Key Stage 3
National Strategy

Guidance

Curriculum, Examination & Assessment

Literacy in science

For school-based use or self-study

Heads of science and teachers of science

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Contents

Key principles

- To raise awareness of the importance of language in teaching science and literacy across the curriculum.
- To identify the difficulties encountered when learning scientific words and ways of improving pupils' skills in dealing with scientific terminology.
- To explore the ways and purposes of reading in science to improve pupils' skills.
- To explore the purpose of writing in science, the implications for teaching and ways in which pupils' writing in science can be improved.
- To explore the purpose of speaking and listening in science.
- To exemplify techniques that enable pupils to engage fully in discussion.

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Session 1

Introduction

Aims

- To raise awareness of the importance of language in teaching science.
- To raise awareness of pupils' language experiences and literacy across the curriculum.

General introduction to the *Literacy in* … series

The aim of the subject-specific material in the *Literacy in* … series is to exemplify aspects of the *Literacy across the curriculum* training file for individual subjects.

Where appropriate, the relevant module from the *Literacy across the curriculum* training file is indicated, so that you can refer to it.

Key principles

- To develop consistent approaches to teaching and learning in literacy across departments, and to build increased awareness of the skills, knowledge and understanding that pupils could be expected to bring to lessons.
- To use speaking and listening to develop subject learning.
- To develop active-reading strategies to increase pupils' ability to read for a purpose and engage with text and the learning to be gained from it.
- To demonstrate the sequence for writing and modelling writing for a key text-type within the subject; seeing how it is done helps pupils to achieve it for themselves more quickly.
- To make suggestions for the learning of subject-specific vocabulary.

Making use of the *Literacy in* … materials

Each subject is available on a CD-ROM. On the disc you will find both the text (a combination of information, guidance, case-study materials, mini tasks and ideas for practical application in classrooms) and the video clip(s) that accompany it. Where a short task has been suggested, you are invited to check your responses against those of other teachers provided in the examples.

'Doing' the modules by reading through them is not enough. You will gain much more from them if you try out and evaluate ideas in the classroom, and incorporate successful aspects into your teaching plans.

Try to get some support or mentoring for your study. There may be points which you are unsure about, and it is useful to have someone to ask or talk to. It also helps if you study the modules at the same time as another colleague, so that you can discuss what you are learning as you go along. In this way, activities in the classroom can also be trialled and discussed, and greater consistency of practice ensured.

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English Framework objectives

The objectives from the *Framework for teaching English: Years 7, 8 and 9* (DfEE 0019/2001) which apply across the curriculum appear in an Appendix; most are the key objectives (in bold) but others have been added for clarity or exemplification. This will help you to set literacy targets and ensure common approaches through the objectives.

You may already realise the following points:

- While we can regard science in part as a practical subject, language is at its heart. There is a richness of specialised words that often have dual meanings (one in everyday life and another in science) waiting to trip the unwary.
- A glance at the level descriptions shows that in science pupils are often expected to describe, generalise and explain.
- The precise use of scientific language and the ability to explain abstract ideas are important at Key Stage 3.
- The teaching of language has improved in primary schools recently because of the National Literacy Strategy and the National Primary Strategy. Many Year 7 pupils will have better-developed language skills than previous cohorts.
- The Key Stage 3 Strategy is supporting pupils' language development further.
- A key feature of the Strategy is that language is tackled at word, sentence and text level.

The Ofsted secondary subject reports 2000/01: science *(HMI 371) identified increasing attention to literacy in science departments. The report includes some useful examples and points out that the most effective development of literacy skills to support teaching and learning in science involves:*

- *reinforcement of the meaning and use of terminology by pupils in context;*
- *a reduction in routine written descriptions of practical activity and more writing about pupils' own understanding and interpretation of information;*
- *extended writing for other purposes such as 'ideas and evidence';*
- *reading about science issues as well as reading for information*.

Subsequent Ofsted reports in 2002, 2003 and 2004 have identified writing in science as a weakness that schools need to continue to address.

The work you have done on literacy across the curriculum in school will provide a foundation for the use of these materials.

Words in science

Aims

- To raise awareness about the difficulties encountered when learning scientific words.
- To identify the importance of word roots to the teaching of science.
- To introduce a taxonomy of scientific words and show how to identify key scientific words within a topic.
- To introduce a range of techniques for improving pupils' skills in dealing with scientific terminology.

Scientific words can cause pupils problems. Therefore, improving pupils' spelling and understanding of the words will improve their understanding of science.

Task

Consider why some words may cause difficulty and how helping pupils to spell these words correctly might also help them to develop a better understanding of science at Key Stage 3.

Think about these two cases of pupils' use of scientific terminology.

1. Why might these words cause problems?

- energy
- cell
- force

2. Why might these misspellings cause problems?

- hydraulic acid
- sodiam
- photosinthesus

You will probably have identified the problems associated with the difference between everyday use of terms, such as force, and the correct scientific use of the term. Pupils may not recognise the significance of word roots in the way that you do.

- Some words have 'everyday' meanings and pupils have a range of associations with them, for example force = strength.
- Just because a word is easy to read, such as energy, it does not mean that it is easy to understand, because it is a concept.
- Misspellings can cause problems because it will be less easy to spot the word roots that can provide pupils with an insight into the science behind the words.

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Possible problems with scientific terminology

Some scientific words have everyday meanings as well as scientific meanings. It is important to make pupils aware of these differences. Constant reinforcement is needed to encourage correct usage. Scientific definitions of words should be made clear and distinctions made from everyday meanings.

Words with everyday meanings include:

Force often used interchangeably with energy and power; will probably have everyday associations rather than the scientific concept.

Energy often used interchangeably with force; linked to the everyday notion of energy being used up or running out, which will lead to misconceptions.

Material although introduced with a scientific meaning in Key Stage 2, the everyday meaning often persists at Key Stage 3.

Dissolve sometimes used interchangeably with melt, even though introduced correctly in Key Stage 2.

Tissue has a distinct scientific meaning but also has an everyday meaning.

Many scientific words have been developed systematically. Knowing this can help pupils spot patterns and so develop their scientific understanding – for example, knowing that the word root **chlor** means green, and that within the name of a compound this could indicate the presence of a chlorine atom. This will aid understanding. Misspelling of words can lead to these patterns being missed.

Commonly misspelled words where patterns could be missed include:

Hydraulic acid A fairly common mistake; pupils miss the point about the chlorine atom being present.

Sodiam It is not always easy for pupils to accept sodium as a metal. Knowing that the suffix -**ium** has been taken to mean 'metal' provides pupils with a powerful tool for recognising metals from names.

Photosinthesus Misspelling the word misses the word root, **syn**-, so pupils are unable to connect the word with the notion of building or putting together.

In science at Key Stage 3, pupils are expected to use a large number of scientific terms precisely. Helping pupils to use and spell words correctly aids their scientific understanding because scientific terminology is often developed in systematic ways. Having a good grasp of scientific terms helps pupils to communicate observations and scientific ideas.

Science terminology and word roots

At Key Stage 3 you can build on pupils' improved literacy skills to help them to develop a better understanding of science. This is a good investment of teaching time because:

- spending time introducing new scientific terminology well at Key Stage 3 saves time later;
- during literacy sessions in primary schools, teachers discuss new terminology and word roots with pupils;

- many scientific terms have word roots that help us to understand the science behind them;
- Year 7 pupils are familiar with terms such as prefix and suffix. These help them to talk about and understand the structure of words.

Here is a list of some useful word roots.

Root	meaning	Root	meaning
aer	oxygen	iso-	the same
allel	different	lign	wood
amphi-	both	lys	break down
ante-	before	macro-	large
anti-	against	micro-	small
arthr	joint	myc	fungus
bi (bio-, -biotic, -be)	life	-oid	resembling
bi-	two	-on	a unit
cardi	heart	-ose	a carbohydrate
chlor	green	peri-	around
cyt	cell	phot	light
derm	skin	sapr	decay
di-	two	spir	breathe
dia-	across	stoma	mouth
ecto-	outside	sym-, syn-	together with
endo-	inside	therm	heat
gam	mating	trans-	across
ge	earth	troph	feeding
graph	write	vas	vessel
gyn	female	vor	feeding
haem	blood	xyl	wood
hydr	water	zoo	animal

This is not a definitive list, but these word roots are extracts from *Signs and symbols in primary science*, compiled by Neil Burton and Lynne Wright (ASE, 1998). A similar list appears in *Signs, symbols and systematics: ASE companion to 5–16 science*.

Word roots in the naming of elements and compounds

Pupils' understanding of the naming of elements and compounds is not well developed during Key Stage 3. The following information about word roots will help:

- In the eighteenth century, Antoine Lavoisier was credited with the development of the modern view of elements and compounds and is sometimes dubbed the 'father of modern chemistry'. The systematic naming of compounds saw a major revolution from this time onwards.
- New metals that were discovered were to end in -**ium**.
- Acids ending in -**ic** lead to the formation of salts with names ending in -**ate** (or sometimes -**ide**).
- Acids ending in -**ous** lead to the formation of salts with names ending in -**ite**.
- In simple terms, -**ide**, -**ite** and -**ate** can be related to the amounts of oxygen in a group of atoms in the salt.

Key words in science at Key Stage 3

You will probably recognise that:

- many departments help pupils to develop their scientific vocabulary by identifying key words for each topic;
- the 'Language for learning' section of units in the QCA scheme of work provides a helpful source of key words;
- pupils will have met many scientific terms before in Key Stage 2, so may just need reminding of these;
- many departments provide pupils with lists, sometimes placing them on the wall, but if these remain there permanently they can be viewed as 'wallpaper';
- often these lists are too long and contain unnecessary words;
- on their own lists are not effective. Scientific words that are important have to be introduced carefully and then used regularly.

Key words

We can identify words as 'key' if they help pupils to communicate ideas in science clearly and with understanding.

When identifying key words, focus on the **names** of objects or structures, **processes** and the **concepts** within the topic. You will also want to note those words that may cause difficulty because they have different everyday meanings and therefore require special attention.

The trick is not to make the list too long but to concentrate on what matters. You can regard this as forming a taxonomy of words. Names are the simplest words to understand. Some processes cannot be seen easily so they cause problems in understanding what they mean. Concepts are largely abstract, and words such as force, even though easy to read, are nevertheless difficult to understand.

Category 1: Names	e.g. artery, granite, hydrogen
Category 2: Processes	e.g. evaporation, respiration, digestion
Category 3: Concepts	e.g. energy, force, atom

Example for a topic on cells (e.g. QCA scheme of work unit 7A)

Key words

Names:

cell	cytoplasm	chloroplast
cell wall	nucleus/nuclei	ciliated epithelial cell
red blood cell	vacuole	root hair
spermatozoon(oa)	organ	cellulose
ovule	membrane	tissue
neurone		

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Processes:

fertilisation photosynthesis

respiration absorption

Concepts:

adaptation

(Scientific terms and technical language found in the QCA schemes of work for science for Key Stage 2 and Key Stage 3 are listed in Appendix 3 of the Framework.)

Jerry Wellington and John Osborne in their book *Language and literacy in science education* (Open University Press, 2001) state the case for a taxonomy of words and make the point that naming words are easier to deal with because they provide names for observable, real objects. They go on to point out that some process words are less easy to visualise. 'Whilst a teacher can point to a reaction on a front bench and say "There, that's combustion" … other processes belong to a higher category, for example evolution (or geological processes at Key Stage 3). You cannot point these out.'

Another category of difficulty is that of concept words (power, fruit, salt, pressure, force, energy). Even though these may be easy to read, they are not easy to understand. Readability scores, therefore, do not always identify problems with science texts.

At Key Stage 3, a number of abstract concepts are introduced, and throughout the programme of study there are many processes that are introduced. Dividing words into the three categories above can be a very helpful way of identifying key words.

You may want to have different lists of key words for pupils of different abilities. Be careful not to make a longer list for pupils of lower ability.

Neither should you avoid seemingly difficult words. It would be better to focus your attention on a select group of words that would be most useful. For example, for lower-ability groups working on the topic 'cells', it would be appropriate to focus on the words that are to do with structure, including 'difficult' areas such as membrane and nucleus and the plural nuclei, but pay less attention to the names of some specialised cells such as ciliated epithelial cells. You need to use your professional judgement, but always try to focus on a short list rather than a long list.

Now refer to Appendix 3 of the *Framework for teaching science: Years 7, 8 and 9*. This contains a list of scientific vocabulary arranged by year and attainment target which you will find helpful.

QCA Key Stage 3 science tests: notes for teachers contains a list of words that must not be simplified or explained to pupils, since they form part of the scientific understanding tested by the question.

Teaching key scientific words

To help pupils to do their best, you will need to spend time introducing new key words. Pupils need time to practise using them. They need opportunities to pronounce the new words, to explore how they are spelt and used. Do not be afraid to use terms such as noun, adjective or verb. Pupils will know these.

The following text provides a strategy for introducing new words that has proved effective.

Introducing new key words

- Introduce the word (is it a name, concept or process?).
- Write it on the board.
- Say the word.
- Ask pupils to say the word out loud.
- Break the word down into syllables; point out similarities with other words, use mnemonics to remember spellings if necessary.
- Ask pupils to read the word as it is used.
- Ask pupils to use the word in a description or explanation.

Example

The word **hydrochloric** (acid) can be pronounced and written.

- Break the word into syllables to help pronunciation and spelling, such as **hy**-**dro**-**chlor**-**ic** (acid).
- Point out patterns with other words, such as acids ending in -**ic** (or -**ous**) and any word roots, for example **chlor** meaning green as in chlorine, chloroplast, chlorophyll. Relate the **chlor** to a chlorine particle and **hydro**- as in hydrogen.
- Establish the meaning of the word with pupils; for example, hydrochloric acid contains hydrogen and chlorine atoms.

Pupils can be asked to write a sentence using the word to show how it is used, such as 'Hydrochloric acid will neutralise an alkali'.

Here are three points for you to consider (or to use for departmental discussion):

- How do you introduce new words?
- Would a 'word root' list help?
- How could this be used within the department?

Some useful ways to help pupils spell key words correctly

Here are eight ways to improve pupils' spelling of key words:

1 Syllabification

Help pupils by breaking down the word into syllables – get them to say it, write it and read it:
e.g. ox-y-gen, di-ges-tion, re-spir-a-tion, en-er-gy, el-e-ment

It is important to say the words aloud. Pupils welcome this because they recognise that it helps them to spell the word correctly and understand it.

