2 WHAT ARE YOU EXPECTED TO TEACH IN A SCIENCE LESSON?

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This chapter:

- discusses how science teaching fits in to the Every Child Matters framework
- summarizes your responsibility for safeguarding children
- describes how to assess an activity for risk
- describes the background and structure of the National Curriculum
- discusses Science at Work and the place of practical work in the curriculum
- explores how pupils' thinking can be structured through the study of science.

EVERY CHILD MATTERS

When the government set a new agenda called Every Child Matters (DfES, 2003), all matters concerning the welfare of children were brought under one piece of legislation. The Every Child Matters (ECM) initiative places a unified duty of care on all children's services – education, childcare, social services. All these agencies have the same set of responsibilities, which includes an obligation to communicate effectively from agency to agency, because children, but particularly vulnerable children, have been found to be disadvantaged when important information is not shared by those who need it.

The Office for Standards in Education, Children's Services and Skills (ofsted), now regulates care for children and young people, and inspects education and training for learners of all ages.

The government has also produced *Every Child Matters: Common Core of Skills and Knowledge for the Children's Workforce* DfES (2005a). This describes the skills and knowledge required by all professionals who work with children in schools, social services or children's support groups. All these agencies, and the people who work in them, now have an obligation to follow the ECM agenda.

This means that all schools have a legal obligation to operate policies which look after the welfare of the pupils. This is normally overseen by a single member of staff with responsibility for child protection, and you will be expected to work within this policy. If you witness something in school which causes you any concern about the welfare of a pupil, you are not allowed to keep it to yourself. You *must* report it to the senior member of staff – if a child is suffering abuse, do not attempt to deal with it yourself – indeed you are not allowed to.

Abuse takes a number of forms – physical, emotional and sexual abuse or neglect – and may be carried out by children, family members and other people known to the victim. The evidence is not always obvious, and may manifest itself in very different ways; for example, in the form of aggressive or inappropriate sexual behaviour or unexplained bruising. A pupil exhibiting these symptoms may or may not be the victim of abuse, but if you have any suspicions, you must always report them to the school's child protection officer. If a child confides in you, take this seriously and always remember that a child's evidence is as reliable as an adult's. Do not make promises you cannot keep about maintaining secrecy – but try to help the child see that you are trying to keep control of the situation with them.

EVERY CHILD MATTERS AND THE SCIENCE CURRICULUM

There are five 'outcomes' for the ECM agenda:

- staying safe
- being healthy
- enjoying and achieving
- making a positive contribution
- achieving economic well-being.

It is a whole-school responsibility to ensure that the curriculum of all subjects covers these five outcomes appropriately, and all departments will have audited their schemes of work to make the best use of opportunities to reinforce them. Some of them, as we shall see, lend themselves very well to the science curriculum.

Staying safe

Your school will have a policy which expects all members of the school community to respect one another – this means refusing to tolerate or condone bullying and discriminatory behaviour for example, and the way you establish the environment in your classroom is very important in promoting an atmosphere in which pupils feel safe and comfortable. And not just in the classroom – everywhere you go in the school, you should calmly and quietly challenge antisocial behaviour. Children should be taught that personal safety is also a personal responsibility, and in the science laboratory we have an almost limitless opportunity to promote an appropriate attitude to working safely.

So do not waste this opportunity by telling the pupils what to do – when you first meet them, discuss safety with them and find out what they know already, and develop an agreed code of safety for the laboratory. Before you carry out your first experiment with them, challenge them to define the safety procedures. And then stick to these procedures at all times – never give in to the temptation to take short cuts to save time. You may teach many hundreds of pupils in your career, and you never know just when something unexpected is going to happen. Be alert (and ask the pupils to do this as well) not just to the obvious issues such as eye protection, but to long hair dangling too near a Bunsen flame, or to somebody sitting down while working with apparatus (spilling a chemical in your lap is far more serious if you are seated).

Some teachers copy the idea of a bathing red flag on the beach – if the flag is flying, then safety procedures must be observed. This works well, as it is important to remember that the greatest danger to a pupil is the experiment at the next bench – a fragment of glass or a drop of acid can travel a long way if dropped on the floor.

