs of a large city. There are six full-time teachers in the science department. Sixth-form provision is on a collaborative basis, courses being offered jointly with two other schools in the locality.

The school runs the Key Stage 3 course over three years, at the end of which pupils are put into groups for Key Stage 4. Three of the groups follow a Triple Science (TS) course and the other three follow a BTEC course. Parents and pupils are informed of the recommended choice and allowed to 'express an alternative view'; few pupils are transferred.

The time allocation for TS is 24 per cent of total curriculum time and for the BTEC course it is 20 per cent (BTEC groups get more PE). The TS groups are set by ability on the basis of average module test scores during Year 9. The BTEC groups are parallel; this is used to group pupils according to 'who works well with whom'.

Attainment data shows that pupils in TS Set 1 make good progress, and the proportion of pupils getting A* or A is slightly above the national average. Pupils in TS Set 2 make slightly less than the expected rate of progress, and in Set 3 the results are 'not what were hoped for'. The BTEC groups attain outcomes generally in line with expected rates of progress, though with significant variation from pupil to pupil. However, progression to the study of science post-16 is not as high as other schools in the area or schools nationally.

The subject leader was recently persuaded to run a 'pupil voice activity', which indicated that, in general:

- Pupils in TS Set 1 are generally satisfied with their course and feel that it is challenging and gives access to a range of science courses post-16, though not many seemed to be planning to follow such a route.
- Pupils in TS Set 3 felt that they had teachers who were not as effective and that the lessons were 'boring and with lots of writing'. Some of the pupils said that they wanted to change to BTEC but weren't allowed to.
- Pupils in the BTEC groups generally enjoyed their lessons and felt that they were able to do activities that were 'interesting and topical'. Some felt that there was a lot of writing, and a few were worried that 'their folders were in a bit of a mess'.

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Handout 3.2: Background information on Carvoza Community College

- Carvoza Community College is an 11–16 comprehensive school with an eight-form entry and 1000 pupils on roll. It is situated on the outskirts of a medium-sized town; pupils are drawn both from the town and the surrounding villages. There are two other secondary schools in the town.
- Last summer 59 per cent of pupils attained at least five GCSE grades of C or higher, 51 per cent when English and mathematics are included, and 53 per cent of pupils attained grade C or higher in at least two sciences.
- Residuals for pupils in science are slightly positive for high-attaining pupils, slightly negative for pupils on the C/D borderline and zero for lower-attaining pupils.
- 21 per cent of pupils leaving in 2008 made four levels of progress in science; 49 per cent made three levels.
- The science department had previously offered science plus Additional Science for pupils in Years 10 and 11, with two groups in each cohort only doing science to allow time for block release to access courses at the local FE college.
- Triple Science is offered by running a ‘twilight’ session, with a rota of teachers providing extension topics.
- Additional Applied Science was offered as an alternative to Additional Science but discontinued following issues with portfolio assessment and poor residuals for the group.
- Leaving the school, pupils are very likely to continue with full-time education and transfer to a range of institutions, including the sixth form of an 11–18 school in the town, the FE college in a nearby town and, for a few pupils, transfer to a private college. However, the uptake of science post-16 is lower than the regional and national averages in chemistry and physics, though strong in psychology.
- The science department has eight full-time staff, though two have slightly reduced timetables through being Director of Learning in Year 8 and Coordinator of Careers Education. There is a team leader and a Key Stage 3 coordinator. There is a good range of subject backgrounds of the teachers, though a minority regard themselves as physical sciences.

Task

- The headteacher is newly arrived and is concerned that the science department is ‘coasting’ and ‘not meeting the learning needs of all pupils’. Not a scientist herself, she is keen to engage with the issues and, as this is her first opportunity, to oversee a curriculum design project.
- She arranges for you to meet her and the assistant headteacher who line manages science. The purpose of the meeting is for you to advise them on:
  - the key points to raise
  - the options to explore
  - the constraints to be mindful of.

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Handout 4.1: Aide memoire – supporting EAL learners

Section	Notes	My actions	Expected outcomes
Introduction			
Data analysis			
Challenging practice			
Plenary			

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Handout 4.3: Glossary of terms

EAL	English as an Additional Language – so called because many pupils use and understand more than two languages.
TEFL	Teaching English as a Foreign Language (abroad)
Advanced bilingual learner	A pupil who has been learning EAL for five years or more and has usually had a full education in the UK.
BICS	Basic Interpersonal Communicative Skill: a term coined by Jim Cummins (1979)[1] to describe the type of language needed for social interactions and which is typified by the sort of language used in the playground. It is often about the 'here and now' between people who know each other. This is usually acquired within two years.
Bilingual	Pupils who, as part of their everyday lives, are exposed to or have to use more than one language. Equal facility in these languages is not implied as it is difficult to achieve.
BME	Black and/or minority ethnic.
CALP	Cognitive Academic Language Proficiency: a term coined (Cummins, 1979)[2] for the type of academic language needed to succeed in school. It involves understanding abstract language and academic registers. According to Cummins, it takes between five and seven years to develop CALP in a language.
ESOL	English for speakers of other languages. This term is used in adult education (post-16) and describes courses which often teach English for social rather than curricular contexts.
Ethnic minority	Defined as any ethnic category that is not white British. In certain areas a given ethnic minority might be the local majority group, but is still a minority within the UK. Also referred to as minority ethnic.
First language	Used to refer to the language a person first learns – often called the 'mother tongue'. However, this might have been superseded by a second language, for example Twi/English.
Register	A particular style of language associated with different contexts and purposes. It involves choosing the correct vocabulary, tone and sentence pattern to match a given audience.

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[1] Cummins, J. (1979) 'Cognitive/academic language proficiency, linguistic interdependence, the optimum age question and some other matters', Working Papers on Bilingualism, 19, pp.121–9.