2 Grouping words

Talk to pupils about words with similar patterns:
e.g. -tion endings for processes – nutri-tion, filtra-tion, distilla-tion
-ic endings for acids – sulphur-ic, nitr-ic, hydrochlor-ic

3 Making links

Talk to pupils about new words by making links with those they already know:
e.g. electrode from electron, filtration from filter

4 Spelling rules

Remind pupils of spelling rules (check with the English department):

(a) the split vowel digraph (formerly known as magic 'e'):
e.g. bit → bite, rat → rate

(b) y changes to i when adding a suffix:
e.g. geology → geological, classify → classification

(c) the 'i' before 'e' except after 'c', *when the sound is* ee:
e.g. believe and receive

5 Personal dictionaries

Ask pupils to make up their own dictionaries based on key words. Encourage them to write definitions.

6 Cued spelling

Ask pupils to use mnemonics, or memory hooks, to remember troublesome words:
e.g. diarrhoea → Down In Africa Red Riding Hood Only Eats Apples
laboratory → Lab or a Tory (humour)

Some people remember the shapes of words and these can be exaggerated.

On some occasions saying a word differently can help:
e.g. Wed - Nes - Day or Elec-trol-Y-sis

7 Look, say, cover, write, check

This is a common, well-practised technique used in English departments and for pupils with special educational needs.

8 Calligrams

Sometimes exaggerating part of the word to help illustrate its meaning is helpful, for example, making the double 'll' in parallel much longer when writing it on the board helps pupils to remember the spelling.

These ideas about spelling have been adapted from *Developing literacy – a course for teachers of Key Stage 3 and Key Stage 4*, reproduced by permission of the Basic Skills Agency. There is a similar list in the spelling section of Literacy across the curriculum.

Practising using key words

There are many ways in which pupils' use of scientific terminology can be developed throughout a topic:

- During oral work you can insist on correct pronunciation and increase the opportunities for pupils to say words aloud.
- Lesson starters could focus on the key words for the topic, for example using a loop game or a card activity matching words to definitions, or even a quick 10-question test. (These will be covered in more detail later.)

- Rather than putting a key word list for the topic on the wall, select out the key words that will be used during the lesson. These can be attached to a Velcro® pad and held up to display them.
- A homework activity could focus on word-level work, using activities such as word-webs and word completion exercises.

Strategies for developing scientific terminology

The panel below lists a range of activities for developing pupils' scientific terminology.

Strategies for developing scientific terminology

1 Words and definitions (card games and flashcards)

- word and definition cards
- flashcards
- definition dominoes

2 'Quickie' quiz

3 Word completion exercises

- wordwebs
- word cluster posters

4 Word loop games

5 Concept maps

If you are unsure about any of these methods, details are given in Appendix 1.

This list is not exhaustive; you and your department may have other methods in use.

Watch video clip 1. This demonstrates a word loop game being used. As you watch the video clip, consider these questions:

- How does the activity support scientific understanding?
- How does the teacher ensure that all pupils are involved?

Remember that this game will be played on more than one occasion at the start of lessons. The object is for the class to increase the speed at which they complete it. Heading for a time target over the week can be very motivating.

In conclusion

When considering the importance of word level work in science, the main points to remember are:

- identify key words with care, match your list to the needs of the pupils;
- explore new words together, consider their structure, word roots and correct meaning;
- provide opportunities for pupils to say words aloud;
- paying attention to terminology can help to raise standards in science – the end-of-key-stage tests require pupils to use precise language;
- use strategies to review words regularly (little and often).

Reading in science

Aims

- To explore the ways and purposes of reading in science.
- To provide teaching strategies to support active reading in science.
- To explain how to support reading through shared reading.

Reading in science should be a demanding activity. Often the vocabulary is highly specialised and science texts can be dense. Textbooks often break text down into small chunks to make it more accessible, but the double-page spread can bring its own problems in navigating the text. Chunking can result in insufficient text to carry much meaning or information. Textbooks are now starting to carry more text and pupils need to be shown how to read them.

Supporting pupils in reading and offering them ways to access text is better than reducing the amount and quality of their reading.

Reading and science texts

Ways of reading include:

continuous reading: uninterrupted reading of continuous text;

close reading: careful reading and study;

skimming: glancing quickly through a passage to get the gist of it;

scanning: searching for a particular piece of information.

Pupils are taught these terms and what they mean in English lessons:

- Continuous reading, such as a novel or magazine article for pleasure.
- Close reading, which usually involves pausing to think, and referring backwards and forwards.
- Skimming, for example, to see if an article is worth reading, or looking at sub-headings to gain an overview.
- Scanning, such as looking up a phone number or words in a text.

It is important that teachers tell pupils which strategies to select and why, especially early on in Key Stage 3, so that they can select the appropriate strategy independently as soon as possible.

Consider some of the ways in which you use reading in your own lessons.

- What ways do you use?
- What is their purpose?

Compare your responses with those of a group of teachers.

- Continuous read: background reading on a topic of interest.
- Close read: developing understanding of a concept (such as energy) or a process (such as digestion); considering the pros and cons of an argument.

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- Skim: to find out if a chapter is worth reading; does the text, for example, provide sufficient and appropriate depth of information on cells to be worth reading?
- Scan: to find a topic in, for example, an index or to locate words to do with forces.

It can be difficult to find texts at Key Stage 3 that contain sufficient scientific information to be useful to pupils. Textbooks are often, of necessity, brief and can become outdated quickly. Even when science readers are available, they are not always written so that pupils can engage with them actively (that is, lend themselves to DARTs activities – directed activities related to text – these will be discussed in more detail later).

If specific texts are needed, it might be useful for your department to construct their own round a given topic. This can be helpful for several reasons:

- They can be differentiated easily.
- They can ensure both a good scientific experience for the pupils and a good read.
- They will provide a richer teaching and learning experience than a traditional work sheet.
- They can be stored in the department for future use and easily updated using ICT. There is no need to rewrite, just amend.
- Pictures, graphs and other support material can be imported easily to enhance the learning.

The texts which you will see later in this section have been created with specific science purposes in mind. They have also been written in such a way that pupils can actively engage with the text. They will help you to write your own.

Below is an example of a text created for specific science purposes.

- First skim read it to get the gist and then close read the text.
- Where could it be used?
- What kind of information does it contain?
- Why would this be useful at Key Stage 3?

How fresh is fresh?

You may have noticed that supermarkets sell apples and other fruits all year round. Apples ripen in England in the autumn. Once ripe, they last up to a week or two. Apples are imported from other countries such as New Zealand to extend the season, but this alone will not make sure that you can have an apple at any time of the year. Many apples are picked just before they are ripe and are then stored in a controlled environment. When stored carefully, some varieties of apple can last up to 12 months. So the apple you buy could be a year old.

How can you store an apple so that it will stay fresh? As apples ripen, the minerals and other chemicals in the cells that make up the apple tissue change. Starches in the cells change to sugars and the cell walls begin to break down, so when you bite into the apple it tastes sweet and juicy. If you want to keep an apple for longer, you need to make sure it does not ripen too soon. You do this by picking the apple at the right time and then by storing it so that it ages slowly.

You can check how close apples in an orchard are to being ripe by testing one or two to see how much of minerals such as phosphorus, magnesium and potassium they contain. Cell walls need some of these minerals to maintain their rigidity. As the apple ripens, so the amount of each mineral in the fleshy part changes. By tracking the changes you can tell how ripe an apple is. Picking the apple at just the right time makes sure it will last longer.

Once picked, the apple will continue to ripen, so this process needs slowing down. An apple is living and each of its cells continues to respire. This means that they continue to absorb oxygen from the air and give off carbon dioxide. As each cell respires, some of the stored food is converted to energy. The apple also gives off a gas called ethylene that helps to ripen the fruit. Controlling the atmosphere in the store can slow down the respiration rate in the apple cells. A slow-turning fan can keep the air circulating and blow away the ethylene as it is formed. If you decrease the level of oxygen and increase the level of carbon dioxide, cell respiration slows. Some varieties of apple will tolerate high levels of carbon dioxide in the atmosphere. For instance, Cox apples will tolerate 9% of carbon dioxide. These varieties can be stored for longer. Apples such as the Worcester will tolerate less, so cannot be stored for long periods.

The apple store is also cooled. This makes sure that any chemical reactions, such as respiration, will take place at a slower rate than normal.

Fruit such as apples cannot be frozen without becoming softer and mushy. This is because, as the water in the cytoplasm freezes, sharp crystals of ice form that burst the cell membranes and cell walls. As water freezes to form ice it expands, and this will also cause the cell walls and cell membranes to burst.

Growing and selling apples and other fruits is big business, so it is in the interests of many to extend the shelf life of these products as long as possible. But do they taste the same as freshly picked apples? The industry claims they do. If you are lucky enough to live in an apple-growing area you could try your own experiment, but you may have to wait until next autumn.

- This article helps pupils to realise that respiration takes place in the cell. Most would not regard a picked apple as living, or that the flesh of an apple is made of cells.
- The article brings some relevance to the science which they are learning and makes connections with everyday life. This can be motivating to many.

The article *How fresh is fresh?* has been written with pupils in mind.

- It has an engaging title.

- It has been written in the active voice, so it is easier to understand than if written in the passive voice.
- Paragraphs break up the text.
- The text is relevant to everyday life yet well matched to Key Stage 3 science, containing key scientific terms in new contexts.

You could use this checklist to judge the worth of commercially produced texts.

You could use this text with pupils as it stands, asking them to skim read to get an overview and then close read each paragraph. The style in which it is written, however, allows us to use it in ways to encourage pupils to engage actively with reading. This approach is explored next.

Active reading in science

Directed activities related to text (or DARTs), which were introduced in science education in the 1970s, are good ways to ensure that pupils engage with text in a way that promotes understanding. They are **directed** because pupils are told why they are reading and what they should gain from the experience before they start. The activities are **active** because they make pupils think and take decisions. A good rule of thumb is '**if an activity does not require pupils to make a decision, don't do it**'.

Directed activities related to text (DARTs): a summary

Reconstruction activities **use modified text**. Pupil tasks: completion-type activities with deleted or segmented text.	Analysis activities **use straight text**. Pupil tasks: text marking and labelling or recording.
1 Text completion Pupils predict deleted words (cloze), sentences or phrases.	***1 Underlining*** Pupils search for specific target words or phrases that relate to one aspect of content, e.g. key words.
2 Diagram completion Pupils predict deleted labels on diagrams using text and other diagrams as sources.	***2 Labelling*** Pupils label segments of text which deal with different aspects, e.g. labelling a scientific account with labels provided by the teacher, such as *prediction*, *evidence*, *conclusion.*
3 Table completion Pupils complete deleted parts of a table using table categories and text as sources of reference.	***3 Segmenting*** (a) Segmenting of paragraphs or text into information units. (b) Labelling of segments of text.
4 Completion activities with disordered text (a) Predicting a logical order for a sequence. (b) Classifying segments according to categories given by the teacher.	***4 Diagrammatic representation*** Constructing diagrams from text, e.g. using flow diagrams, concept maps, mind maps, labelled models.
5 Prediction Pupils predict next part(s) of text with segments.	***5 Tabular representation*** Pupils construct and represent information in tabular form, extracting it from a written text.

This summary is adapted from Reading for learning in the sciences*, by Davies and Green (Pearson Education Limited, 1984).*

- The first column (restructuring) shows those activities which you can use with modified text, that is segments for sequencing or text where parts have been removed.
- The second column (analysing) is potentially more useful and shows the sorts of activity that you can use to help pupils engage purposefully with blocks of extended text.
- Although used a lot, cloze procedure is often unsuccessful as an active-reading strategy because pupils can often complete it from their general knowledge; they pick words out too easily from a passage or use grammatical cues to select words from a passage or a list, such as nouns, verbs, adjectives. They recognise that they can only go in one place so guessing is often easy.
- Guessing in this way does not help pupils to develop a better understanding of science.
- If you want pupils to use key words or subject-specific terms, it might be better to use alternative means such as those suggested in section 2, for example, matching words with definitions.

Example 1 Text marking (analysis)

Look again at the article *How fresh is fresh?* on pages 15–16.

Skim read the article, then:

- highlight in red those things that happen as the apple ripens;
- highlight in blue ways of preventing ripening;
- once pupils have completed the highlighting, they would complete the grid below by answering the questions. You can try it if you wish.

Text marking (analysis) grid

How can ripening be slowed?	What process does it stop?

Note some of the ways in which this exercise helps pupils to engage with the text and encourages understanding of respiration:

- Pupils know what they are looking for and have a clear purpose for reading.
- They have to engage with the text; they cannot copy passages.
- The skimming exercise ensures that pupils have an overview of the text before they close read.
- They have to think about the information and understand it in order to complete the columns.
- Working in pairs supports learning and develops discussion towards common understanding.
- Pupils are not isolated and do not have to commit themselves to an answer immediately.
- The teacher has a record in the grid to monitor understanding.
- Pupils have an *aide-memoire* for future reference or revision.

Example 2 Table completion (analysis)

Re-read the text of *How fresh is fresh?* on pages 15–16, then:

- find reasons for the statements in the left-hand column of the table below;
- write the explanation in the right-hand column.

Statement		**Explanation**
Apples are imported from other countries such as New Zealand	**because**	
When you bite into a ripe apple it tastes sweet and juicy	**because**	
The apple store is cooled	**because**	

Statement		Explanation
Levels of oxygen are decreased	**because**	
You cannot use freezing as a method to store apples	**because**	
An unripe apple contains phosphorus, magnesium and potassium	**because**	

Consider how this task supports pupils' reading and understanding.

- Encouraging pupils to link cause and effect and provide explanations is essential in science at Key Stage 3. This type of table works well.
- Using 'because' encourages pupils to use connectives appropriately when they talk and/or write.
- Pupils could be encouraged to construct sentences from the table as a follow-up activity **if** there is a need to develop pupils' ability to write explanations.

There is a range of DARTs activities, including sequencing, with which you will be familiar.

In summary:

- DARTs can be used to help pupils understand text better.
- Be wary of using the cloze procedure as the only technique.
- Analysis techniques operate on 'whole text' and are ultimately more useful.
- It may be better to invest your time in finding or creating good examples of scientific text that pupils can explore rather than providing more standard worksheets – remember: **think active**!

Shared reading

Shared reading is a good way to introduce new or more difficult texts, especially those that contain a lot of new, specialised vocabulary. Pupils can then go on to an independent, active-reading task. Whilst many are working in pairs, small groups or independently, the teacher can support one group who may need additional help, or more-able pupils who could be given a more difficult text on the same subject.

Below is a sample text about cells that might be used as a shared reading exercise. It could be difficult for pupils because there are many scientific terms; however, it has been constructed with a scientific purpose in mind. The text is designed to help pupils to gain a better understanding of the link between form and function in cells.

Cells

Almost all cells have a nucleus which is suspended in a jelly-like fluid called cytoplasm. This cytoplasm is contained within a membrane that lets some substances in and out.