All the experimental procedures you use will have to be assessed for risk using a form like the one in Figure 2.1.

In fact the school will already have done this and will be able to advise you, because the Health and Safety Executive requires employers to control substances hazardous to health under the COSHH regulations. Remember that a risk assessment is not a device to try and prevent you from doing something interesting – it is a procedure to help you find a way to do it safely. Indeed the organization CLEAPSS, which exists to advise a consortium of local authorities on safety issues, published a booklet in which they 'investigated alleged bans on the use of various chemicals or particular procedures that were commonly used in the past' (CLEAPSS, 2005). They list about 60 activities and procedures which some teachers have refused to carry out, believing them to be banned.

There are two questions you need to ask every time you make a risk assessment: 'How likely is an incident?' and 'how serious would it be?' Let us take a look at an example for a neutralization experiment in Year 7. The normal procedure involves adding acid to a measured amount of alkali through a burette. The use of stronger solutions and a burette allows for an accurate determination of the volume required for neutralisation. The resulting liquid can then be evaporated to reveal common salt. So Table 2.1 shows the substances and procedures placed in the first table on the form in Figure 2.1.

The next step is to decide on the likelihood and severity of the various mishaps. We have to be realistic here – pupils in Year 7 have been known to drop things – and we have to say that even with the best organized and most

School Practice Risk Assessment Form

Title of practical activity: ……………………………………………..
Teachers and pupils involved: ……………………………………..

	Substances hazardous to health – Chemicals regulated by COSHH*		**Hazardous procedure or item of equipment**
1		1	
2		2	
3		3	
4		4	

Risk estimator: A score of 10 or more means the risk is unacceptable

Likelihood of occurrence	**'L' score**	**Severity of outcome**	**'O' score**
Highly unlikelyy	1	Slight inconvenience	1
May happen but rare	2	Minor injury	2
Does happen but rare	3	Medical attention required	3
Occurs time to time	4	Major injury leading to hospitalisation	4
Likely to occur often	5	Fatality or serious injury	5

Hazard	**L score**	**O score**	**Total (L × O)**	**Control measures**

*** Control of Substances Hazardous to Health**

Figure 2.1 School practice risk assessment form

Table 2.1 Examples of hazards

	Substances hazardous to health – chemicals regulated by COSHH		Hazardous procedure or item of equipment
1	Sodium hydroxide (Molar)	1	Fill burette via funnel
2	Nitric acid (2M)	2	Use of burette to control flow into flask
3		3	Use of mixture for evaporation
4		4	Preparation of salt by evaporation

Table 2.2 Scoring hazards

Hazard	L score	O score	Total (L x O)	Control measures
Spillage of acid on clothing or skin	4	3	12	Use of weaker acid reduces O score to 2
Spillage of alkali in eye	3	4	12	Use of weaker alkali reduces O score to 2; use of eye protection reduces L score to 2.
Danger of upsetting burette due to height	5	3	10	Use alternative apparatus – bulb pipette and measuring cylinder – L score reduces to 3, O score is 2 if reactants are weaker
Boiling using evaporating basin to form crystals – spitting	5	3	10	Use of eye protection reduces O score to 1
Burns from hot apparatus	3	2	6	Warn pupils, leave time for apparatus to cool

careful of groups, sooner or later someone is going to tip something over. So the risk estimator for these procedures might look like that in Table 2.2.

Nearly all the scores are above the limit – therefore we *must* reconsider. Fortunately, this is quite easily done – use of much weaker solutions such as 0.25M for the acid and alkali means that spillage now becomes an inconvenience – there is time to rinse the spill away before it does any harm. Use of a pipette to transfer the acid avoids the use of a burette – many Year 7 pupils will simply not be tall enough, and we cannot have them clambering onto stools! Liquid will spit from the evaporating basin, and eye protection and an instruction to stand well back will cover this risk.

In reality you are not going to fill any risk assessment forms with risk estimator tables like the one above – the aim is to work out the control measures which ensure the score is below the limit, and then to fill in the form, which then demonstrates that you have taken appropriate measures to control the risk.

go to www.sagepub.co.uk/secondary
Now try amending this form by using the sample on the website, and look at the other examples there.