[2] *ibid.*

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Handout 4.4: ‘Narrowing the gap’ approach to data analysis

All data shows the 2007–08 percentage of pupils gaining one A*–C in science.

National (all pupils) A*–C 59.8 per cent

LA (all pupils) A*–C 46 per cent

School	Ethnicity	Ethnicity % A*–C	School % A*–C	Gap to school	LA % A*–C	Gap to LA	National % A*–C	Gap to national
A	**Pakistani**	44	39		46		59.8	
A	**African – Caribbean**	45	39		46		59.8	
B	**Pakistani**	42	63		46		59.8	
B	**Bangladeshi**	61	63		46		59.8	
C	**Somali**	16	25		46		59.8	
C	**Turkish**	22	25		46		59.8	

What questions does this data generate?

A similar analysis could be done for the attainment of two A*–C in science (to include BTEC and OCR Nationals).

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Handout 4.5: Using school data summary sheet

How could you find out if pupils were making less than expected progress because of these reasons?

Possible reason	Sources of evidence
Language issues	
Interrupted schooling	
Gender	
Late start to UK education	
Low expectations	
Racism	
Poor behaviour	

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Handout 4.6c: Answers

Do these classroom practices support learning?

Barriers to progress	Supportive of learning
The teacher corrects all spoken errors. **This is very inhibiting and causes language anxiety.**	Pupils can use heritage language when discussing/planning/explaining. **Improves cognitive development.**
Pupils work better on their own and in silence. **It has been shown that collaborative work improves learning.**	Collaborative work encourages language development. **It has been shown that collaborative work improves learning.**
Pupils are asked to write a paragraph after just *listening* to the teacher. **This decontextualised work is very hard.**	Language is stimulated by practical 'hands on' work. **The need to communicate is stronger when pupils have experienced the science.**
EAL learners are placed in lower sets to ensure teaching assistant support. **This is very demoralising for able children.**	Seat new EAL pupils next to pupils with very good spoken English. **This promotes learning by providing them with a good model.**
It depends…	Providing visual prompts and DARTs activities. **This helps to support independent learning for most pupils.**
Some textbooks in other languages could be useful in the department. **The teacher needs to be aware of how this could be useful for project or topic work but not habitual use.**	Pupils are given plenty of opportunities for speaking scientific language. **We learn by practising.**
Teacher corrects all scientific language mistakes. **The teacher needs be aware of when and how to correct to best support progress in learning.**	Teacher models correct language patterns, for example rephrasing to use the passive mood. **Modelling supports all language learning**
Seating EAL pupils next to children who speak their language promotes learning. **This puts too much pressure on the interpreter but can be used for practical situations.**	Teachers are aware that as part of language development EAL learners may remain silent at first. During this time they will be developing their language skills. **The length of the silent phase depends on the pupil; they are not all the same. Pupils need opportunities to talk so that they can contribute when they are ready.**
Using a bilingual dictionary is important when participating in group discussions. **This hinders conversation.**	

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Handout 4.7: Why are some scientific texts difficult?

Sentences

Who did what to whom?

In everyday spoken English we tend to talk about what people do. However, scientific writing is usually impersonal, i.e. we don't need to know who carried out the action. This is achieved by using the **passive voice**:

Compare 'Miss Patel **heated** the test tube over a Bunsen burner' with 'The test tube **was heated** over a Bunsen burner'.

The second sentence is more typical of scientific writing – we don't need to know who did it!

This type of sentence construction also occurs when describing natural processes:

- 'the embryo is implanted.'
- 'rocks are eroded.'

It's just an expression…

The sentence 'GM foods are a political hot potato' can cause real problems for pupils with EAL because it doesn't mean exactly what it says and understanding depends on being familiar with the expression 'hot potato'. **This is an idiom**.

There is also a high probability that some words will appear together in a sentence. 'High probability' is itself an example of this. Other such phrases are food chain, positive correlation and science lab. These are examples of **collocation**.

The bigger they come the harder they fall

A crucial aspect of science is identifying relationships between variables. To do this, pupils need to be able to understand and use a particular sentence pattern expressing degrees of comparison:

- 'The…er the X, the…er the Y.'

For example:

- 'The higher the temperature, the faster the reaction.'
- 'The more acidic the solution, the more vigorous the reaction.'
- 'As the temperature increases, the rate of reaction increases (proportionally).'

These phrases should be specifically taught through modelling and shared writing.

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This and that

As pupils' writing in all subjects develops, they learn how to make their writing flow by avoiding repetition. In scientific writing, there are many examples of the use of pronouns such as 'this', 'that', 'these' and 'those'. For example, 'Elements cannot be broken down into anything simpler. When **these** combine together, **they** make compounds.' 'These' and 'they' are both examples of pronouns and in this sentence refer back to 'elements'. This will not necessarily be obvious to some pupils with EAL. Particular attention needs to be given to pronouns and the words to which they refer.

Should have, could have, would have…

At the heart of science is reaching decisions about what is doubtful, certain, probable or possible. In investigations and problem-solving activities, we start off tentatively saying, 'It might be X… it could be Y'. Then we reject options saying 'It can't be X', to finally draw a definite conclusion: 'It must be X.' To do this we need to understand and use **modal verbs**. These include 'can', 'could', 'might', 'may', 'should', 'ought to' and 'would' and their negative and question forms as well as different tenses. For example, when looking back at an investigation, we might want to consider what 'might have happened' or what 'should not have happened'. Modal verbs can be specifically taught through exploring degrees of certainty (certain – impossible).

Vocabulary

Had it, put it, got it

In English there are some very common **delexical** verbs such as 'have', 'do', 'make', 'give', 'put' and 'get'. These verbs have different meanings depending on how they are used and also are often used incorrectly by pupils with EAL. For example, we 'do' homework but 'make' a bed; we 'have' a cold but 'get' hot.