Cells can be different in shape, size and colour. This is because they do different jobs. Sperm cells have a small head and a long, lashing tail. Their job is to fertilise an egg cell. They have to swim to the egg; the head carries the genetic material. A palisade cell is found in the upper parts of a leaf and is green. The green colour is due to chlorophyll, a chemical that helps plants to photosynthesise. The job of a leaf cell is to produce glucose from carbon dioxide and water using energy from the Sun. A root hair cell is long and thin and so has a large surface area. Its job is to absorb water and minerals from the soil. Nerve cells have a small region which contains the nucleus and most of the cytoplasm. Other parts of the nerve cell can be very long and thin and even be shaped like the branches and twigs of trees. Their job is to pass on messages, in the form of electrical signals, to different parts of the body. For example, if your hand is burned in a flame, nerve cells would transmit messages from your hand to the central nervous system in your spine and then back to your arm muscles to pull your hand away from the flame.

So while all cells have the same features, such as cell membrane, nucleus and cytoplasm, what they look like can be very different. Their form and what extra they contain, such as chlorophyll or haemoglobin, helps them to perform different functions.

Here is a method of organising shared reading.

A strategy for shared reading

- The class can share in the reading.
- The teacher should copy the text onto an OHT or PowerPoint slide.
- Pupils then look at the teacher and the text.
- The teacher gives the class an overview of the text.
- Specialist vocabulary could be taught before the reading.
- The teacher reads the text aloud to the end, encouraging pupils to follow it.
- The teacher then explains meanings and difficulties.
- Explanations can be written on the OHT or slide and be linked to the text with an arrow.

Bear in mind that you would not be asking pupils to read aloud round the class where they might feel threatened and stumble over new words.

Shared reading clearly includes using comprehension-type questions with pupils to clarify meaning. Pupils could then either work on the existing text or be given another similar text to develop their skills. Once pupils have an overview of the text and understand the vocabulary, they can be set independent tasks to develop their understanding.

A number of activities that could follow the shared reading are outlined below.

Suggested activities

1 Text analysis (DARTs)

(a) Pupils could be asked to consider the text. For instance, they could be asked to:

- underline in BLUE all words that identify different types of cells;
- underline in RED all phrases that identify their function;
- underline in GREEN all phrases that identify the structure of the cell.

(b) As a follow-up activity, pupils could be shown how to WRITE sentences which EXPLAIN the link between structure and function, using connectives which indicate cause and effect (see connectives handout in *Literacy across the curriculum*, section 3).

You could provide a sentence structure indicating connectives, such as the structure of 'BLUE have GREEN because/as RED':
e.g. Sperm cells have small heads and long, lashing tails because they have to swim to the egg to fertilise it.

2 Group reading leading to a writing activity

Pupils could be asked to read a piece of text. In groups they then discuss the text. They might 'mark' it, for example, use highlighting to identify features such as key words to do with names of parts of a cell. Pupils then, individually or as a class, write about an aspect of cells using the key words and information from the text.

Note the following points:

- This use of the text has a specific scientific outcome in mind.
- The pupils are working together, supporting each other.
- The text on cells is demanding and technical words have not been avoided. However, the text has been carefully constructed to lend itself to DARTs activities.

Further examples of active-reading resources are provided in appendices 2, 3 and 4. You may wish to try these with your pupils.

In conclusion

- all the activities ensure information processing and selecting rather than just passive reading, copying or the more usual form of note taking;
- active-reading strategies ensure that pupils access text and make sense of it;
- they involve all the pupils so there is less off-task activity;
- they ensure a variety of learning styles: sort activities are good for kinaesthetic learners; mind-mapping and diagrammatic responses help the visual learner; aural learners are helped by the talk;
- groups can be organised carefully for purpose, such as mixed ability, gender groupings, less-able pupils with more able.

In doing any of these activities with your pupils, you will need to decide:

- which group you will use it with;
- what type of active reading you want to promote and why;
- whether you need to produce any different resources;
- how you will evaluate effectiveness.

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Writing in science

Aims

- To explore the purpose of writing in science and the implications for teaching.
- To exemplify the structures and types of writing that are important in science.
- To consider ways in which pupils' writing in science can be improved.

Pupils' writing skills at Key Stage 2 are steadily improving although at a slower rate than reading. Many science teachers have been paying more attention to writing in science recently because they recognise that Key Stage 3 science requires pupils to use language precisely. This section will explore the purposes of writing in science, what you should expect of pupils and how you can best support them.

Think about how often you ask pupils to write in science at Key Stage 3. Think about the lessons for one Year 7, Year 8 or Year 9 group over the last week.

- What proportion of time was devoted to writing?
- Were all homeworks written tasks?
- What were the purposes of the writing?

Record your responses in the table below.

Why write in science?

Type of writing	Purposes
e.g. answer to questions	e.g. to check understanding

Research shows that, on average, pupils spend about a third of their time writing in science lessons. This is a considerable investment. It is, therefore, important to make sure that **what** we ask pupils to write helps them to learn science.

(Newton, Driver and Osbourne conducted this research in 1999. Davies and Green quoted similar findings in their book *Reading for learning in the sciences*, published in 1984.)

Compare your responses with those of a group of teachers printed below.

Purposes for writing in science

Examples of types of writing	**Possible purposes**
Answers to questions	■ To check understanding ■ To provide a task for homework
Plan for an investigation	■ To learn how to make decisions about how to collect evidence that is valid and reliable ■ To learn how to set out a procedure ■ To assess planning skills
Record of observations or measurements	■ To learn how to assemble evidence in such a way that it can be interpreted easily ■ To assess recording skills
Conclusion to an experiment	■ To learn how to analyse evidence, construct arguments and develop reasoning skills ■ To assess understanding
Evaluation of an experiment	■ To learn how to evaluate procedures ■ To check procedural understanding, e.g. of the need for a fair test or the reliability of measurements
Note making	■ Aid for revision
Explanation	■ To help pupils to make links between ideas and apply their understanding ■ To probe understanding and reveal misconceptions ■ To help pupils to explain their thinking
Argument	■ To analyse and present conflicting views ■ To develop the skills for considering evidence ■ To engage pupils ■ To allow pupils to demonstrate achievement ■ To capture creative thought
Experimental write-up	■ To show how scientists report findings ■ To make sure pupils have completed the work
Worksheet completion	■ To check understanding ■ To provide a task for homework

The list above does not differentiate between those written tasks which contribute more to pupils' learning in science and those which are less effective at this. However, the list below indicates ways in which writing can be supportive of pupils' learning in science.

Supporting pupils in writing in science

Writing will support pupils' learning in science when:	Comments
■ the purpose is clear	Pupils can find writing in science a chore because they do not see the point. You should be clear about why setting a writing task will help pupils to develop their understanding of science further.
■ the writing helps pupils organise	Some types of writing help pupils to learn by organising their scientific thinking (e.g. writing an explanation on how digestion takes place, or constructing an argument about what the evidence is for a spherical Earth). Currently these happen infrequently. More opportunities should be provided to do this.
■ pupils are challenged to think and make decisions about their writing	Some types of writing do little to challenge and merely let pupils mark time (e.g. copying notes). Research has shown that learning does not take place if pupils merely copy. The rule of thumb is: ■ if the writing task does not require pupils to make decisions – don't do it.
■ pupils are asked to write for a variety of purposes and audiences	Giving pupils little variety in their writing can be demotivating (e.g. answering the questions in the textbook or writing up the experiment).
■ the writing is well chosen to support the point of the lesson	Think carefully how writing can help pupils to learn the science. If you are teaching pupils how to record observations in a particular format, don't waste time asking them to write up the whole experiment. This distracts pupils from the point. This is a case where less means more.
■ pupils are clear about the characteristics of the writing expected	To write well, pupils need to understand the characteristics of different text-types. For example, they need to be taught how to structure a conclusion, how to frame an argument when considering ideas and evidence, and how to construct an explanation. There are differences between explaining how and explaining why. Pupils need models for their writing. Just as a picture paints a thousand words, so examples achieve the same.

Reflection
- What are the implications?
- How well do your writing tasks support pupils' learning in science?

It is worth noting that:

- The write-up of complete experiments is not obligatory and there is no 'correct way', such as using the third person and the past tense. Remember that the type of writing should support the learning objective.
- At Key Stage 3, there is no requirement to write about or do investigations in the manner required by an awarding body for GCSE. Key Stage 3 is far more flexible and you should use this opportunity to continue to teach investigative skills explicitly. The type of writing you use should support this.
- Pupils have been writing up their investigative work for 6 years in primary schools so have many skills in this area already.
- Copying notes for 'revision' is not a very effective use of time; copying does not promote learning. If the information is important you can provide it in a different way. Some schools provide pupils with a cheap revision book at the start of Year 8 or Year 9 as their 'home' textbook and encourage them to personalise it and annotate it. This reserves the exercise book for learning tasks.
- Some types of writing are more effective in aiding learning. This type of writing should be encouraged.

You may find it useful to trace the article on writing in science by R. Staples and R. Hesledon in *School Science Review*, 83 (303), December 2001, pp. 35–46.

Developing a strategy to support pupils' writing in science

There are many types of non-fiction writing that the curriculum demands of pupils. *Literacy across the curriculum* identifies the main types of non-fiction writing. These are shown in the middle column of the table on the next page. The table shows how these match the main types of writing in science.

Types of writing

Science writing	**Type of non-fiction writing**	**Examples**
Explaining how Explaining why	Explanation	How digestion takes place Why some metals rust
Experimental report	Recount (report)	The refraction of light through a prism
Observational account		What happens as a candle burns
Description	Information	A description of different types of rocks or soils
Persuasion	Persuasion	Using facts to persuade someone to give up smoking
Argument	Analysis	Considering evidence – the possible causes of global warming
Planning an experiment	Analysis	Consider the factors affecting the rate of dissolving
Drawing a conclusion	Analysis	Analysis of results of an experiment on the factors affecting the strength of an electromagnet
Evaluation	Evaluation	Considering improvements to an experiment
Description	Discursive	The possible effects of burning fossil fuels and how to minimise these

Each of these categories (types of writing) has its own conventions at word, sentence and text level. Whichever text-type you are dealing with, there is one common strategy that you can use to teach pupils. This is set out on the next page.

A strategy for supporting writing in science

1. Establish clear aims
2. Provide example(s)
3. Explore the features of the text
4. Define the conventions
5. Demonstrate how it is written
6. Compose together
7. Scaffold the first attempts
8. Develop independent writing
9. Draw out the key learning
10. Review

From Literacy across the curriculum (DfEE 0235/2001), *Key Stage 3 National Strategy.*

You will have used writing frames (prompt sheets) to scaffold pupils' attempts to plan their investigations or to write up an investigation. You may have used other writing frames. Writing frames can provide good support but they should not be seen as the solution. You should aim to help pupils to write independently.

Pupils will make more rapid progress if you use all the strategies suggested here.

Watch video clip 2 which will illustrate part of this sequence in helping pupils to develop better skills when drawing conclusions.

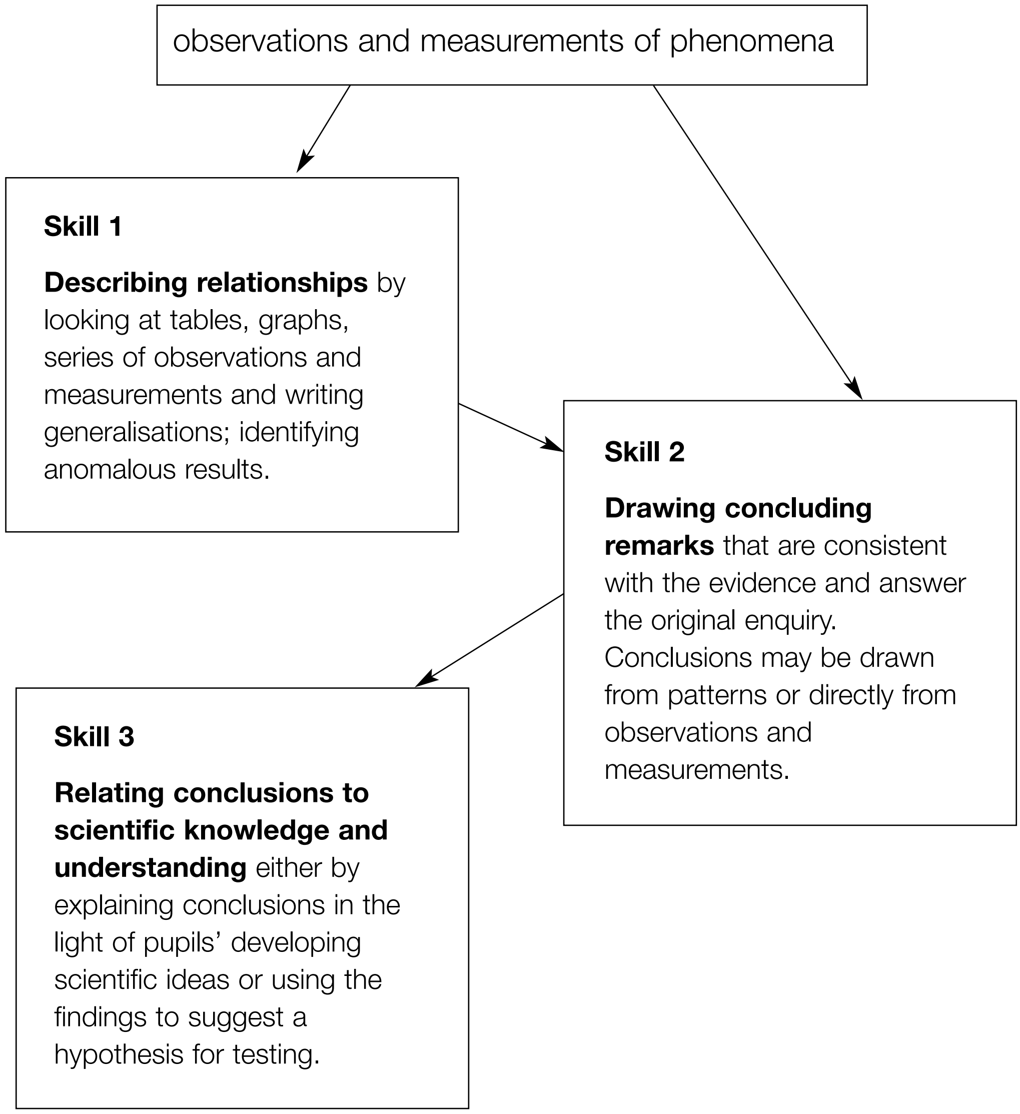
Make a note of the strategies which the teacher uses to help pupils to produce a good written conclusion.

To put this video clip into context, it shows a Year 9 class. They are of mixed ability. The teacher is helping them to improve their writing of conclusions. The final conclusions written by each group are contained in Appendix 5 if you wish to refer to them.

Can you identify elements of the 10-point strategy listed above?

The structure of a conclusion will vary slightly depending on the context, but will follow the main stages as illustrated with three different skills.