You will also take pupils out of the classroom from time to time – either for fieldwork in the school grounds, or further afield. Do not take this upon yourself without seeking advice first. Your colleagues at the school will not take kindly to groups of children banging bin lids together outside their room while you measure the speed of sound! Trips outside school involve a whole extra level of organization – parents and carers must be informed, permission sought, payments made and taken, and so on. Your school will have a policy for this, and you should follow it.

Being healthy

Once again, science lessons offer a wide range of opportunities to encourage pupils to develop a healthy lifestyle, whether this be physical, mental or sexual.

We can encourage children to eat healthily by teaching them what foods contain and what effect overindulgence can have. We can encourage them to make good decisions relating to sexual matters and drugs by teaching them the consequences of abuse. We can encourage them to discuss these issues openly so that they are able to argue a viewpoint and resist temptations provided by others.

In your lesson planning, you should be aware whenever these issues of health and safety crop up, and make good use of them.

Enjoying and achieving

We hope it goes without saying that you will try to make your science lessons interesting and enjoyable, for example by putting plenty of varied experiences into your teaching and by giving pupils active things to do, because the essence of science teaching is to enable learners to observe, describe and explain the things they see around them. If you can challenge pupils' thinking sufficiently, their sense of achievement will come from overcoming these challenges. There is a bit of a balancing act here – make the challenges too hard and they may give up; make them too easy and they will get bored. Absorbing science lessons will encourage pupils to attend regularly, and while they are attending regularly, their personal and social development will be supported positively. This sort of approach is designed to help learners recognize and take responsibility for their own learning – once they have determined a need for their learning there will be no stopping them. It is fair to say that this section would fit into a textbook for teaching any subject – all of the above skills you would expect to see in the best lessons, where teachers are aiming to get the best out of all their pupils by target-setting, monitoring, and providing support when the going gets difficult. If you can achieve all of these, then the pupils will leave your room with a sense of fulfilment, good examination results and a liking for your subject.

Making a positive contribution

Pupils need to leave school with a good sense of what it takes to be a responsible citizen – are they able to take an active part in their community? We can mirror this in the school committee – for example when there is a general election, schools will organize a parallel event, selecting candidates to represent the parties (some of the best actually choose to represent a party they do not particularly support, but are able to develop the arguments anyway!), and arranging for voting and counting on polling day. It can be surprising just how the results conform to national trends. Many schools run councils of one form or another, and when these bodies are involved in real decision-making, it is interesting how responsibly most of them act – they are aware that halving the school day and abolishing homework are not options, and they set about looking for ways to improve the school environment. We want them to develop a sense of perspective about life and a positive attitude to school. It is surprising how the little things can help here – do not fall into the trap of talking yourself and your subject down. Perhaps there is one part of the syllabus you are not particularly fond of – make the effort to take a special interest in it – if you present it with enthusiasm, the pupils are far more likely to be enthusiastic themselves and to take an active interest in the lesson, and will volunteer for the tasks you set them. Then you are likely to find the whole experience more rewarding yourself.

Other opportunities will present themselves – most schools will enter challenges of one sort and another, and good schools will have pupils involved in a whole range of projects – perhaps there is a science club providing an opportunity to build a more informal relationship between pupil and teacher. Generally it is the enthusiasm of individual teachers that drives these initiatives forward, and invariably it is the successful and dynamic departments that get involved this way.

Achieving economic well-being

Research shows that pupils in the early stages of their secondary career are often unable to recognize the link between education and employment – they are often unaware of the opportunities that an interest in a particular subject can open up.

The curriculum at Key Stage 4 and beyond has developed considerably in the last few years, with the introduction of a wider range of subjects which involve an understanding of the relevance of subject knowledge to the world of work. The new 14–19 diplomas being introduced over the coming years are an example of this: they aim to bring together a blend of specialist learning in the relevant subject, along with functional skills in English, mathematics and information and communication technology (ICT) and a key element of work experience, which is now compulsory for all pupils in Key Stage 4.

Point for reflection

Make sure that you are familiar with the five Every Child Matters outcomes. In this section we have given examples of how you can use your science teaching to work with the agenda. Consider each of the five aims, and think of other ways you can develop the way you approach ECM. Compare this with how the schools you observe have tackled the ECM agenda. What should the lessons contain, what materials and approaches can you prepare?