They also combine with other words and change their meaning again: 'put down' (deposit, place, humiliate, suppress, write); 'make up' (comprise, invent). These are called **phrasal verbs**. In order to avoid confusion, it is better to teach the precise scientific language.

Scientific talk and 'posh' talk

Science has its own vocabulary, which is used to specifically identify processes (e.g. photosynthesis), names (e.g. potassium permanganate) and concepts (e.g. entropy). There are also many everyday words that have a particular meaning when used scientifically: 'work', 'energy', 'conductor', 'tissue', 'property', 'value', 'field'.

And finally there are a large number of 'posh' words, not exclusive to science, but not found commonly in speech, sometimes called academic language. These can cause barriers to learning, for example 'factor', 'conversely', 'variable', 'random' and 'rate'.

Further reading

Literacy in Science, DfES 2004

Access and Engagement in Science, DfES 0610/2002

Language and Literacy in Science Education, Wellington, J. and Osbourne, J., Open University Press (2001)

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Handout 4.8: Newspaper article illustrating difficulties with texts

Steer clear of burgers to avoid bowel cancer

People who eat a diet high in red and processed meat increase their risk of bowel cancer by as much as a third, research showed today. Earlier research has also highlighted a possible link between eating large amounts of red meat and a bowel cancer.

This latest research used data from a long-running study of the diets of more than half a million people across Europe and was published in the *Journal of the National Cancer Institute*. This study found that the risk of developing bowel cancer for people who regularly ate more than two portions of red and processed meat a day was a third (35 per cent) higher than for those who ate less than one portion a week.

The study also found that the risk of developing the disease increased for those people who had a low-fibre diet. Eating poultry did not increase the risk of bowel cancer, and people who ate more fish were less likely to develop the disease. The risk of bowel cancer dropped by nearly a third (30 per cent) if people ate one portion or more of fish every other day – compared to those who ate fish less than once a week.

This research was funded by the Medical Research Council (MRC), Cancer Research UK and the International Agency for Research on Cancer. Professor Ed Walsh cut to the chase: 'The study, which includes different populations and diets, has provided an accurate picture of how these foods relate to the incidence of bowel cancer.'

Factors such as smoking and excess alcohol were all taken into account in the analysis. The study also showed that bowel cancer risk could be cut by increasing fibre in the diet and reducing consumption of red and processed meat. There are 35,000 cases of bowel cancer each year in the UK and more than two-thirds of colorectal cancer cases – 25,000 cases in the UK – could be avoided by changes in lifestyle.

The research has gone down like a lead balloon with the Meat and Livestock Commission, who said that Britons eat well below 160g-per-day consumption levels that were used to class high intake in the study. They said that the amount of red and processed meat eaten by the average Briton was only 93g a day.

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Handout 6.1: Strengthening teaching and learning of particle theory

Introductory section

How to use this study guide

This study guide is one of a suite designed to support the development of aspects of subject knowledge with which you are less secure. All teachers recognise that some parts of science can be difficult to teach and this can be even more problematic if it is outside your area of expertise.

It has been produced for teachers who are planning to teach pupils in the secondary phase using contexts taken from Chemical and material behaviour. It assumes a general scientific background and an understanding of effective pedagogy. There will be aspects of the guide where you will need to consult other reference materials on chemistry, however no detailed knowledge of the area is assumed.

This study guide offers background information and practical suggestions to support classroom practice when teaching about particles and particle theory. All the strategies suggested have been tried and tested by teachers and draw upon academic research. Equally, many of the activities could be used with pupils who need to develop similar knowledge.

Your science consultant can help you work through this unit or you could team up with a colleague/s who also wish/es to enhance the teaching of this aspect of science. The unit contains tasks for you to undertake which will help you consider the advice or try out new techniques in the classroom. It also contains 'reflections' and next steps which may encourage you to revise an idea or change your own practice.

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

- Work with your science consultant on developing and planning the teaching of an aspect of particle theory. After three weeks, meet together to review progress.
- Discuss which strategies have been the most effective with one class and plan to use these with other classes.
- Find another science teacher to pair with and team-teach. Design the activities together and divide the teacher's role between you.
- Work with a group of teachers in the department. Use the study guide as a focus for joint working, meet regularly to share ideas and then review progress after a few weeks.
- Identify the sections of the guide that are the most appropriate for you and focus on those. You may find it helpful to keep a learning log as you work through the tasks. You could add this to your personal continuing professional development (CPD) portfolio.
- Ask a chemistry specialist to help by providing a sounding board for your ideas.

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Important considerations when teaching particles

Particle theory is an important explanatory idea in science and it is explicitly taught for the first time at Key Stage 3.

- Pupils need to be taught explicitly about **consensus models** of particle theory and, importantly, how these can be **used to explain phenomena**.
- Understanding particle theory doesn't happen in one step. Throughout the science curriculum, from secondary school to university, ever more sophisticated views of particle theory develop to explain wider ranges of phenomena.
- At Key Stage 3 teachers should seek to develop models of particle theory that are '**good enough**' in a step-by-step fashion.
- The yearly learning objectives set out clearly the progression expected.
- Although many pupils will not be capable of assimilating fully abstract ideas about particles early in their Key Stage 3 career, it is important that these ideas are carefully introduced from Year 7 if the pupils are to have developed sufficient understanding by the end of Year 9 and then into Key Stage 4.

Remember that many pupils start Key Stage 3 unable to handle abstract concepts and this cognitive ability develops during these three years. It is necessary for teachers, particularly in Year 7, to be sensitive to this and to use supportive visual and physical models. Many pupils will not be able to form a fully abstract model of particles immediately, but the yearly learning objectives are based on an evolving understanding of particles across the five years. Teachers will need to adapt and differentiate their teaching according to the cognitive abilities of the pupils in their classes.