Considering evidence



- Pupils need to be taught to describe relationships , using comparative adjectives, when appropriate, to make generalisations.
- Pupils need to be taught to draw concluding remarks that relate back to the enquiry question and are consistent with the evidence. They may need to relate their conclusion to a prediction made.
- Pupils need to be taught how to use their scientific knowledge and understanding to support their conclusions or suggest further ideas to test.

The table on the next page shows the main features of the text in the form of a teacher guidance sheet. The 'language features' column will help you to identify those points that need to be made to pupils.

Teacher guidance on writing conclusions

Text-type	Purpose	Language features
Conclusion **Examples** ■ *What affects the strength of an electromagnet?* • *How are plants adapted to suit their environment?*	■ To present an analysis and interpretation that is consistent with the evidence.	**Text** Generally has three parts: ■ One section describes any patterns in the results as generalisations, e.g. *the larger the number of coils the stronger the electromagnet. Also the larger the current…* ■ Another summarises these as a concluding remark which relates directly back to the enquiry question, e.g. *the factors that affect the strength of an electromagnet are…* ■ In the third section, attempts are made to explain the remark in terms of scientific understanding or relate back to any prediction made, e.g. *the reasons for this are that when electricity flows through a wire it produces a magnetic field… I predicted that…* It may suggest further ideas to test. **Sentence** ■ Active voice, often first person. ■ Connectives help to describe patterns using comparative adjectives, e.g. *longer, hotter, heavier*. ■ Connectives used to establish cause and effect, e.g. *because, since, therefore, as a result…* Also relate to evidence, e.g. *this shows that, I know this because…* **Word** ■ Process words and concept words dominate.

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Notice the text-level, sentence-level and word-level comments. Pupils make good progress when language is promoted at these three levels. Refer back to the introductory section and the word-level work in section 2. Remind yourself of naming, process and concept words.

Remember that key words were identified at three categories of difficulty: names, processes and concepts. Some process words are more difficult to understand because the process cannot easily be seen or there is an insufficient grasp of the 'big picture', such as photosynthesis or digestion. Asking pupils to write an explanation of how these take place aids their understanding because they will have to use their imagination to explain something they cannot see and put all the pieces together for themselves in a logical sequence. Explaining why will bring into sharp relief the category of words we call conceptual. These concept words are abstract and often have dual meanings.

Handout 3.1 (Connectives as signposts) from *Literacy across the curriculum* is a helpful summary of connectives.

Putting the strategy for supporting writing into practice

The six text-types that are important in science at Key Stage 3 are:

- Explanation – how
- Explanation – why
- Argument
- Conclusion
- Evaluation
- Plan

These types of non-fiction writing help pupils to organise their scientific thinking. They are important in science at Key Stage 3 because:

- ***constructing explanations*** (of how and why) helps pupils to describe and explain processes and link ideas together using concepts;
- ***constructing arguments*** is a skill which pupils need for exploring ideas and evidence;
- ***drawing conclusions***, ***writing evaluations*** and ***constructing plans*** are skills needed for scientific enquiry.

These types of writing have conventions that pupils need to be taught explicitly.

Text-type	Purpose in science
Explanation (of how and why)	***Explanation*** helps pupils to develop their scientific knowledge and understanding and reveals misconceptions across all attainment targets. ***Explaining how*** helps pupils to understand processes better by describing them, e.g. how digestion takes place, how light travels through materials. ***Explaining why*** helps pupils to link ideas together. They use concepts, abstract scientific ideas and models to explain phenomena, e.g. explain why diffusion occurs using the particle model; or why enzymes are needed for digestion.
Argument	***Constructing arguments*** is a skill pupils need in order to explore ideas and evidence. It helps pupils to explore and see the significance of evidence. Questions relating to ideas and evidence are new to the Key Stage 3 tests.
Conclusion	***Drawing conclusions***, ***writing evaluations*** and ***constructing plans*** are skills needed for scientific enquiry. Drawing conclusions helps pupils to describe patterns, generalise and use scientific understanding to explain observations.
Evaluation	***Writing evaluations*** helps pupils to consider the reliability and validity of the evidence collected and suggest improvements.
Plan	***Constructing plans*** helps pupils to apply their developing understanding. Pupils use their scientific ideas to make predictions, and to decide what evidence should be collected and how. Constructing plans helps pupils to organise their thinking by describing safe procedures for collecting the evidence.

Use the information in the table above as the basis for a discussion within your department.

- What balance do you give to these types of writing across each year group?
- Are there sufficient opportunities for pupils to develop their understanding of science through writing?

There are other types of writing that can be used to help pupils to understand science, such as storytelling (for example, the story of an oxygen molecule passing through the body) or poetry. Such creative writing has its place, but we must make sure that the expected ways of communicating science are fully developed.

The table overleaf indicates the progress in each category that pupils should make in their writing in science, across the three years of Key Stage 3, as they move from dependent to independent writers.

From dependent	To independent
Explanations of how: ■ lack organisation and sequence ■ use naming words occasionally **Explanations of why:** ■ do not link cause and effect ■ demonstrate no clear understanding of how the key ideas at Key Stage 3 can be used to explain phenomena	■ have well-sequenced explanations ■ use naming words and process words correctly or incorrectly ■ have good links made through the use of suitable connectives, e.g. *because, so* and *therefore* ■ use the key ideas in science at Key Stage 3 well to explain phenomena ■ use process and concept words effectively
Arguments: ■ lack structure ■ express opinion ■ pay little attention to the evidence	■ have a clear structure ■ present a reasoned approach ■ state clearly what evidence there is and how it supports a point of view ■ state where there is evidence to the contrary
Conclusions: ■ restate the results ■ do not make generalisations ■ do not answer the original enquiry questions ■ do not attempt to explain observations using scientific ideas	■ have a clear structure ■ describe patterns ■ make generalisations using connectives, e.g. *as… so…* ■ relate directly to the enquiry question ■ make attempts to explain observations using scientific knowledge ■ show how the evidence supports any prediction being made
Evaluations: ■ have no logical structure ■ do not explore ideas of reliability or validity ■ state how to improve an experiment without explaining how this will improve the validity or reliability of the evidence	■ are well structured ■ justify improvements in procedures by explaining how these will improve the validity or reliability of the evidence collected
Plans: ■ are disorganised ■ lack purpose and do not set out adequate procedures ■ make predictions without justification	■ state clearly what is to be investigated, what evidence needs to be collected and a clear procedure for doing this ■ may state a prediction, and if so, will provide justification for this

Several appendices are available on the CD-ROM to support improvement in writing by your pupils.

Appendix

5 Writing conclusions
6 Writing explanations
7 Constructing arguments
8 Writing evaluations
9 Writing plans

In order to use the appendices you need to decide:

- which group you will be working with;
- what type of writing you want to promote and why;
- whether you need to produce any different resources;
- how you will evaluate its effectiveness.

In using them with your own pupils, you may have to modify the materials to suit their age and abilities.

Talk in science

Aims

- To explore the purpose of speaking and listening in science and the implications for teaching.
- To exemplify the techniques that enable pupils to engage fully in discussion:
  - how to organise whole-class discussions;
  - how to organise small-group discussions.

Research shows that pupils spend about a third of their time listening in science lessons but very little of their time in discussion with each other or with their teacher.

Pupils need opportunities to describe, explain and justify their understanding of scientific ideas and to use precise scientific vocabulary. Speaking scientific terms aloud helps pupils to spell correctly. Pupils need opportunities to 'think aloud', to discuss and explore ideas with each other. Where talk is modelled well, it helps pupil to write – it gives them a voice into their writing.

The purpose of speaking and listening

Why talk?

- We talk to make sense of the world and try to exert some control over it.
- We talk in order to find out what others know, and to share what we know.
- We talk in order to develop our thinking.
- We use talk to entertain, to tell stories, to create imaginative worlds.
- We use talk to evaluate our work, achievements and learning.
- We use talk to demonstrate and to describe what we know or have found out.

From Teaching talking and learning in Key Stage 3 *(National Oracy Project, 1991).*

Discussion in science

Consult the programme of study for science at Key Stage 3 in your copy of the National Curriculum.

- Where will discussion **particularly** aid the development of understanding in science and why?
- Highlight your copy or make a list.

Compare your reponse with the points overleaf, raised by a group of science teachers.

Aspects	Comments
1 Ideas and evidence	Talking about ideas enables pupils to 'think aloud' and explore issues with each other. Discussing the evidence to support a particular idea helps pupils to develop an understanding of evidence, e.g. talking about health provides pupils with opportunities to express views and separate fact from opinion.
2 Investigative skills	Talking about what evidence should be collected and how it should be collected helps pupils to improve their planning skills. Practising with others how to describe patterns in graphs, and discussing how results provide evidence for an idea, helps pupils to draw conclusions.
3 Concepts	Discussion about key ideas in science helps pupils to link ideas together. Pupils need opportunities to talk about concepts, to explore their own understanding through talk with others and to attempt explanations using these concepts.
e.g. particles	Talking about how a particle model can explain how substances dissolve or why mass is conserved in chemical reactions can help to develop pupils' understanding and reveal misconceptions.
e.g. energy	Talking about energy can help to develop science-specific language and pupils' understanding of how ideas about energy can be used to explain a range of phenomena and reveal misconceptions.

The programme of study for science states that pupils should be taught to communicate scientific ideas using scientific language, and to provide scientific explanations based on evidence (see Breadth of study section).

Note the following points:

- There are many opportunities to use talk in science.
- Discussing ideas does help pupils to develop their understanding of science.
- Discussion does, however, need to be organised to be effective. This will be considered later in this session.

Departmental discussion focus

Progression in speaking and listening

From:	**To:**
simple answers to closed questions	complex answers to open questions in which pupils explain their thinking
discussion in pairs or small groups	speaking to a larger audience
listening to or giving a narrative account	listening to or giving an analytical account
listening to or using simple vocabulary	using specialised vocabulary

Adapted from SCAA 1997; cited in Language and literacy in science education, *by Wellington and Osborne (Open University Press, 2001)*

Progression in speaking and listening

We should expect pupils to make progress in talk. You may like to consider the discussion points below, either with regard to your own lessons or as points for departmental discussion.

From:	**To:**
simple answers to closed questions	complex answers to open questions in which pupils explain their thinking
discussion in pairs or small groups	speaking to a larger audience
listening to or giving a narrative account	listening to or giving an analytical account
listening to or using simple vocabulary	using specialised vocabulary

Adapted from SCAA 1997; cited in Language and literacy in science education, *by Wellington and Osborne (Open University Press, 2001)*

Discussion

- How does the way talk is organised change across Years 7 to 9 to make sure pupils make progress?
- How does the teaching make sure that pupils recall and use the scientific language they developed in their primary schools?

Organising whole-class discussions

To be effective, whole-class discussions need to:

- be planned;
- have clear, explicit and useful outcomes;
- have precise time limits;
- engage all pupils;
- have a clear concrete focus (i.e. a model or analogy) when abstract concepts are involved;
- lead to some other task such as writing or practical work.

The following points may help in structuring effective discussion:

- Class discussions do not work well when one or more of these features is not present.
- Talk sessions should be well timed. Whole-class discussions that are too long will cause many pupils to lose interest. Aim for no more than 10–15 minutes.
- There should be an appropriate balance between speaking and listening.
- Pupils should not be expected to talk about abstract ideas without reference to a model or an analogy.
- Pupils should be prepared by giving them the vocabulary they need beforehand.

Discussion is often used at the beginnings and ends of science lessons. Oral starters to lessons can engage and motivate pupils and develop their scientific language very effectively.

You may wish to watch video clip 1 again, where pupils were encouraged to develop their scientific understanding through talk at the start of a lesson using a card loop game.

Reflection

- How do you manage whole-class discussions in your own classroom?
- What were the key characteristics of the successful discussions?
- How do you know that the discussion has been successful?

Case study

An example of a successful whole-class discussion involved an oral starter on elements. The teacher asked the class if they knew the names of any chemical elements ('no – don't tell me!') and encouraged pupils first to think for themselves (noting the names of elements on a piece of paper), then to discuss ideas in a pair, then to discuss ideas further in a small group (about four).The teacher then took feedback from each group in turn to build up a list of elements that the group knew. This was brought to a conclusion by summarising what the group had found and offering pupils the opportunity for brief further comment and discussion.

It was successful because the teacher:

- provided clear time limits, e.g. 'On your own you have 30 seconds to think of as many elements as possible';
- made sure that, as a pair or small group, pupils had to make a decision, e.g. 'As a pair, come up with an agreed list of elements. Those you are doubtful about leave to one side';
- made sure that pupils moved deliberately from one to two to four and even to eight before giving feedback;
- organised the furniture so that pupils faced each other when discussing ideas, and could move easily to fours and then to eights.

It is helpful if thought is given to the arrangement of furniture so that it promotes group discussion – sitting pupils in a line is not helpful.

When using teacher questioning to initiate pupil talk, pupils need to be given 'think time' or 'wait time' before they are asked to respond. This can be achieved in a variety of ways, e.g. thinking on their own or discussing in pairs before feeding back.

Whatever the purpose of the discussion, some visual focus helps stimulate debate, e.g. a rock when discussing its features.

Some further examples of oral starters for science lessons are given in Appendix 10.

Organising small-group discussions

Discussion is particularly important for exploring ideas and evidence in science and for developing an understanding of scientific concepts.

Sustained discussion is often better developed at Key Stage 3 through organised small-group discussions, such as snowballs. Predetermined outcomes and time limits for each stage of the discussion help pupils to move on effectively. Encouraging pupils to work together, in other than only friendship groups, will widen their learning experience and can develop confidence. The furniture needs to be organised so that pupils can face each other and move easily if required. There is a wide variety of ways of organising small-group discussion. Eight of these are shown below.

Pair talk

This is easy to organise even in cramped classrooms. It is also ideal to promote high levels of participation and to ensure that the discussions are highly focused, especially if allied to tight deadlines. It can be used in the early stages of learning for pupils to recall work from a previous lesson, generate questions, work together to plan a piece of writing or take turns to tell a story.

Pairs can also be used to promote 'response partners' during the drafting process, and to work as reading partners with an unfamiliar text. It is also ideal for quick-fire reflection and review, and for rehearsal of ideas before presenting them to the whole class.

Pairs to fours

Pupils work together in pairs – possibly friendship, possibly boy/girl, etc. Each pair then joins up with another pair to explain and compare ideas.

Listening triads

Pupils work in groups of three. Each pupil takes on the role of either talker, questioner or recorder. The talker explains something, or comments on an issue, or expresses opinions. The questioner prompts and seeks clarification. The recorder makes notes and gives a report at the end of the conversation. Another time roles are changed.