Point for reflection

THE STRUCTURE OF THE NATIONAL CURRICULUM IN THE SCHOOL

English, mathematics and science were established as the foundation subjects which must be taught to all pupils from Year 1 to Year 11, and National Tests were developed at each of the key stages to monitor progress. The tests established an expectation for pupils at each stage of the National Curriculum (Table 2.3).

Table 2.3 Expected attainment at Key Stages

Age	End of key stage	Expected level
7	1	2
11	2	4
14	3	5–6

Naturally, there is considerable variation from pupil to pupil and from school to school, but there is an underlying expectation that children will advance by about two levels in each key stage. How to recognize the level of a child's learning is the subject of Chapter 6.

The establishment of a common curriculum for all took place against a background of accountability and the belief that market forces would drive out failing schools, since parents would choose to send their children only to successful schools. Successive governments therefore provided more and more guidance for schools in the form of the Key Stage 3 (and later Secondary) National Strategy. This specified not only the subject matter to be taught, but also the order in which it should be taught, and even went down to the detail of how the individual lesson should be structured.

It must be said at this point that the guidance provided by the National Strategy is sound advice, and you will see that the lesson planning we tackle in the next chapters follows closely the National Strategy.

Since 1989, the science content of the school syllabus has been prescribed by the National Curriculum. From the perspective of the science curriculum, this was a response to an imbalance in the teaching of biology, chemistry and physics as three separate subjects. There was a tendency for boys to study the physical sciences, and girls often opted for biology, and to address this issue it became compulsory for all pupils to study a balanced programme covering all three subjects equally. It soon became the norm for schools to provide at Key Stage 4 what became known as 'co-ordinated science' – a blend of the four strands of the National Curriculum delivered in the time allocated to two GCSE subjects. There were rules which allowed for some pupils to opt for a single award, the original intention being for someone gifted in, say, music to be able to spend extra time on the subject. In practice, it became common to offer the single version to less able pupils as they often found the full curriculum too demanding and many lost interest.

Since then, a greater variety of courses has been developed, with vocational courses, and applied science in addition to the 'traditional' course.

THE STRUCTURE OF THE NATIONAL CURRICULUM IN SCIENCE

The science National Curriculum aims for all young people to become:

- successful learners who enjoy learning, make progress and achieve
- confident individuals who are able to live safe, healthy and fulfilling lives
- responsible citizens who make a positive contribution to society. (QCA, 2007a: 207)

You will see how this matches the Every Child Matters agenda, but it also means that the science curriculum must provide more than simply subject knowledge. The programme of study gives a set of key concepts which underpin the teaching of science:

- *Scientific thinking.* Summarizes the way scientists approach phenomena: develop theories and models to explain them, and use creative thinking to devise ways of testing them. This is followed by critical analysis and evaluation of the results.
- *Applications and implications of science.* How does the creative application of science affect the way we live? What are the moral and ethical implications of this?
- *Cultural understanding.* Recognizing that science has origins in many cultures, and draws on a variety of methods.
- *Collaboration.* Sharing developments with others.

In order to get these key concepts across, pupils need to become skilled in a range of key processes, listed in the programme of study as:

- Practical and enquiry skills.
- Critical understanding of evidence.
- Communication.

The practical skills will be those which enable pupils to use appropriate methods and equipment accurately and safely, assessing risk as they go along. They should be able to plan and carry out investigative work individually and with others. Using these techniques, they will gather and record data using ICT where appropriate, and analyse the data. The analysis of the data gives evidence for scientific explanations for phenomena, and in order to understand the evidence fully, they will need to have a critical awareness of the validity of their evidence and methods. Finally, pupils need to be able to communicate these ideas to an audience, again using ICT as appropriate.

So as you will see in the next chapter, planning to teach science is not a case of lining up a number of topics and taking the class through them one by one. The pupils themselves are to play the part of scientists exploring and testing the world around them.

The programme of study now begins to specify the subject matter to be taught, by listing them under four attainment targets:

- How science works.
- Organisms, their behaviour and the environment.
- Materials, their properties and the Earth.
- Energy, forces and space.