There is an emphasis in this study guide upon Key Stage 3; this is not because this is seen as being more important, but because it was considered more likely that a teacher preparing work in this area at Key Stage 3 will be looking for support and guidance. Furthermore, courses at Key Stage 4 are likely to be following a unitised structure and to have support from awarding bodies in terms of the structuring of teaching and learning. However, the learning pathways are strongly based upon progression to Key Stage 4 and recognition is given to this.

The learning pathway

The Framework for science includes a set of learning pathways that provide guidance on the relationship between the concepts in a topic; this helps to place these within the context of the pupils' wider understanding of science.

The pathways suggest a relationship between concepts in the secondary phase. It is important to remember that:

- they show one possible arrangement and are not intended as definitive models
- the development of concepts starts prior to this phase and for some students will continue beyond this
- they are designed to show how contexts that are used with students in Key Stage 3 will form foundations for other learning activities in Key Stage 4.

The pathway attempts to present a big picture of the teaching of Chemical and material behaviour. Within the learning pathway there are three main 'journeys' highlighted in the three diagrams below. It is important to make the links between these 'journeys', and to other aspects of science, explicit to pupils, particularly the use and development of the particle model. Too often pupils experience the teaching of particles and particle models in a disjointed way and they fail to see how and why the model evolves.

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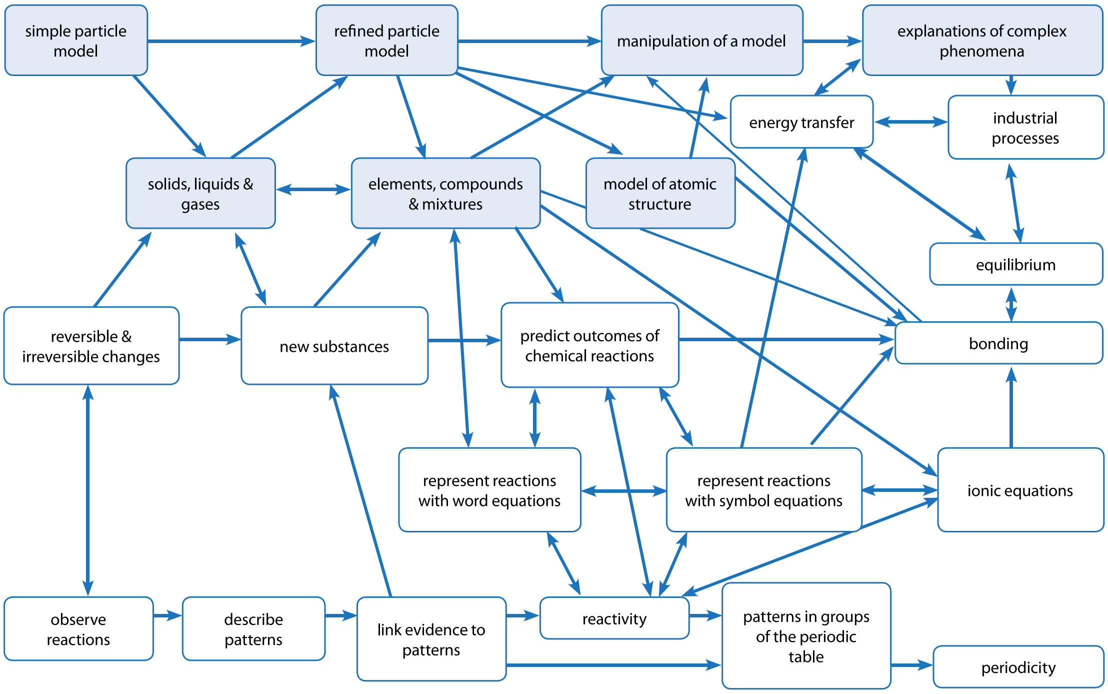
The three journeys

The following sequence shows how the three 'journeys' merge and link and the importance of the particle model.

- Formulate a simple particle model to explain the physical characteristics of solids, liquids and gases.
- Use the simple model of particles to explain the effect of temperature on states of matter.
- Develop the simple model of particles to include elements, mixtures and compounds.
- Use a particle model to explain the outcomes of simple chemical reactions.
- Use a particle model to explain the outcomes of a range of chemical reactions.
- Use a particle model to predict the outcomes from a range of chemical reactions.
- Use a particle model to include the effect of external factors on chemical reactions e.g. temperature, pressure, concentration and catalysts.
- Use particle models to produce word equations of chemical reactions.
- Use particle models to produce symbol equations of chemical reactions.
- Use particle models to produce ionic equations of chemical reactions.
- Use particle models to explain the structure of an atom.
- Use particle models to explain dynamic equilibrium.
- Use particle models to exemplify different types of chemical bonding.
- Use particle models to explain endo- and exothermic reactions.
- Predict whether a reaction will be endo- or exothermic using particle models and bond enthalpy.
- Use particle models to describe and explain trends within groups of the periodic table.
- Use particle models to describe and explain trends within periods of the periodic table.
- Use particle models to describe and explain trends in the reactivity series.
- Manipulate models in a range of contexts including industrial contexts.