Envoys

Once groups have carried out a task, one person from each group is selected as an 'envoy' and moves to a new group to explain and summarise, and to find out what the new group thought, decided or achieved. The envoy then returns to the original group and feeds back. This is an effective way of avoiding tedious and repetitive 'reporting back' sessions. It also puts a 'press' on the envoy's use of language and creates groups of active listeners.

Snowball

Individuals explore an issue briefly; then pairs discuss the issue or suggest ideas quickly; then double up to fours and continue the process into groups of eight. This allows for comparison of ideas, or to sort out the best, or to agree on a course of action. Finally, the whole class is drawn together and a spokesperson for each group of eight feeds back ideas. This is a useful strategy to promote more public discussion and debate and works well in science.

Rainbow groups

This is a way of ensuring that pupils are regrouped and learn to work with a range of others. After small groups have discussed together, pupils are given a number or colour. Pupils with the same number or colour join up, making groups comprising representatives of each original group. In their new group, pupils take turns to report back on their group's work and perhaps begin to work on a new, combined task.

Jigsaw

A topic is divided into sections. In 'home' groups of four or five, pupils allocate a section each, and then regroup into 'expert' groups. In these groups experts work together on their chosen area, then return to original 'home' groups to report back on their area of expertise. The 'home' group is then set a task that requires the pupils to use the different areas of 'expertise' for a joint outcome.

This strategy requires advance planning, but is a very effective speaking and listening strategy because it ensures the participation of all pupils.

Spokesperson

Each group appoints a spokesperson. The risks of repetition can be avoided if:

- one group gives a full feedback, and others offer additional points only if they have not been covered;
- each group is asked in turn to offer one new point until every group 'passes';
- groups are asked to summarise their findings on A3 sheets which are then displayed – the class is invited to compare and comment on them.

> When trying one of these methods of organising group discussion for the first time, it is best to plan your approach. Think about:
>
> - what the outcome will be;
> - how you will start the discussion (question, stimulus etc.);
> - what the time targets will be for each stage;
> - what extra resources you will need.

Some examples of these methods include:

Pair talk: To identify three key points from the previous lesson's work on acids, alkalis and indicators. Each pair has two minutes to agree the three key points before feeding back.

Envoys: Following an investigation into the factors affecting the size of current in a series circuit, envoys are sent to share their initial conclusions together with the supporting evidence with another group. Pupils had explored the effect of different aspects, e.g. number of batteries, length of wire, and number of components in the circuit. They worked in pairs and compiled the final results as a team of four. One of the four acts as an envoy.

Snowball: To compile a list of evidence to support the idea that light travels in straight lines. As an individual, pupils have one minute to set down their ideas; as a pair, pupils have two minutes to compile an agreed list; as a four, pupils have five minutes to sort their evidence in order of priority (strongest evidence at the top) and finally, as an eight, they have five minutes to agree their priority list before feeding back.

If you feel less confident about managing small-group work, try the snowball first. It works very well.

Exploring understanding of concepts and understanding of evidence provides fertile ground for discussion.

Although this section focuses on starters, plenaries also provide an opportunity for purposeful talk in science. The DfES publication *Making good use of the plenary* (DfES 0192/2002) gives useful guidance on how they can be developed. Materials to support starters and plenaries in science have also been supplied to any of your colleagues who attended the strategy training unit on effective lessons in science.

To conclude, there are a number of ideas presented in these five sections which can form the basis of follow-up work within your department. You could apply some of these in your own classroom, others might be the focus for departmental discussion or agreed actions.

The appendices provide a rich resource to support departmental developments, as does the *Literacy across the curriculum* (DfEE 0235/2001) training file which is in your school.

Literacy in science

Main messages from the booklet

There are four important aspects to literacy in science – words, reading, writing and talk.

Words in science

Science is rich in specialised words, many of which have an everyday meaning as well as a scientific meaning. Improving pupils' spelling and understanding of these words will improve their understanding of science.

The use of 'word roots' helps to develop an understanding of the scientific meaning of the word.

The taxonomy of words (words that describe objects, processes and concepts) can be used to identify those words which are 'key' to the communication of ideas and understanding.

Identify key words with care, matching your list to the needs of your pupils.

Explore new words together, consider their structure, word roots and correct meaning.

Provide opportunities for pupils to practise using key words during class discussion or during question-and-answer sessions.

Review words regularly (little and often).

Reading in science

Reading in science should be a demanding activity.

Supporting pupils in reading and offering them ways to access text is better than reducing the amount and quality of their reading.

Tell pupils how to read (continuous reading, close reading, skimming, scanning) and why.

Make use of a range of DARTs (directed activities related to text) where pupils are actively engaged with the text and are clear about why they are reading and what they should gain from the experience.

Develop the use of a range of texts related to particular topics and purposes.

Shared reading is a good way to introduce new or more difficult texts, especially those that contain a lot of new, specialised vocabulary.

Writing in science

Research shows that, on average, pupils spend about a third of their time writing in science lessons. It is important to ensure that what we ask pupils to write helps them to learn science.

Writing supports learning in science when:

- the purpose is clear;
- pupils are challenged to think and make decisions about their writing;
- the writing helps pupils to organise their thinking;
- pupils are asked to write for a variety of purposes and audiences;
- the writing is well chosen and supports the objective of the lesson.

Copying notes for ‘revision’ is not a very effective use of time; copying does not promote learning and understanding.

There are six main types of writing (text-types) which are important in science. These can all be taught using the strategy for teaching writing outlined in section 2 of the *Literacy across the curriculum* folder.

Talk in science

Pupils need opportunities to describe, explain and justify their understanding in science lessons. They need opportunities to ‘think aloud’, discussing and exploring ideas with each other.

Where talk is modelled well, it helps pupils to write – it gives them a voice into their writing.

Discussion needs to be organised to be effective. It should be planned and have clear, explicit and useful outcomes. It should engage all pupils and lead to some other task, such as writing or practical work.

Discussion is often used at the beginnings and ends of lessons. Oral starters can engage and motivate pupils and develop their scientific language very effectively.

We should expect pupils to make progress with their science talk.

Small-group discussion can take many forms and encourages pupils to work together in different groups to reach predetermined outcomes. This widens their learning experience and helps to develop their confidence.

Implications for the department

The priority which the department has given to developing literacy in science will be reflected in the action points identified in the departmental action plan. A number of actions which could be taken by individual teachers, or the department as a whole, are listed below.

For the department

- Review the scheme of work for science to ensure that appropriate opportunities are provided for reading, writing, talk and the introduction and use of key words.
- Check whether these opportunities allow for progression as suggested in the unit.
- Use the discussion points to promote debate about the purposes of writing in science.
- Consider how you will evaluate the effectiveness of any changes you make.

For individual teachers

Consider a future topic:

- Review the key word list in the light of the taxonomy provided (names, processes, concepts).
- Select one of the suggested techniques (from words, reading, writing and/or talk) and integrate it into your teaching of that topic.
- Decide how you will evaluate the effectiveness of the change in teaching.

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Index to appendices (on the CD-ROM only)

Appendix 1

Strategies for developing scientific terminology

1 Words and definitions (card games and flash cards)

These activities are card based and can be quite varied. Loop cards are similar.

Word and definition cards

Two boxes of cards are used for a topic: one contains the words, the other contains the definitions. Pupils are asked to match the words with their definitions. Alternatively, the words and their definitions could be stored on computer and pupils could cut and paste the correct pairs.

Flash cards

In this variation, a whole class is given a set of 'flash cards', for example key words to do with cells (perhaps seven each). The teacher then reads out a definition. Pupils, facing the teacher, hold up the word that they think the teacher is describing. Because all pupils are facing the front, the teacher can easily see which are correct and which are wrong.

Definition dominoes

In this game each card contains two ends (like dominoes). The idea is that pupils can play the game of dominoes using key words and definitions. Cards can be placed next to each other provided the definition matches the key word. Cards can be combinations of 'definition–definition' or 'key word–definition' or 'key word–key word'.

2 'Quickie' quiz

In this activity pupils take a 'five-minute' quiz read out by the teacher. Pupils respond with one-word answers. They exchange papers and check answers. ***Importantly, the questions that the majority of the class answered incorrectly should be repeated in the next test, so that pupils have the chance of success.*** There will need to be a number of alternative tests, to be used as pupils move through a topic. One test per week seems to work well.

Example for cells

1 What is the name given to the fluid found inside a cell?

2 What is the name of the film surrounding cells, which controls what gets in and out?

3 What is the name of the stiff outer coat of a plant cell?

4 What is the oval body that controls cells and contains instructions to make more cells?

5 What is the name of the space found within cells?

6 What is the name of a group of the same type of cells?

7 What is the green body in plant cells that absorbs sunlight?

8 What is the name of the green chemical in plant cells?

9 This type of cell found in plants is long and thin with a large surface area to absorb water and minerals.

10 This type of cell makes antibodies to fight disease.

3 Word-completion exercises

There are a number of word-completion exercises that are often used such as cloze procedure, word searches and key word crosswords. When using these, care should be taken to make sure they are sufficiently challenging to pupils and do not merely become a way of occupying them. The examples below show how the level of challenge can be increased by requiring pupils to explore word roots.

There are some helpful comments about cloze procedures in an article on reading in science, *School Science Review*, 83 (304), March 2002, pp. 51–62.

Word webs

The purpose of this activity would be to point out the patterns in words through attention to word roots and so aid spelling and understanding. Pupils can use rhyming dictionaries to help find suffixes, and dictionaries to help with prefixes. You could provide sheets with starters, for example, the words shown in bold in the example below. Pupils would have to add words they found, such as those in italics. This could be used as a homework activity.

Example

CELLULOSE

Cellar
Cellophane
Cellule
Celluloid
...

So what does cell mean?

Glucose
Sucrose
Fructose
Dextrose
...

So what does -ose mean?

Glyc
Glycerine
...

So what does glyc- mean?

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Word cluster posters

Here words with a common root are displayed together. The common root, often Latin or Greek, is pointed out, and the teacher explains how this makes spelling and remembering the meanings of the words easier. Pupils create their own cluster posters for their science laboratory, for example photosynthesis, photograph, photosensitive, photoreceptor, phototropism.

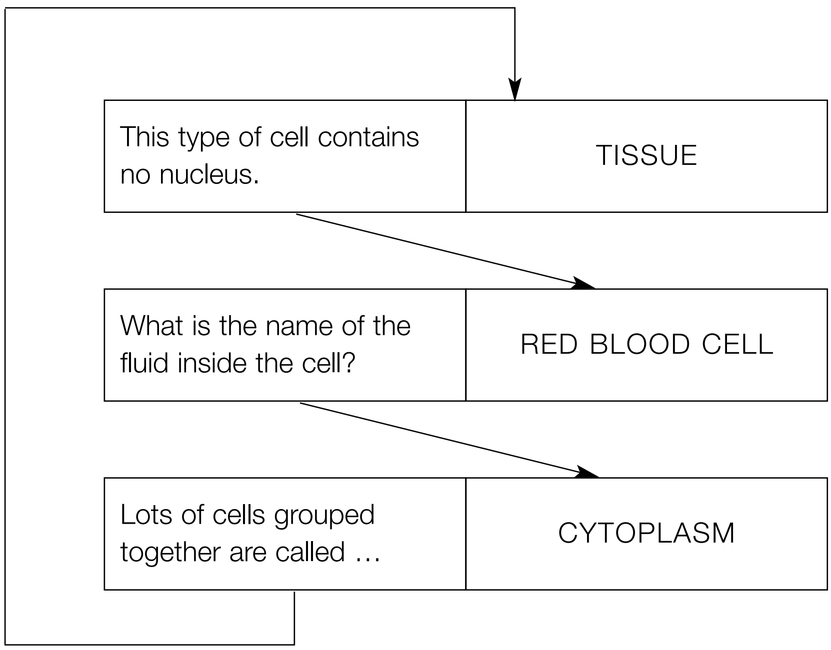
4 A loop card game

This is very effective at helping pupils to learn and remember the **key words**.

Thirty playing cards are prepared with questions on one side and key word answers on the other side. The key word answer on one card relates to a question on a different card. Each pupil is given a card. (More-able pupils might be given two depending on numbers.) One pupil will start the game by asking the question on their card. The rest of the class look at their cards and the correct answer is read out. That pupil then reads out the question on the other side of their card. The game continues until all questions are answered. The game is timed (say four minutes). This can then be repeated over a week until the class can answer in a shorter time, e.g. 90 seconds. This is motivating and generates enthusiasm.

Questions and answers can be printed on labels and stuck onto blank playing cards, which are available from a number of suppliers.

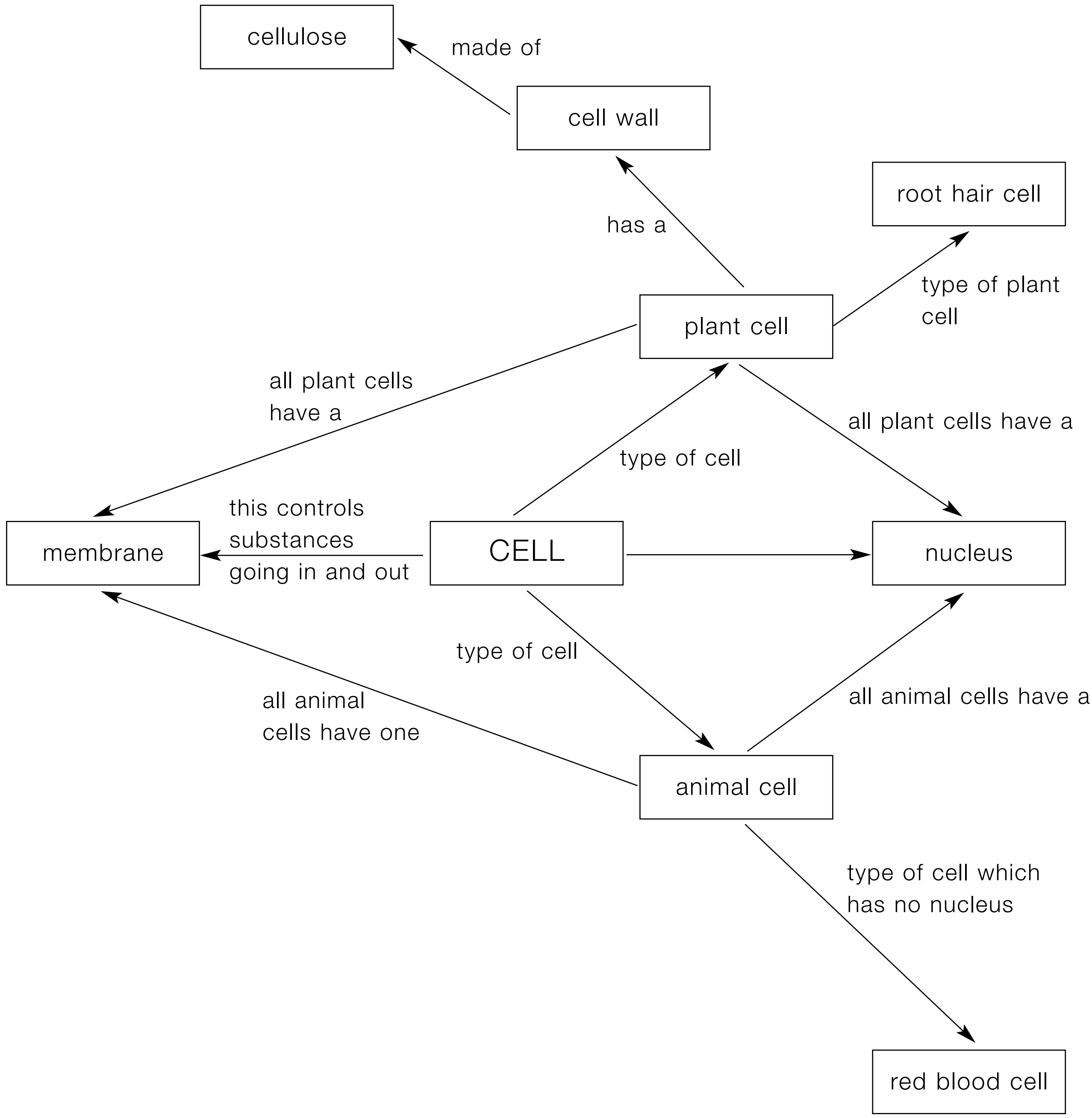
A three-card loop for cells



5 Concept maps

In this activity pupils can be provided with key words on cards and asked to link them together, in a way similar to mind maps. Pupils need to think about organisation (i.e. grouping) and how key words are connected. They place the cards on an A3 sheet, draw the connections and then write on the connections.