You will recognize the last three under the traditional labels of biology, chemistry and physics, and most schools still divide their teaching under those labels.

At Key Stage 4, the programme of study is worded somewhat differently:

> During the key stage, pupils should be taught the *Knowledge, skills and understanding* (original emphasis) of how science works through the study of
>
> - organisms and health,
> - chemical and material behaviour,
> - energy, electricity and radiations, and
> - the environment, Earth and universe. (QCA, 2007b: 224)

Now the subject boundaries are less obvious, with a significant proportion devoted to the environment. In devising a timetable, schools tend to share out subjects like geology between the chemists and physicists, though more and more, there is an expectation that as a science teacher you will be expected to deliver the National Curriculum at all subjects confidently to the end of Key Stage 4.

Each document then goes on to specify the actual subject content required, but the difference at Key Stage 4 is that this is all within the framework of Science at Work. Therefore, with the study of Science at Work at the centre of the National Curriculum, it is vital that all our teaching incorporates an understanding of how scientists plan, observe, describe and explain evidence. This focus on scientific enquiry from the start of the National Curriculum led to the development of a very different approach to the teaching of practical work to replace the idea of providing pupils with activities on the lines of a recipe, with 'experiments to prove … ' in which the outcome was effectively predetermined. Now pupils are given the task of defining the problem for themselves and undertaking an investigation divided into four distinct areas:

- *planning*, which involved setting the scene, making predictions about the outcome, and planning a strategy to collect data
- *observation* – the collection and presentation of data with appropriate precision and taking into account the need to ensure that measurements were accurate
- *analysis* of the results, providing an explanation of the outcome
- *evaluation* of the investigation, looking for flawed results, improvements and possible future developments.

This means that experiments can be devised to engage pupils while still covering basic science knowledge. Consider the example in Figure 2.2, in which a trainee provided the pupils with a letter, apparently from the local football club (insert your team here!) asking for assistance with the surface of their training pitch. The pupils took part in the investigation with gusto, and in the process learned a great deal about friction and forces.

The example in Figure 2.2 probably leads to a fairly traditional 'fair test' investigation which will compare the properties of different surfaces under controlled conditions. Watson et al. (2006) suggest that there are six categories of enquiry and suggest examples for each:

- Classifying and identifying (for example, What chemicals are in this green rock? How can we group these spiders?)
- Fair testing (for example, What is the effect of exercise on heart rate? How does the rate of reaction of sodium thiosulfate solution with an acfid change with different concentrations of the acid?)
- Pattern seeking (for example, What causes the variation over time in levels of air pollution? What affects how far people can throw a tennis ball?)
- Exploring (for example, How does the size of the hole in the ozone layer over the Antarctic change over time? Is there a pattern in hourly measurements of the concentration of nitrogen dioxide in the air in central London?)
- Investigating models (for example, Why does the population of ladybirds in the school nature trail change? Why do the bubbles in a fizzy drink get larger and faster as they rise up the glass?)

E H F C

Dear Ms Teacher
My new player (name of latest signing here) is having trouble on the training pitch. He keeps falling over because his trainers do not grip on the grass. Can you ask your pupils to investigate the problem and tell me which type of surface would be best for us to train on? This is very important to us, as we want to win the European Champions League again, so please help.

Yours sincerely
Football manager
(They change too quickly to use the real example!)

Figure 2.2 Putting the subject into context

- Making things or developing systems (for example, Devise a way of retrieving pure salt from salt that has been spilt on the soil. Design a regime to improve your fitness and to evaluate its effectiveness)

Website

What other ideas can you provide to stimulate pupils' thinking? The website has some suggestions ('Stimulus and Support' sheets) written by trainee teachers to start you thinking. It helps pupils if their scientific study is put into a familiar context. Watch the video of the start of lesson 2. How could you devise an introduction to the lesson which might involve pupils' experience of metals reacting (rust, tarnished metal, and so on)?

From the 1990s, investigations became a significant part of the GCSE syllabus, but there was a problem: some schools were highly successful in coaching their youngsters to complete their investigation with high marks, but some observers felt that learning was not always evident, particularly for the less successful candidates, who felt unable to see an investigation from start to finish. In particular, the concept of evaluation was particularly difficult to grasp.