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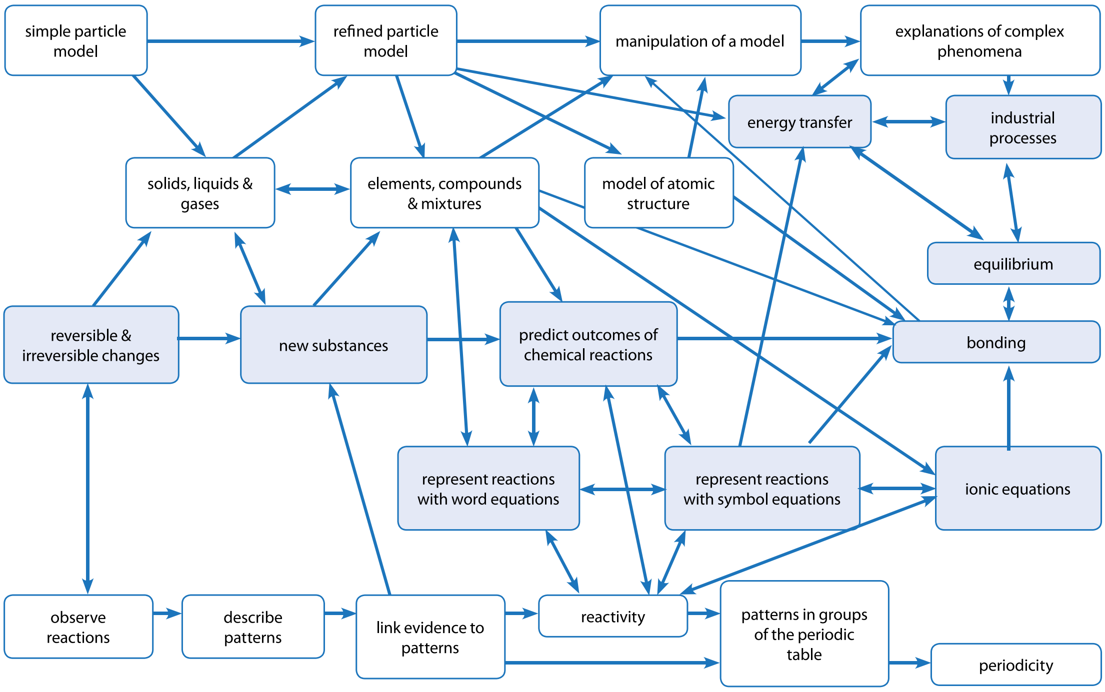

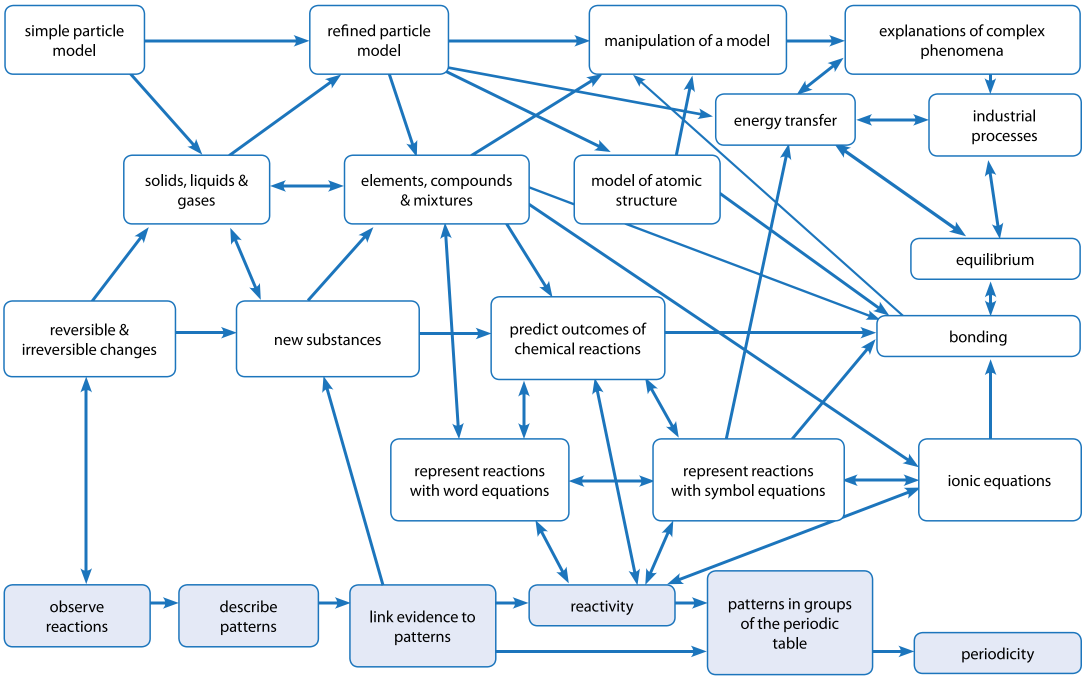

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The learning demand

One way of thinking about why some science topics are more difficult to teach and learn than others relates to the concept of 'learning demand'. The 'learning demand' focuses on the *differences* between everyday ways of talking and thinking about phenomena and the scientific way of doing so.

For example, take the case of smelling fish and chips as you pass a chip shop:

Everyday way of explaining	Scientific way of explaining
You smell fish and chips as you walk past the shop because the smell moves to your nose.	The cooking of the chips results in fast-moving gas particles because the average speed of particles increases with temperature. These particles diffuse quickly into the air. Chemical receptors in the nasal passages detect these gas particles.

Here there is a **big** difference between the everyday or 'common sense' way of explaining and the scientific way. Rather than thinking in terms of smell as an entity the pupil must get hold of the idea of particles and diffusion and the relationship between the two.

For other science topics, the everyday view is similar to the scientific view and the learning demand is **small**. For example, everyday understandings of speed are likely to be the same as the scientific definition: pupils know that high speed involves covering a certain distance in a short time.
Some areas of science have a high learning demand because:

- they are counter-intuitive
- of their tiny scale
- of their big scale
- they rely on interlinked variables
- they depend on being able to integrate other concepts
- they are abstract concepts
- they involve mathematical concepts
- they are not taught at Key Stage 2.

The everyday ways of explaining phenomena are what are referred to as *alternative frameworks* or *misconceptions*.

See Appendix 1 for more information on the learning demand.

Key Stage 2 experience

It is likely that at Key Stage 2 pupils:

- will have been introduced to changes of state and will have been taught the simple definitions of words such as melting, evaporation, freezing, boiling, dissolving, reversible and non-reversible
- will have learned about some irreversible changes, including baking, burning, vinegar reacting with bicarbonate of soda and the effect of mixing water with plaster of Paris
- will have learned to distinguish irreversible change in terms of not being able to get the original material back or new substances being formed
- may have investigated the formation of crystals, e.g. of sugar and may have incidentally heard about particles, but the particle explanation is not formally introduced until the Key Stage 3 programme of study.