For example, part of an outcome might look like:



Appendix 2

Sequencing activity (restructuring)

Slowing down respiration

This page should be printed onto card and guillotined into 14 individual cards.

Pupils are provided with a fragmented paragraph on cards and are asked to sequence the text to re-form the paragraph. Doing this will not only help pupils to develop a better understanding of respiration but also help them to formulate ideas about how to construct a logical argument.

Once picked the apple will continue to ripen, so this process needs slowing down.	An apple is living and each of its cells continues to respire.
This means that they continue to absorb oxygen from the air and give off carbon dioxide.	As each cell respires some of the stored food is converted to energy.
The apple also gives off a gas called ethylene that helps to ripen the fruit.	Controlling the atmosphere in the store can slow down the respiration rate in the apple cells.
A slow-turning fan can keep the air circulating and blow away the ethylene as it is formed.	If you decrease the level of oxygen and increase the level of carbon dioxide then the cell respiration slows.
Some varieties of apple will tolerate high levels of carbon dioxide in the atmosphere.	For instance, Cox apples will tolerate 9% of carbon dioxide.
These varieties can be stored for longer.	Apples such as the Worcester will tolerate less so cannot be stored for long periods.
The apple store is also cooled.	This makes sure that any chemical reactions such as respiration will take place at a slower rate than normal.

Pupils can be asked to think of a title for their reconstructed paragraph.

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Appendix 3

Diagrammatic representation (analysis)

Apple store

In this example of locating information, pupils are asked to convert text to labels.

Draw a box to represent the apple store. Label it with the features that make it a good store in which to keep apples.

Apple store

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Appendix 4.1

Pupil sheet 1

To tell an acid from an alkali

You can group substances according to whether they are acidic, neutral or alkaline. But what does that mean? We all have an idea about what acids are and perhaps even what alkalis are. If you stopped someone in the street and said, ‘What is an acid?’, the chances are they would say it is something that burns you. Lemon juice contains an acid, so does vinegar. These substances do not burn, so this cannot be the whole story. We need a better way to tell what an acid is as well as ways of describing alkalis.

Acids and alkalis only really behave as acids or alkalis when they are in water. In the laboratory you use them diluted in water. Have you ever looked at them closely? They often look the same – colourless transparent liquids. So what are they and how can we tell them apart?

As said before, lemon juice and vinegar both contain acids, so too do sour milk, limes, oranges and apples. Sour apples contain more acid. Does this give you your first clue? All these examples have something in common that is true of all acids. They all taste sour; they have a sharp taste. You would not want to taste acids such as sulphuric acid or nitric acid because these are harmful, even when diluted. When they are concentrated (more acid to less water) they are ***corrosive***. What does this mean?

Corrosive means that the acids react with substances such as metal or skin cells. When this happens you can often see fizzing and things can get quite hot. This heat is a result of the chemical reaction. If concentrated acid is spilt on skin it can cause a burning sensation. So perhaps this is where the idea of ‘burning’ comes from. It is quite wrong, however, to say that acids burn. Burning happens in fires; it is a reaction between things such as fuels and oxygen.

Another property of acids is their ability to react with metals. Diluted acids react with many metals to form solutions and release bubbles of hydrogen gas. Acids also react with some rocks such as limestone. This is because rocks such as limestone contain calcium carbonate. You can see the reaction taking place as a ‘fizz’. The fizz is carbon dioxide gas being released.

Did you know that normal rain water is slightly acidic because it contains dissolved carbon dioxide? Carbon dioxide in water is called carbonic acid, and of course acids attack limestone rocks … So the cycle continues.

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Appendix 4.2

Pupil sheet 2

To tell an acid from an alkali

Alkalis are quite different from acids but they can also be corrosive. Sodium hydroxide and ammonium hydroxide are two common alkalis. If you spilt alkali on your skin it would feel soapy, because the alkali sets about dissolving the fat on and in the skin (another chemical reaction). This makes alkalis quite useful as cleaners. Oven cleaner sprays often contain sodium hydroxide. Alkalis are also used in the manufacture of soaps. Another useful alkali is potassium hydroxide which is sometimes used in the production of fertilisers.

Alkalis are therefore also corrosive. Like acids, they can react with metals and skin but they react in different ways. Alkalis can be just as harmful as acids, and they are even more harmful to eyes than acids. Indeed, our bodies are designed to cope with acids better than with alkalis. Did you know that the sweat from our skin is slightly acidic and that our stomachs contain hydrochloric acid to help with the digestion of food?

So how can we tell the difference between acids and alkalis? It would not be sensible to rely on taste or on a soapy feel to the skin. Luckily there is a better way. Extracts from some plants can be used to make indicators. These indicators often go red or yellow in acidic solutions and blue or violet in alkaline solutions. Litmus is an example which is made from a lichen. It turns red in acidic solutions and blue in alkaline solutions. You can also make your own indicator from red cabbage. Universal indicator is commonly used in the science laboratory. It is made from a mixture of compounds and will turn red, orange or yellow according to the strength of the acidic solution, red indicating the strongest acidic solution.

Even though acids and alkalis are both harmful, when you mix them together in the right proportions you can end up with a neutral substance that is no longer corrosive and is less harmful. The chemical reaction that occurs between acids and alkalis is called neutralisation. The resulting neutral solution will turn a universal indicator green. So we have a way to tell an acidic solution from an alkaline one, and from a neutral one, using indicators.

A final thought – have you noticed anything about the naming of acids and alkalis? Look at the names above. Can you spot a pattern? Can you tell an acid from an alkali by the way it is spelt?

Appendix 4.3

Teacher guidance sheet

To tell an acid from an alkali

Suggested activity

Ask pupils to work in pairs and read either the article on Appendix 4.1 or the one on Appendix 4.2. They should then use an A3 sheet of paper to summarise what the article says about acids and alkalis. They should start by putting the words 'acid' and 'alkali' in the middle of the paper. Ask pupils to then produce either a concept map or a mind map with information from the article.

Display the cognitive maps and discuss similarities and differences with pupils. Match this information to the text.

This is likely to be an effective learning activity because:

- pupils have shared the work so have refined and clarified ideas as they work;
- they have supported each other in the activity, hence they are not exposed;
- they have begun to make links between concepts;
- the exercise permits the teacher to assess the level of understanding;
- the final A3 sheets can be displayed to support further learning through the topic;
- the map can readily be used as a process for the start of another text-type, such as a talk;
- the concept mapping ensures a variety of learning styles other than straightforward note-making.

Next step

Use the same text with a different group and try one of the other suggested activities from the active reading and shared reading sections.

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Appendix 5.1

Pupils' work: What makes a good conclusion?

Commentary

This Appendix contains the written conclusions provided by each group on flipcharts in the Year 9 video clip *Writing conclusions*. They have been typed, but contain original spellings, phrases and paragraphing.

Group 1

The cooler the water the longer the salt takes to dissolve. The hotter the water the faster the salt dissolves.

We conclude that the greater the termpurature, the faster the salt dissolves.

When the water heats up the water particles move faster. This ables the salt to dissolve quicker. So this means that the cooler the temerature of the water the slower the water particles move around so they don't collide as much. The warmer the water the faster the water particles move so they collide into the salt particles more often dissolving the salt faster.

Group 2

How does the temperature effect solubility of SALT?

We found out the hotter the water, the quicker the salt dissolved and the cooler the water, the longer it took the salt to dissolve.

The cooler the water particals, the slower the salt particals move. The hotter the water particals, the faster the salt particals move.

The heat of the water effects how fast or slow the salt particals collide and dissolve.

Group 3

How does temperature effect the solubility of salt

The graph shows that the cooler the temperature the longer it takes for the salt to dissolve. The higher the temperature the shorter amount of time is taken.

From this we conclude that the higher the temperature the less time it takes to dissolve.

When the water is hotter the particles move faster so the salt dissolves quicker. When the water is cooler the particles move slower so the salt dissolves slower.

Group 4

HOW DOES THE TEMPERATURE AFFECT THE SPEED OF WHICH SALT DISSOLVED?

In this experiment we found out that the cooler the water the more time it took the salt to dissolve, the warmer the water the less time it took the salt to dissolve.

We conclude that the warmer the water the quicker the salt dissolves.

When the water is cool the particles move slowly and when the water is warm the water particles move faster and when they bump into the salt, the salt dissolves making a solution.

Appendix 5.2

Pupil sheet A

Experiment: What happens when acid is put on rock?

When pupils were investigating rocks they were asked to find out what happened when dilute acids were placed on the minerals that made up the rocks. Here is a set of their results.

Results

Mineral salt	Acid added	Observation
Calcium sulphate	Hydrochloric acid	No reaction seen
Sodium silicate	Sulphuric acid	No reaction seen
Calcium carbonate	Hydrochloric acid	Fizzes a lot, bubbles and gas
Iron chloride	Nitric acid	No reaction seen
Sodium carbonate	Sulphuric acid	Fizzing, bubbles
Aluminium sulphate	Hydrochloric acid	No apparent reaction
Copper sulphide	Hydrochloric acid	No reaction seen
Sodium sulphate	Sulphuric acid	No reaction seen
Copper carbonate	Sulphuric acid	Fizzing, bubbles, blue colour seen
Iron sulphate	Nitric acid	No reaction seen
Zinc carbonate	Nitric acid	Fizzing, bubbles seen
Iron carbonate	Hydrochloric acid	Fizzing, bubbles seen

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Appendix 5.3

Pupil sheet B: Examples of conclusions

Example 1

My results show me that some rocks fizz and some do not when acid is added. Hydrochloric acid made calcium carbonate fizz, sulphuric acid made sodium carbonate fizz and copper carbonate made hydrochloric acid fizz. Fizzing also happened between zinc carbonate and nitric acid and iron carbonate and hydrochloric acid. None of the other rocks fizzed. The reason for this is that there is a reaction between some types of minerals that might be in rocks and acids. You could use this as a test for some minerals, but you could not tell which is which. The bubbles mean that a gas is made in the reaction. The gases I know about are hydrogen, oxygen and carbon dioxide, it could be one of these, but I would need to test them.

Example 2

My results show me that fizzing only occurs with those minerals that contain carbonate. The results also show that it doesn't matter what type of acid you use.

I conclude that carbonates react with acids to produce a fizz. You could use acids to test whether rocks contain carbonates or not.

The fizz means that a gas is given off. This gas is probably carbon dioxide, because it comes from a carbonate and the names are similar. I could test it and be sure by seeing if the gas turns limewater milky.

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Appendix 5.4

Pupil guidance sheet: Writing conclusions

Step 1: Describe the patterns

- Describe patterns or trends in graphs or data.
- Phrases to use:
  - comparative adjectives such as *longer*, *heavier*, *hotter*
    e.g. *The brighter the light the faster the plant photosynthesises.*
  - *as the …, so the …*
    e.g. *As the number of batteries increases so the current increases.*
- You may need to comment on how good the pattern is, e.g.
  This is a good pattern because … or *The pattern is not very strong.*

Step 2: Make a concluding remark

- Answer the original enquiry question.
- Phrases to use:
  - *To conclude …, I conclude that* … (relate to original question or question and prediction)
  - *The experiment shows that …, In general …, This means that … .*

Step 3: Explain the conclusion

- Use the science you know or can find out to explain your conclusion. Say if this leads to another experiment.
- Phrases to use:
  - *This can be explained by …*, *As I predicted …*, *This is because …*, *The reason for this is …*, *To be sure I will need to test …*
- Aim to:
  - use paragraphs;
  - use the present tense;
  - use scientific words accurately.

Appendix 5.5

Teacher guidance sheet: Writing conclusions

Pupils need to see examples of conclusions and discuss the merits of each one.

They need to build up a picture of what the structure of a conclusion looks like and how paragraphs help to organise the text.

They need to know how to describe patterns, draw concluding remarks and explain their observations in the light of scientific knowledge and understanding.

Pupil sheet B provides two examples of conclusions. You can use these to discuss how to write conclusions with pupils.

A suggested approach

- Ask pupils to work in pairs.
- Provide each pair with a set of results (pupil sheet A).
- Ask them to think about what conclusions they might draw from the results.
- Provide each pair with the two conclusions (pupil sheet B).
- Ask pupils to annotate each conclusion (using different colours) to show what is good about each one and what is bad.
- Invite discussion about the merits of each one.

Some points to make

Example 1 has a better conclusion than example 2.

Example 1 strengths are that it:

- starts by stating what the results show;
- uses scientific terms correctly;
- attempts to summarise with *The reason for this is...* .

Example 1 weaknesses are:

- no description of a pattern, merely repeats results although is partially selective (separates carbonates from others);
- no paragraphs, so difficult to follow sequence;
- no clear generalisation or concluding remark;
- because no pattern was identified (i.e. carbonates produce fizz), it was difficult to explain using scientific understanding.

Example 2 strengths are:

- clear structure demarcated with paragraphs;
- clearly identifies pattern in results, generalises by referring to carbonates;
- makes a concluding remark and identifies significance (*You could use acids to…*);
- explanation uses appropriate scientific understanding, good speculation about name of gas.