Now that this attainment target has developed into Science at Work, there is a much broader brief in which investigative work is still taught, but without necessarily requiring pupils to demonstrate a holistic approach. Pupils must now also study the work of scientists past and present, and show an understanding of the development of scientific knowledge and understanding.

SCIENCE, NUMERACY AND LANGUAGE

Included in the National Strategy is a rationale for teaching children key skills – particularly in the early stages, literacy and numeracy. We cannot separate science teaching from the need to construct clear and precise language – for if the purpose of teaching science is to enable pupils to observe, describe and explain the phenomena they see, how can this be achieved without language and an understanding of number? Therefore it is worth considering how pupils are to develop this understanding of science thinking through language, and Fisher (2005: ch. 7) provides a useful commentary on our understanding of how children learn. Traditionally, teachers have regarded knowledge as a body of ideas which they must transfer into their pupils' heads (the transmission model) Alternatively, and perhaps more recently, the 'discovery model' suggests that children can uncover hitherto hidden truths which will become fixed in their minds by the very process of discovery.

The reality is more complicated than this, and we need to be aware of children's modes of thinking as they learn. For example, a child with a misconception (for example, the belief that there is no gravity in space), must first of all see how the misconception raises a conflict (why does the moon not fly off into space) before resolving it with a revised conception (there is no weight in space without anything to stand on).

The development of understanding of the way children think has passed through a number of phases described by McGregor (2007). Behaviourism, in which children's responses can be trained, suggests that pupils learn through involvement in didactic procedures with the whole class, resulting in rote-learning. Piaget recognized that pupils are able to adapt when they meet a new experience, and are able to construct new meaning to situations as they compare their existing knowledge with the latest encounter (constructivism). Piaget also recognized that children follow a hierarchy of cognitive processes which inhibits understanding of a given concept until they have achieved a stage of maturity to cope with it. Vygotsky takes this a stage further into social constructivism, in which 'learning can be influenced by social, historical and cultural factors' (McGregor, 2007: 54).

Thus we return to the need for language and the 'Literacy Across the Curriculum' training received by all schools from 2002, and a summary of the ways in which children use language.

Thinking out loud

Children need to be given time to try out ideas. They are often highly reluctant to do this, as it places them in a vulnerable position through the completely understandable fear that they might be wrong. We can provide them with the space for this type of thought by lowering their feeling of exposure – talking to them individually, inviting them to talk to their classmates and knock ideas around. Concept cartoons are particularly good for this, as they offer familiar situations with a range of plausible explanations provided by the children in the cartoon thinking aloud.

Talking

Children need *time* to think. If we ask them a question in the heat of the moment, and when a child is obviously struggling with the question you have just given them, it is all too tempting to supply the answer too soon. Fisher (2005: 158) suggests five ways in which we can encourage the child to talk:

- Pausing – allow the child 'think time' during question-and-answer or discussion. Waiting for an answer demonstrates a trust in the child's ability to answer, and expectation of thoughtfulness even if the silence sometimes seems to be interminably long!
- Accepting – do not 'rush to judgement' on a child's response; give the child time and give yourself time to reply in a thoughtful way. Ways of accepting a child's idea are to restate it, reapply it, recognize it, compare it to another idea, or simply to acknowledge her view. Passive acceptance can be the non-verbal nod of the head, active acceptance will show understanding, or perhaps elaboration of the idea.
- Clarifying indicates that the teacher does not understand fully what the child is trying to say. Instead of 'rushing in' to explain to the child what he is trying to say, the adult requests more information and invites the child to elaborate on his idea. 'Can you explain what you mean by … ?' 'Tell me again, I couldn't quite understand … '
- Facilitating means sustaining talking and thinking through feedback and response. The teacher needs to provide opportunities for the child to check her ideas to see if they are correct. 'Are you sure?' 'Let's check it and see'.
- Challenging – to be understood by other is part of the stimulus a child needs, but children also need challenge and should be encouraged to challenge each other and adults. 'Do you agree with what I/another child says?' 'Can you see any problems?' 'What do you think?'

Website

Watch lesson 1. Here the pupils are given an opportunity to discuss a problem without too much intervention from the teacher. How many of the above points are covered by this approach. It is useful to listen to Paul's discussion of his planning – also on the website.