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Teaching needs to be planned to build on prior knowledge and experiences that pupils bring with them in order to progress their learning. Similarly, it is important to provide pupils with the opportunity to consolidate and develop ideas that may previously have not been secure without considerable repetition.

Barriers to learning

There are common barriers that could prevent learning in this area. They need to be identified in your scheme of learning and addressed through teaching. In particles you might find that pupils think that:

- substances contain particles rather than consist of particles, e.g. pupils think water has particles in it, with water or air between the particles; pupils think that air has oxygen particles in it and there is air between the particles
- particles are comparable in size to cells, dust specks, etc. and they can be seen with an optical microscope
- particles of the same substance have different properties in solid, liquid or gas state, e.g. some pupils think solid ice particles are cold and hard, liquid water particles have expanded and so they are larger and softer, while water vapour particles expand even more and are very large and squashy
- all liquids contain water
- air is good (breathing) and gas is bad (flammable or poisonous)
- gases have no weight, or even have negative weight, and that is why things filled with gas float
- when water evaporates it splits up into atoms of hydrogen and oxygen
- the bubbles in a boiling liquid are bubbles of air
- melting and dissolving are the same
- boiling points are not fixed and the temperature will continue to go up as more energy is transferred
- condensation forms as a result of the ‘cold’ causing oxygen and hydrogen in the air to make water
- atoms are a small bit of the parent material with all the same properties as that material
- the proportions of combining elements in a compound are not fixed
- metallic properties are due to properties of the atom rather than the atomic arrangement
- non-metals are substances such as sugar or wood rather than non-metallic elements
- chemical change is what is observed during the reaction, e.g. fizzing, not the production of a new substance.

Pupils are often confused or uncertain about:

- the function of the air, although they know that air is needed for burning
- the use of scientific words, such as material, matter, substance and pure lead, where there is also a different everyday meaning, e.g. ‘pure’ means it doesn’t contain anything harmful
- conservation of mass if they still think gases are weightless or substances disappear, e.g. by evaporation or burning.

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How science works

How science works is more than just scientific enquiry. It provides a wonderful opportunity for pupils to develop as critical and creative thinkers and to become flexible problem-solvers. As well as developing a range of practical enquiry skills pupils need to be able to:

- process and evaluate evidence from secondary sources
- use evidence to produce and test explanations and arguments
- present and share explanations to a variety of audiences
- understand how the scientific communities function to strengthen the quality of explanations.

In the science Framework *How science works* has been split into two substrands:

Explanations, argument and decisions	Scientific thinking: developing explanations using ideas and models Scientific thinking: challenge and collaboration in the development of explanations Scientific thinking: developing argument Applications, implications and cultural understanding Communication for audience and with purpose
Practical and enquiry skills	Using investigative approaches: planning an approach Using investigative approaches: selecting and managing variables Using investigative approaches: assessing risk and working safely Using investigative approaches: obtaining and presenting primary evidence Working critically with primary evidence Working critically with secondary evidence

Often work is repeated because it is felt that pupils have 'not understood' an aspect of range and content. Too often this 'understanding' is demonstrated by how well pupils recall and apply scientific knowledge. This lack of understanding is not because pupils need repetition, i.e. the same lesson again, but because they need to engage with the science in a way that promotes their thinking and challenges their understanding.

How science works is sometimes considered 'that bit of science that is added on' to a range and content lesson or even worse taught as a separate lesson. In fact, *How science works* should provide the teaching approach in science lessons and it provides the route into consolidating particle theory without tedious repetition.

Good pedagogy in science consists of two interwoven strands, generally referred to as 'range and content' and *How science works*. The former consists of the big ideas in science, such as the gene theory of inheritance or the particulate model of matter; these are cherished as they provide ways of making sense of a variety of phenomena. The latter consists of the processes and skills that scientists use, ranging from the use of equipment, through to the manipulation of data, to an understanding of how scientific ideas are challenged and tested.

These two strands are sometimes seen as 'theory' and 'practical work', but the relationship is much closer than that. For pupils to interact with a concept in a meaningful way, they need to be able to deploy a range of process skills; they may need to be able to apply it to a new context, to communicate it to a particular audience, or to find evidence to support or oppose it. This is enshrined in the level descriptors, and Assessing Pupils' Progress (APP), and gives us a very powerful and flexible way of assessing progress.

Task 0: What is the difference?

Consider the difference between the first activity and the two that follow it.

1) Pupils recognise the differences between solids, liquids and gases.

2) Support pupils in exploring possible misconceptions they might have about particles.

3) Create opportunities for pupils to compare and contrast different particle models used to explain changes in state.

In the first example, pupils could classify a range of materials, be told the 'scientific' definition of solids, liquids and gases and then copy diagrams to show the arrangement of the particles. A teacher might feel confident that pupils have 'understood about solids, liquids and gases' when they can recall the scientific definitions and answer questions correctly on a worksheet or from the text book.

Examples two and three have *How science works* integrated and provide a way of teaching particles that will prompt discussion and exploration of ideas. This can be daunting because it is a different style of teaching and teachers might be concerned about how to cope with the ideas pupils have. But this approach supports better learning and the pupils' conceptual development.

Below is a small selection of the teaching strategies taken from the science Framework section on Particle models.

1. Identify where the *How science works* aspect has been integrated.
2. Range and content is being taught but through an approach that will develop pupils' thinking and understanding. Compare these teaching strategies to those in your scheme of learning or that you currently use.