Appendix 6.1

Teacher guidance sheet: Explaining how

Text-type	Purpose	Language features
Explain how **Examples** ■ *How digestion occurs.* ■ *How weathering of rocks occurs.* ■ *How energy is transferred in conduction.*	 ■ To explain processes involved in natural phenomena. ■ To explain how something works.	**Text** ■ Text usually starts with general statement, e.g. *Digestion is a process…* ■ A series of steps follows in sequence. ■ Diagrams, illustrations or bullet points may be included to aid clarity. **Sentence** ■ Sentences contain connectives that indicate sequence, e.g. *first*, *next*, *then*, *gradually*, *meanwhile*, *finally*. ■ Active voice or sometimes passive. ■ Present tense or past tense. **Word** ■ Key naming words are important.

Appendix 6.2

Teacher guidance sheet: Explaining why

Text-type	Purpose	Language features
Explain how **Examples** ■ *Why air exerts a pressure on things.* ■ *Why current is not 'used up' by components in an electrical circuit.* ■ *Why we need to breathe air in and out.*	■ To develop conceptual understanding by linking ideas together. ■ To provide explanations for phenomena using the key ideas in science at Key Stage 3.	**Text** ■ Text usually starts with a description of the phenomenon, e.g. *Air exerts a pressure on things,* or *In an electrical circuit the current is not used up when…* ■ This is followed by an explanation using the conceptual ideas in science. At Key Stage 3 this will often be *particles, energy, force, interdependence* or *cells.* ■ Diagrams, illustrations or bullet points may be included to aid clarity. **Sentence** ■ Sentences contain connectives that indicate causal links, e.g. *because, the reason for this is, consequently, a further reason, so, therefore*. ■ Active voice. ■ Present tense. **Word** ■ Process words and concept words are important here.

Appendix 6.3

Pupil sheet A: Examples of explanations

Example 1: Explaining how digestion occurs

I want to explain how a piece of bread is digested.

First you place the bread in your mouth and your teeth start to chew the bread, breaking it down into smaller pieces whilst saliva mixes with it. Next, the saliva, which is an enzyme, starts to break up starch, which is a big molecule, into sugars.

You then swallow the sticky bread pieces. These are forced into your stomach by muscles squeezing it down your oesophagus. The food then enters the stomach where it is mixed with acids and enzymes. These help break the food down a little more.

Next the food mixture passes into the small intestine where more enzymes break the large molecules of fats and proteins into smaller ones. This allows the smaller molecules to pass through the intestine wall into the bloodstream. The intestine acts a bit like a sieve and only lets small molecules through.

What is left passes into the large intestine where water and mineral salts are absorbed. Finally what is left passes out of the body through the anus as faeces.

Example 2: Explaining how digestion occurs

This is an explanation of how digestion occurs.

After digestion you end up with faeces and food that has gone into the bloodstream. This happens because the food in your stomach and intestines has been broken down into smaller pieces by enzymes. Acid in your stomach helps break down food as well. In your mouth, there is an enzyme that changes starch, which is a big molecule, into smaller ones. You swallow your food when the muscles in your neck contract and force it down. They can only do this if there is a ball of food. You make this by chewing it with your teeth. Water passes through the large intestine into the body.

Digestion happens in stages, with different parts being absorbed in different places. This happens in the mouth, the stomach, the small intestine and the large intestine. Teeth chew on the food and mix it with water. This helps you swallow it. The stomach mixes things with the food and when the food ends up in the large intestine most of it has been absorbed into the blood stream and you are left with faeces.

Appendix 6.4

Pupil sheet B: Examples of explanations

Example 1: Explaining air pressure

Air hitting the surface of things as it moves around causes air pressure. The density of the air can change and this makes the air pressure change. The higher the density of the air, the higher the air pressure. This is because there is more air to hit the surface because the air is thicker in denser air. In lower density air, the air is thinner. This means that the air pressure is lower. There is a lot of air around us but we do not feel the pressure because we are used to it.

Example 2: Explaining air pressure

Air causes pressure. Sometimes the air pressure is high and sometimes it is low. You can explain this using the idea that air is made up of particles.

The particles are very small and move very quickly in all directions so they sometimes hit the ground, or you, or anything else in their way. Each time a particle strikes a surface it pushes against it so the air particle exerts a force on the surface.

Many millions of these collisions are happening every second. Consequently, this causes air pressure. If the air is not very dense, then there are fewer particles present and this causes low air pressure. Dense air causes high air pressure because there are more particles hitting the surface at any one time.

Appendix 6.5

Pupil guidance sheet: Writing explanations

Explaining how

You might want to explain ***how*** something happens or how something works. Start by stating what you want to explain and then use connecting words like those below.

- I want to explain how…
- First…
- Next…
- Then…
- Finally…

Explaining why

If you are trying to explain ***why*** something happens, you will need to start by stating what you are trying to explain. Follow this using connecting words and phrases like those below.

- I want to explain why…
- This is because…
- So when…
- A further reason is…
- Consequently…

Appendix 6.6

Teacher guidance sheet: Supporting the writing of explanations

When supporting pupils' writing of explanations you will need to make the distinction between explaining how and explaining why.

Structure

In each case, encourage pupils to write an opening sentence that describes what they are attempting to explain. This should be followed by either a sequence of steps (how) or reasons that link a phenomenon to a scientific idea (why).

Connectives

You will need to show pupils which connectives they should use.

Typical connectives to use when:

Explaining how	Explaining why
First…	Because…
Next…	So…
Then…	Consequently…
Finally…	It causes…

Pupils need to see examples of explanations and discuss the merits of each. They need to build a picture of what the structure of an explanation looks like and how paragraphs help to organise the text.

Appendices 6.3–6.5 provide pupil materials to use with a class. Pupil sheets A and B (Appendices 6.3 and 6.4) provide examples of explanations. You can use these to discuss how to write conclusions with pupils. The pupil guidance sheet (Appendix 6.5) can act as a prompt.

A suggested approach

- Ask pupils to work in pairs.
- Provide each pair with two explanations (either pupil sheet A or B).
- Ask pupils to read each and then to identify which they think is the better and why.
- Ask pairs to team up and compare their answers. Can they agree?
- Invite discussion on each, then provide the pupil guidance sheet and ask pupils to write their own.

Some points to make

Explaining how

The first explanation is better because:

- it follows a logical sequence;
- it correctly uses the scientific terms (e.g. oesophagus);
- it also separates the ideas into paragraphs so is easier to follow;
- it could, however, benefit from a diagram.

The second example is muddled.

Explaining why

The second explanation is better because:

- it attempts to provide a reason based on a key scientific idea.

The first does not really provide an explanation although it does contain some useful connectives such as *This is because…*

Appendix 7.1

Teacher guidance sheet: Argument

Text-type	Purpose	Language features
Argument **Examples** ■ *Provide the evidence to support the view that we see because light enters our eyes.* ■ *Provide the evidence for a spinning Earth.* ■ *What causes day?* ■ *What are the possible causes of global warming?*	■ To analyse evidence and present a view that is consistent with it. ■ To analyse conflicting views on the basis of evidence. ■ To develop the skills of considering evidence.	**Text** ■ Text usually starts with a statement of an idea or a particular point of view, e.g. *We see because light enters the eye* or *Seeing because light enters the eye makes more sense,* or *The spinning Earth causes day and night.* ■ Presenting a case, which sets out the evidence, follows this. ■ Presenting a case, which sets out the evidence, follows this. It may include diagrams to aid clarity. **Sentence** ■ Sentences contain connectives that show formal logic, e.g. *this shows…, my reasons are…, because… ,therefore…, the evidence for this is…* ■ There may be reference to a model or analogy, e.g. *it is like...* ■ Counter-arguments may be set up to be demolished. *Some people think that… another point of view is… but the evidence shows...* ■ Active voice, often first person. ■ Present tense. **Word** ■ Process words and concept words are important here.

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Appendix 7.2

Pupil sheet: Arguments for seeing because light enters the eyes

We need light to see things. Some people believe we see because light bounces off things and enters our eyes, others because light leaves our eyes, striking an object, so helping us see.

Argument 1

We must see because light enters the eye. We need light to see by, otherwise we would be able to see in the dark because light could come out of your eyes.

Argument 2

Seeing because light enters the eye makes more sense. We can't see when there is no light at all. If something was coming out of our eyes, we should always be able to see even in the pitch black. Another reason for believing this is that if you are standing outside looking into a dark room you cannot easily see things. If, however, light is let into the room from a window you can see things in it. This is because the light bounces off objects into your eye.

From 'Enhancing the quality of argument in school science',
by Osborne et al., School Science Review *(published by ASE), June 2001, pp. 63–70.*

Appendix 7.3

Pupil guidance sheet: Constructing arguments

My argument

- My idea is…
- My reasons are that…
- Arguments against my idea might be that…
- I would convince somebody that does not believe me by…
- The evidence I would use to convince them is that…

From 'Enhancing the quality of argument in school science', by Osborne et al., School Science Review *(published by ASE), June 2001, pp. 63–70.*

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Appendix 7.4

Teacher guidance sheet: Supporting the writing of argument

Constructing arguments helps pupils to explore ideas and evidence and make a case based on evidence. Arguments may also analyse conflicting points of view. It is important to avoid opinion and to encourage pupils to support their views with evidence.

Structure

Constructing a good argument is not a simple task.

Start by writing an opening statement about an idea or point of view, e.g. *My idea is…, I believe that…, There are different views about…*

Follow this by presenting the evidence that supports this view or the conflicting views. In the case of conflicting views, make a judgement about the balance of the evidence and then summarise.

A suggested approach

- Ask pupils to work in pairs.
- Ask them to draw a picture to show how we see. Quickly review the drawings to see if there are any standard misconceptions present (there probably will be). If there are, discuss them before moving on.
- Provide each pupil pair with the pair of arguments on Appendix 7.2.
- Ask them to identify the evidence for the view in each argument.
- Ask them to decide which is better and why.
- Carry out a 'modelled write' that would improve the argument.
- Give each pupil a copy of Appendix 7.3. Ask them to make the links with the 'modelled write'.

Some points to make

Neither argument presented on Appendix 7.2 is very good, but the second is better because it provides some evidence to support the idea.

Start writing the argument on the board together with pupils. Help them to understand the structure by agreeing the opening and then starting the next paragraph with *'The evidence for this is...'*.

At this point it may well help to break the class into small groups so that pupils can suggest pieces of evidence to be included in the argument.

Once this has happened, discuss with pupils what evidence there is and then together finish the argument.

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Appendix 8.1

Teacher guidance sheet: Evaluation

Text-type	Purpose	Language features
Evaluation **Examples** ■ *An evaluation of an investigation photosynthesis.* ■ *An evaluation of the methods for determining the speed of an object.*	■ To suggest improvements to methods. ■ To consider whether evidence is sufficient to support a conclusion. ■ To explain anomalous results.	**Text** ■ An opening statement about the evidence, e.g. its **reliability** *(accuracy, error, sample size)* or its **validity** *(control of variables, appropriateness of model, such as a beaker to represent a washing machine when testing washing powders).* ■ Suggested improvements; demonstrate how the collection of the evidence could be improved and why this is important. ■ Text will differ depending on the context. Explaining anomalous results is regarded as a much higher-order skill (L8+). **Sentence** ■ Opening statement refers to evidence collected. *The measurements show…, The sample size was…, My results show wide variation…, This means that…* ■ Improvement statements start with *to improve…, next time I could…,* and contain connectives that indicate causal links, e.g. *this is because…* ■ Active voice. ■ Present tense and future tense in the main (but may be past tense). **Word** ■ Critical vocabulary includes *evidence, reliable, valid, accuracy and error, variation, agreement.*

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Appendix 8.2

Pupil sheet: Examples of evaluations

Experiment

Comparing the porosity of different soil types (clay, sand, garden, etc.). Water was poured onto soil and the time for it to trickle through was measured. Each soil was tested twice.

Evaluation 1

If I did this experiment again I would change the following things:

- I would use very fine soil rather than soil with small granules.
- I could try and sieve the sand to get rid of anything in it that isn't needed in the experiment (i.e. plants, stalks, humus).

Evaluation 2

The results show that for most soils there is good agreement between the first and second test. However, the garden and school soils show wide variation in the time taken for water to pass through between the first and second samples. This is probably due to the size of lumps in different samples. This means that measurements for these soils are not reliable.

To improve the experiment, I would sieve the soil first to get rid of the lumps. This would mean that each sample had an even texture and this should lead to closer results so more reliability.

Appendix 8.3

Pupil guidance sheet: Writing evaluations

Step 1

Make an opening statement about how good you think your evidence is.

- How reliable do you think your results are?
- Do you think the evidence you have collected is valid (e.g. was it a fair test)?

Things to consider

- Are there enough results to spot a pattern?
- If you repeated your measurements, is there wide variation or are they similar?
- How accurate are your measuring instruments?
- How accurate are your observations?
- What possible errors could have crept in?
- How confident are you about your results?

Step 2

Make some suggestions about how to improve your experiment.

Step 3

Explain why these suggestions would provide better evidence.

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Appendix 8.4

Teacher guidance sheet: Supporting the writing of evaluation

At Key Stage 3, pupils are expected to consider anomalies in observations or measurements, to consider whether the evidence is sufficient and to suggest improvements to methods.

Structure

Evaluations should start with an analysis of the evidence, and then make suggestions for improvement, giving reasons.

A suggested approach

- Ask pupils to work in pairs.
- Ask them to read the pupil guidance sheet Appendix 8.3.
- Ask pupils to read the two examples on Appendix 8.2 and identify the main features that are present (e.g. opening statement).
- Invite discussion about what a good evaluation looks like – reinforce the main features.
- Ask pupils in pairs to review some evaluations that they have previously written. Each member of the pair should suggest some improvements that the other could make (peer review).
- Ask each pupil to rewrite his or her own evaluations in the light of the suggested improvements.

Some points to make

The first example on Appendix 8.2 only provides suggestions without considering the evidence. The second example has an opening statement about the evidence collected. It analyses the results and suggests reasons for differences. There are reasons given for the improvements suggested.

Appendix 9.1

Teacher guidance sheet: Planning

Text-type	Purpose	Language features
Plan		
Examples		**Text**
■ *A plan to determine the effect of surface area on the size of the frictional force.*	■ To identify the evidence that should be collected to answer an enquiry question.	■ An opening statement about the purpose of the enquiry and what evidence should be collected. It may include a hypothesis or prediction.
■ *A plan to gather the evidence that smoking is harmful.*	■ To outline a procedure for gathering the evidence so that it is valid and reliable.	■ A justification of the procedure to make sure the evidence is reliable and valid, and a statement of any predictions, e.g. *If heating substances causes their particles to vibrate more and gain energy, I would expect substances to dissolve faster in hot water. This is because…*
■ *A plan to determine from secondary sources the effect of engine size on the top speed of a car.*	■ To make a prediction if appropriate.	■ This is followed by an outline procedure to collect the evidence.
		Sentence
		■ Procedure can be bulleted or numbered lists.
		■ Connectives used to justify procedure often link cause and effect. *I will make sure…, this is because…, I will need to make sure that…, so that the results are reliable I will need to…*
		■ Active voice.
		■ Future and present tense.
		Word
		■ Critical vocabulary includes *evidence, reliable, valid,* and names of apparatus.