- Explore with pupils how the particle model can start to explain changes in matter and some of the limitations of the model.
- Explore with pupils how the use of the particle model can support an explanation of the behaviour of solids, liquids and gases.
- Provide and support opportunities to explore and compare the strengths and weaknesses of the particle model, e.g. explaining what is between the particles.
- Explore with pupils to what extent materials can be classified by identifying their particular properties.
- Provide opportunities for pupils to start to form links between the energy-transfer model and the particle model to explain changes in state.
- Provide opportunities for pupils to experience changes of state and the reverse, including the associated energy changes.
- Provide opportunities for pupils to select an appropriate model to explain separation techniques.

If you have not seen the progression in How science works, you can download a copy from the secondary science Framework area of the National Strategies website (**www.standards.dcsf.gov.uk/nationalstrategies**) or go to Appendix 2.

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Assessing Pupils' Progress (APP) in science

A fundamental aspect of planning effective teaching and learning is the role of assessment. A good teacher will want to know how pupils are progressing in terms of their command of an area of study. This enables the teacher to evaluate the strategies that are being used, to support the pupil and to identify the next steps in the pupil's learning journey.

Instead of trying to gauge what a pupil knows (never a good test of a scientist) we can assess the process skills they have mastered which are generic to the whole of science. This approach is used by APP and is based around five Assessment Focuses (AFs):

- AF1: Thinking scientifically
- AF2: Understanding the applications and implications of science
- AF3: Communicating and collaborating in science
- AF4: Using investigative approaches
- AF5: Working critically with evidence

Each AF consists of a series of outcomes between levels 3 and 8 at Key Stage 3 that represent what pupils will be able to do at that level. By using Assessment for Learning (AfL) and looking across a range of evidence it is possible to recognise the progress that has been made against a range of AFs and to identify the next steps in the development of that process.

APP and the study of particles

If *How science works* is built into a range of teaching strategies when pupils are studying particle models, this presents a variety of opportunities to assess their progress. Depending upon the activity it will be possible for the teacher to assess using criteria from different assessment focuses. APP is periodic assessment and is designed to be used approximately once a term to inform a synoptic view of progress.

The following two examples of lesson episodes exemplify how assessment should be an integral part of teaching and learning not additional 'assessment activities', devised purely for the purposes of testing pupils, but learning activities that are valid in their own right.

Example 1: Year 7 mixed ability, working at levels 4 to 6: Particles.

In this sequence of lessons pupils had been exploring the differences between solids, liquids and gases and what caused a change of state. The teacher had not yet introduced pupils to the particle model. Pupils were asked to work in small groups to create their own models to try to explain the differences between solids, liquids and gases.

The teacher listened to the pupils' discussions, only prompting if absolutely necessary. Each group presented their model to the whole class where questions could be asked or clarification sought. Once all groups had presented, pupils returned to their small groups to review their models and make changes.

The teacher was able to assess a number of pupils and use this to contribute to a periodic assessment against AF1 (Thinking scientifically), AF3 (Communicating and collaborating in science) and AF5 (Working critically with evidence).

Example 2: Year 9 Set 1, working at levels 6 and 7: Making new materials

In this sequence of lessons pupils had been studying a range of chemical reactions when the teacher realised that there was some confusion about conservation of mass. The teacher then presented the class with information about the phlogiston theory, Priestley's work on oxygen and Lavoisier's experiments on burning.

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The pupils were challenged to use the particle model, and other evidence, to explain to what extent the findings agreed or differed with the ideas we have today: some pupils realised that their ideas matched those of earlier scientists!

The teacher discussed their ideas with them and used this as evidence for periodic assessment against AF2 (Understanding the applications and implications of science), AF3 (Communicating and collaborating in science) and AF5 (Working critically with evidence).

More information can be found on the secondary science Framework at the National Strategies website (**www.standards.dcsf.gov.uk/nationalstrategies**)

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Handout 6.4: Using particle models to understand digestion and absorption

During Key Stage 3 pupils will learn about the structure and function of the digestive system, the names of organs and their function. This is generally well understood. However, their understanding of how and why food is broken down and absorbed is less well understood. The visking tubing model of the gut can confuse pupils about the process of digestion and absorption as the model has limitations.

The teaching of digestion provides a good mechanism for pupils to apply their knowledge of particles. At the same time emphasising the role of particle size can improve their understanding of digestion. Pupils could be asked to apply their knowledge to explain how 'energy' drinks work.

Most such drinks supply glucose at an appropriate concentration to be absorbed through the stomach wall almost immediately. This is because glucose is a small carbohydrate molecule and does not have to be broken down into smaller molecules before it can be absorbed into the blood. Other more complex carbohydrates do require digestion before absorption and are better for longer-term energy supply. More sophisticated sports drinks contain complex mixtures of different-sized carbohydrate molecules, designed to match the energy requirements of the athlete and nature of the sport.

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Task 10: Try this as an alternative!

You can look quickly at items 1 to 4 below, which may represent a fairly typical start to this topic, but you may want to spend more time on items 5 to 9, which focus on the role of molecule size within digestion.

The true/false cards and the *Predicting the digestion of starch* task are intended for pupil use.

1. The topic can be introduced in the usual way. For example:

- drawing a life-size body on paper (e.g. wallpaper) and adding internal organs and labels
- check size and position of organs with textbook
- teach names of the parts (oesophagus, stomach, small intestine, etc.) and other key words, with careful pronunciation and other vocabulary strategies.

2. Ask pupils to think about the possible process of digestion and to suggest how food is digested. Scaffold their answers suggesting the framework: first …, then …, next …, etc.
3. Ask pupils to find out the role of enzymes in the digestion of food using standard textbooks as a source of reference.
4. Use the 'Digestion – true or false?' cards as a card sort activity. Then take just the true cards and sort them into an approximate sequence to represent the process of digestion. There is more than one possible sequence. These could be attached to appropriate places on a wall poster if one is displayed. Invite faster workers to explain the mistakes in the false cards. Cards 1, 6, 9, 10, 11, 13 and 16 are the deliberately false statements.
5. Ask pupils to explain *why* enzymes are needed for digestion. Scaffold their answers by giving them the root 'Enzymes are needed in the process of digestion *because* …' Review their answers. How will you test to show that this has happened?
6. Once pupils are clear about their explanation, introduce the visking tubing experiment. Get them to predict what will happen and why.

- What do you know about the connection between glucose and starch?
- What do you know about the action of enzymes (amylase) on starch?
- What do you know about the visking tubing walls?
- What do you expect to happen?

7. Alternatively, you could use the 'Predicting the digestion of starch' diagram labelling exercise as a group work activity.
8. Pupils can now carry out the visking tubing practical with a greater certainty of understanding the purpose and details of the practical work and how this is a model of digestion.
9. It is possible for pupils to model the process of digestion on a larger scale (see following page).

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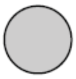
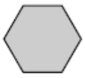
How to model the process of digestion on a larger scale

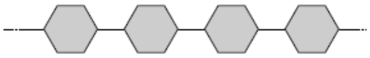
A **By drawing** using:



to represent a water molecule;

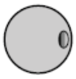


to represent a glucose molecule (which is approximately hexagonal in structure);

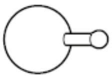


to represent a starch molecule.

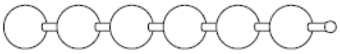
B **A bead model** using:



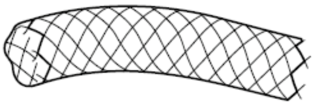
a small bead to represent a water molecule;



a single poppet bead to represent a glucose molecule;

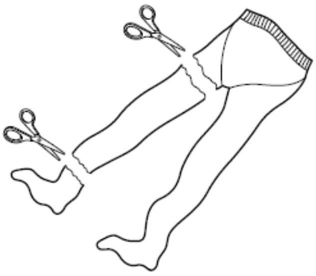


a string of poppet beads to represent a starch molecule;



a length of net tubing (used to sell oranges) to represent the intestine.

C **A wet model** using:



a length of leg from a pair of tights to represent the intestine;

spaghetti in tomato sauce or chopped tomatoes to represent the 'soup' of large and small molecules.

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Digestion – true or false?

1 The food molecules that get through the gut wall get passed out of your body when you go to the toilet.

2 Enzymes help break down large food molecules into smaller molecules.

3 Enzymes such as amylase in saliva start breaking down the starch in potato as you chew it.

4 Many food molecules are large and need to be broken down into smaller molecules.

5 In the large intestine water is extracted from the 'soup' to leave a more solid waste.

6 Starch molecules are much smaller than molecules of sugars such as glucose.

7 The food and liquid is churned up to make a liquid like soup.

8 As the mashed-up food goes along the small intestine small molecules can get through the intestine wall.

9 In the stomach all the goodness is removed from the food to leave just waste.

10 Chewing protein molecules breaks them up into small molecules.

11 Enzymes in the human body work best at a temperature of 87°C.

12 The food molecules that get through the gut wall are picked up by the blood supply and carried round the body.

13 As the mashed-up food goes along the small intestine big molecules of starch can get through the intestine wall.

14 More digestive juices are added to the food in the stomach.

15 Only some molecules are able to go through the gut wall.

16 Enzymes are powerful acids that break down other chemicals.

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Predicting the digestion of starch

Draw arrows from each label to the correct part of the diagram

Tap water

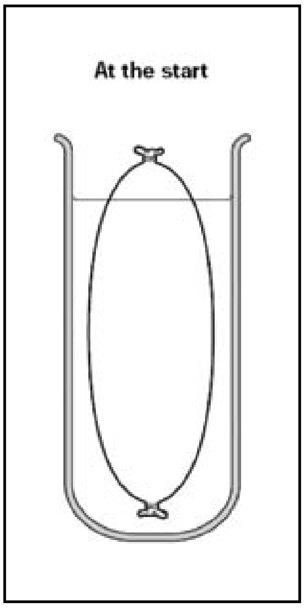
This will turn dark blue with iodine

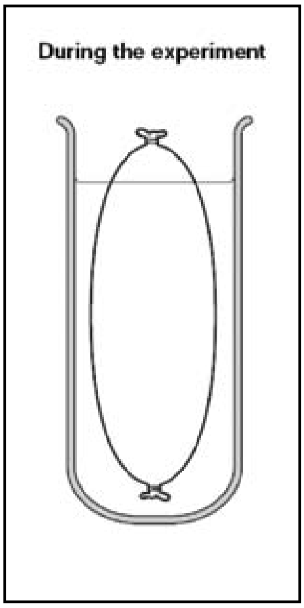
This is like a piece of intestine

The small molecules can get through the wall of the tubing

This now contains water and sugars

This will go brown with Benedict's test





Starch, water and amylase (enzyme)

This is like the food inside the intestine

At 37°C, like body temperature

This represents the blood supply

The enzyme is breaking down the starch into sugars

This won't change colour with iodine

Now consider the three suggested models to show digestion on a larger scale – drawing; bead model; wet model.

- Are any of these three models suitable for use when you teach this topic?
- Be sure to consider the strengths and limitations of any model you might think of adopting (or you currently use).
- Are there any other advantages to this suggested approach which you might adopt?

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Acknowledgements

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Bloom's Revised Taxonomy by Kurwongbah State School, Australia. Used with kind permission.

Note making table is adapted by Meredith Lane-Richardson from that appearing in Top-level Structure Written in Low-level Language by D Klarwein. It also appears in the Stepping Out Program (Education Department of Western Australia, 2001) and in Stepping Out: Reading Strategies for Success (Heinemann (UK), 2001).

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Audience: Science subject leaders
Date of issue: 01-2010
Ref: **00004-2010DOM-EN**
Ref: **00004-2010PCK-EN**

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