Appendix 9.2

Pupil sheet A: Planning

Investigation To See
Whether The Length And Cross
Area Section Of A Wire Affects
The Current In The Wire.

Introduction

This is an investigation to see whether the length and cross area section of a wire affects the current in the wire.

Hypothesis.

I think that as the length increases the current will decrease I think this because if the length of a wire is increased there is more length for the current to go through. This therefore makes it harder for the current to go through the wire so the current decreases. I think that the current will decrease when the cross area section of the wire is increased. I think this because there is more space for the current to push through the wire.

TEACHER: Does the current increase or decrease when the cross-section of the wire increases?
RACHEL: It increases. More electrons can get through at once.

This example is taken from the National Curriculum in Action website created by QCA © Qualifications and Curriculum Authority 2001. It is regularly updated and examples of pupils' work with commentary: www.ncaction.org.uk.

Appendix 9.3

Pupil sheet B: Writing plans

How does changing the number of masses on a piece of wood affect how much force is needed to pull it along?

Introduction:

For wood to be pulled along a surface, the amount of force needed to get it moving must be greater than the total force of the forces that are stopping the object from moving, e.g. friction, and then equal to those forces to sustain a steady speed. I will test what force is needed to pull the block along at a steady speed and what effect changing the mass of the object will have. The force will be measured in newtons (N).

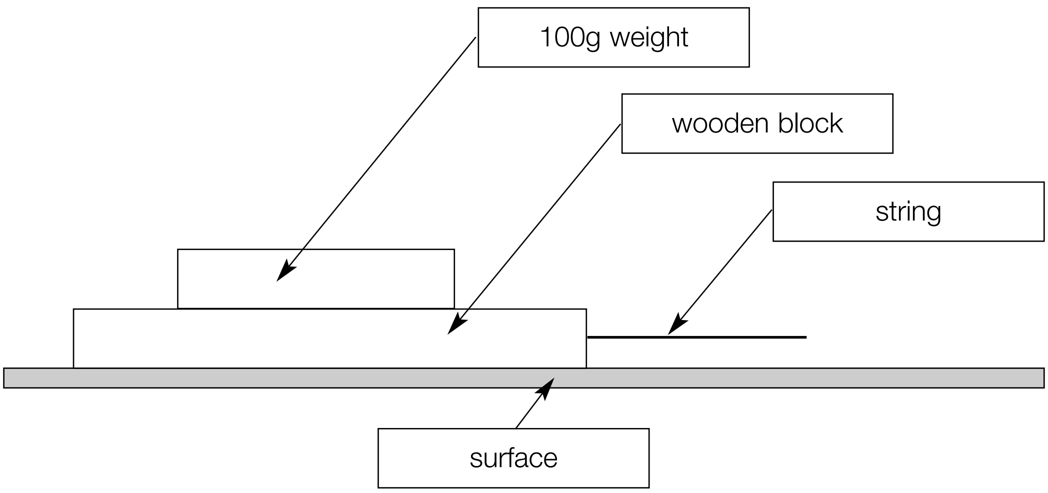
Hypothesis and predictions:

I think that the larger the mass of the wood and the weights combined the more force will be needed to move them at a steady speed.

Everything on Earth has a mass and in result, a downward force. This downward force is caused by gravity acting upon this mass.

Another effect which may change the force needed to pull the block and masses along is friction. Friction is caused by microscopic 'bumps' on the surfaces of the two objects. These 'bumps' run into each other when the two surfaces rub along each other. These collisions prevent the objects moving past each other smoothly, which means more force is required to keep the object moving at a steady speed. Also, the less smooth the surfaces, the more friction will be caused, meaning even more force will be needed to keep the object moving at a steady speed.

Diagram:



Apparatus list

- wood and string (41g)
- newton meter
- 2000g of 100g weights (20 weights)
- metre ruler
- table
- scales

Plan

To find the effect of changing the mass of a block of wood has on the force needed to pull it along the desk, I will need to follow this plan closely to ensure the test is fair and achieves the correct results. Firstly I will select the equipment I need (listed in the apparatus list above), then I will weigh it and make a note of this weight. I will next select the surface on which the experiment will take place. Then I shall place one 100g weight on to the block and pull it along for a distance of one metre at a steady speed and measure the amount of newtons (N) it takes to pull the block and weight. I will then repeat the process, adding one weight (100g) each time.

Fair testing

To ensure the results I get are as fair as possible, I should follow the following rules as closely as I can.

I must use the same block of wood and piece of surface for my experiment otherwise, different amounts of forces, either friction or gravity, may be placed upon the block and wood. This may cause an increase in the force required to pull the block along.

I must plan carefully the direction on which the surface that I pull the block as I will need to keep pulling the block in that direction as the grain in the wood will cause additional resistance, meaning more friction. Pulling the block across the wood grain will cause more friction and pulling the block in the same direction as the wood grain will mean there is less resistance, meaning less friction and less force needed to pull the block.

This example has been taken from Sci-Journal, edited and published by the Research and Graduate School of Education, University of Southampton. It is a web-based collection of pupils' scientific enquiries, available at www.sci-journal.org. Comments are invited about the submissions.

Say that at the end of the test the pupil could fall below the level of the test and be awarded an N. **Move the slide on**. Alternatively the pupil could be confirmed at level 4 or (**move the slide on**) judged to be at level 5.

Appendix 9.4

Teacher guidance sheet: Supporting planning

Structure

Plans should set out what evidence is to be collected and why. Often a prediction is made, although this may not need to be the case.

At Key Stage 3, pupils should collect evidence from first-hand experience or secondary sources. Secondary sources of evidence are currently underused.

Criticising plans that others have made can help pupils structure their own in more purposeful ways.

The unit on scientific enquiry provided a ‘thinking frame’ strategy for making decisions about what to investigate. It was provided on a large poster for class use.

A suggested approach

- Ask pupils to work in pairs.
- Ask pupils to read pupil sheet A (Appendix 9.2).
- Ask them to consider what evidence they would need to collect to test this hypothesis.
- results would be reliable.
- Ask each pair to write this in no more than two sentences.
- Ask each pair now to team up as a group of four and compare results – who has the most succinct statements?

Provide pupils with pupil sheet B (Appendix 9.3).

- Ask them to skim read the plan.
- Explain that this is rather long and we would like to make it shorter.
- Display the planning poster and ask them to use the prompts to help them restructure the plan.
- Alternatively, you could use the same poster to select from the plan those sentences that are useful and start pupils off by collaboratively writing the first few sentences.

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Appendix 10

Discussing science: Oral starters to science lessons

A: Language-building activities

Example 1 Talking explanations

Within a topic on electricity the teacher starts the lesson with a five-minute starter activity designed to help pupils to focus on cause–effect relationships. This will be followed by some practical problem-solving activities.

The teacher asks the class to think about some possible reasons why a bulb might not light in a circuit. He tells pupils that each of them must provide a reason in a sentence they say aloud. They must use one of the connective words *because, so, the reason* or *consequently* (written on the board).

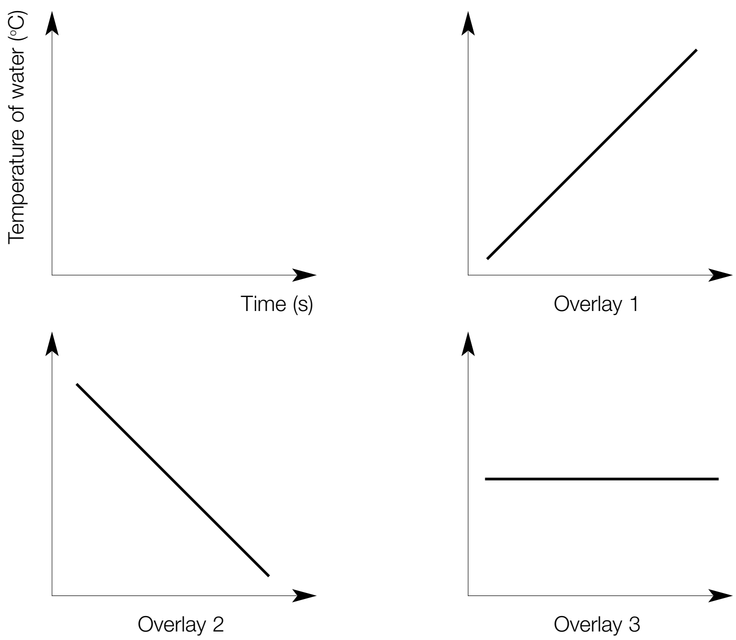
The teacher starts: 'In a circuit… the bulb doesn't light *because* there might be a flat battery.'

Pupils then have to change the sentence by giving a different reason or changing the connective:
e.g. 'The circuit has a flat battery, *consequently* the bulb will not light.' or
'In a circuit… the bulb doesn't light *because* there might be a broken wire.'

This continues round the class.

Example 2 Describing relationships

Pupils are told to use the construct *… as… then…* to describe the relationship between two variables on a graph, filling in with the names of the variables and using comparative adjectives. This could be carried out with the whole class using a range of slides as overlays. Positioning the different overlays, pupils are asked to describe the pattern.



Reproduced from AKSIS investigations: getting to grips with graphs *(published by ASE).*

B: Providing stimulating phenomena

Example 1

When introducing a lesson on adaptation and competition you could start with a wild oat seed. Explain that wild oats are very successful and difficult to get rid of. Demonstrate or ask pupils to hold a seed in their hands and drop water on it. Ask them to observe what happens and then in pairs ask them to hypothesise about why this action might help the plant. Get them to think about as many reasons as possible, then join with another pair and compare notes.

Example 2

Place a plastic rod near a stream of water from the tap. Ask pupils to say what they expect to happen. Show pupils that the water bends. In pairs ask them to come up with an explanation. Pairs form fours to share their ideas and agree on one. Take feedback from the fours. Use this as an introduction to a lesson on static electricity.

Example 3 Whole-class session – Introduction to refraction

Ask pupils to write the word CARBON DIOXIDE in capitals. Provide them with a glass rod, and ask them to place it over the words. What do they see?

What pupils should see is shown below. Both words are inverted, but DIOXIDE is symmetrical and so appears not to have been changed.

CARBON DIOXIDE

Get pupils to work in pairs. Ask them how many possible explanations with reasons they can come up with for what they see. Have them feed back to the class; then start the lesson on refraction.

C: Explore a challenging statement

This is an alternative to questioning. Provide pupils with a statement to explore rather than questions.

Example 1

When introducing a lesson on solutions in Year 7, the teacher says, ‘Substances are likely to dissolve more quickly in hot water because particles are moving faster.’

The teacher asks pupils to work in pairs and attempt to explain what the statement means. Can they identify the particles in question? Can they tell the story of a dissolving ‘particle’ of potassium nitrate?

Example 2

When teaching Year 9 pupils about the role of the root in photosynthesis, the teacher starts with the statement ‘Plants that are watered too frequently may die’. She invites them to discuss this idea with their neighbour, and on their whiteboards jot down as many reasons why this might be so using the word ‘cell’. After about five minutes she asks them to show their whiteboards and then quickly collects suggestions, asking pairs to add any other ideas to their own boards.

D: Encouraging pupils to raise their own questions

Following work on acids and alkalis in Year 7, this Year 8 group are briefly reminded of their work and then are asked what more they would like to find out about acids. The teacher asks, 'What else would you like to find out about acids? Discuss this with your partner and come up with three good questions.'

Some responses may be:

Which is the strongest acid?
Are all acids colourless?
What does acid do to skin?
What is acid rain?
What can you use acids for?
Are there acids that can dissolve glass?
Are there any solid acids?
What does acid do to metals?
Are there any acids in the body?
How many types are there?

With these questions, plus a few raised by the teacher, the class then goes on to plan what they would do in the next topic and how they would find answers.

E: Using questions to stimulate thinking

The teacher quickly reminds the Year 7 class of the work they have completed on forces in their primary schools (e.g. push–pull, gravity, friction, air resistance and upthrust).

She then prepares the pupils for a question by saying:
'I'm going to ask you a question about forces which I want you to think about. I want you to think about it by yourselves for a minute [providing wait time] and then, when I tell you, discuss your ideas with your neighbour. See if you agree. I will then ask each pair to give me one of your ideas.'

She then asks the question:
'What connections are there between forces and movement?'

F: Using a stimulus for discussion

Example 1 Exploring opposing views

Use a concept cartoon to stimulate debate and make learners' views explicit.

The example on the next page is taken from the ConCISE project.

Pupils can first be asked to consider the ideas by themselves, then to discuss their ideas in small groups and try to reach a consensus. At the end of this discussion time, the teacher manages the feedback by asking each group to share their views about what will happen and why.

Full details of how concept cartoons can be used may be found in *Concept cartoons in science education*, by S. Naylor and B. Keogh (Millgate House Publishers, 2000).

8.5 Lemonade

What do YOU think?

Example 2 Constructing an argument

At the start of the lesson pupils are provided with the following:

Pupil sheet Argument

Which of the following arguments is the best piece of evidence that matter is made up of particles and why?

(a) Air in a syringe can be squeezed
(b) All the crystals of any pure substance have the same shape
(c) Water in a puddle disappears
(d) Paper can be torn into very small pieces

From Language and literacy in science education*, by Wellington and Osborne* (Open University Press, 2001).

In groups of four, pupils are asked to consider the statements for three minutes. The teacher then takes initial feedback from each group about which they feel provides the best evidence and briefly why. No further comment is made. Pupils are then given two minutes to reconsider their ideas. The teacher then manages the discussion, inviting views from different camps. Once ideas have been explored, the teacher then explains that pupils will now turn these discussions into a written argument.

Example 3 Constructing a concept map

At the start of the lesson pupils are organised into groups of four seated around a table. They are told they are to construct a concept map to show how all the cards in an envelope they have been given link together. In order to make decisions pupils must discuss their ideas with each other.

The teacher makes the outcome clear: 'What I am looking for is that you as a group summarise what you know about plants. A good concept map will use all the cards and be linked using the right scientific words and ideas. The cards will be set out so that they show logical connections. In 10 minutes be prepared to show your map to others.'

The words on the cards are:

Plant	Root	Stem	Flower
Stigma	Stamen	Carpel	Water
Minerals	Sugars	Reproduction	Seed
Cell	Transport	Day	Night
Growth	Ovary	Respiration	Cells
Palisade	Leaf	Style	Photosynthesis

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www.standards.dfes.gov.uk/keystage3
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