Table 2.4 Using different writing styles

Writing style	Context	Rationale
Concept map	Acids and alkalis	Helps to link ideas together
Cartoons	Digestive system	Allows pupils to revel in the 'yuckiness'
Newspaper article	Thermit process	Reporting a spectacular incident in the classroom
Science Fiction story	Earth in space	Enables speculation about conditions beyond Earth
Love story	Bonding	How the rakish Mr Aluminium stole Miss Sulphate from Mr Copper.
Letter	Photosynthesis	Describing a difficult concept To one of their friends.

Writing

There are so many different ways of putting ideas onto paper, so many of which are fun, and we should make use of them as often as possible. Traditionally there was only one way to describe an experimental procedure: ('Diagram, method, results, conclusion' from the behaviourist school of thought!). Why do children need to write? Who are they writing for? What are they writing for? Does it need to be writing?

The range is huge, and we should make full use of it. Table 2.4 is just a small example. For each one, consider the possible audience(s), and work out some alternative contexts.

Numeracy

Numeracy was defined in the National Strategy as follows:

> Numeracy is a proficiency which is developed mainly in mathematics but also in other subjects. It is more than an ability to do basic arithmetic. It involves developing confidence and competence with numbers and measures. It requires understanding of the number system, a repertoire of mathematical techniques, and an inclination and ability to solve quantitative or spatial problems in a range of contexts. Numeracy also demands understanding of the ways in which data are gathered by counting and measuring, and presented in graphs, diagrams, charts and tables. (DfEE, 2001: 9)

Numbers and measures

We should expect children at the age of 11 to be able to measure and estimate force, and to describe the weight of an object in terms of the gravitational pull upon it. Yet the definition of weight is rooted in an arcane system of units and sub-definitions which would be almost impossible to explain to most 11-year-olds. So to ask them to use the newton scale presents a challenge – what does '1 newton' actually mean?

Mathematical techniques

All the numeracy skills exist in a hierarchy, none more significantly than when children attempt to use mathematical formulae. Being able to calculate the moment of an object when we tell them to multiply force by distance is a very different proposition from the question 'where must Alfie sit on the see-saw to make it balance?' Bloom's taxonomy (see Chapter 3) will be useful here: at the earliest level, children will be able to 'use a mathematical formula to make a calculation' through stages to 'manipulate a mathematical formula to solve a problem'. What are the stages in between?

Quantitative problems

Not all quantitative problems are solved by mathematical formulae. Chemical equations provide another hierarchy of skills – ranging from the simple statement in words, to the balancing of equations with a number of compounds on either side. Before you use the higher-level skills with your class, you need to be sure they can handle the lower-level concepts first.

Graphs and charts

There is not just a hierarchy of skills associated with producing an illustration of the way numbers behave, there is also a sequence to it, and this sequence can be time-consuming. Write down a list of the steps you must go through in order to produce a line of best fit on a graph. Starting with 'identify the variables', the list is very long. So if you are planning to teach a lesson involving graphs, be clear about the focus – if they need practise in plotting data onto a graph, then the process of collecting and tabulating the data becomes less important, and can be done by the class collectively or using a computer and data logger, or by yourself.

What the research says

Patricia Murphy and Elizabeth Whitelegg (2006) describe research that has been undertaken to look into reasons why more boys than girls choose to study physics. This is quite a serious problem, since there is a general decline in the number of students who wish to study physics, and if girls were better represented this would

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help to halt the decline. The authors discuss differences in interests, motivation and aspirations between the sexes; 'teacher effects' such as question technique and feedback, and go on to recommend strategies for schools and teachers to overcome the imbalance. In a follow-up booklet to the one above, a team from the Institute of Physics (Hollins et al., 2006) provides practical guidance on the encouragement of girls in physics. It draws on the research to identify the barriers encountered by girls, and suggests strategies to overcome these barriers. There is a great deal of literature on gender influences in education, and these two books provide a very positive and practical approach. A further book in this series reviewing the impact of this work in the classroom is due to be published in 2008.

Further reading

Corry, A. (2005) 'Mentoring students towards independent scientific enquiry', in S. Alsop, L. Bencze and E. Pedretti (eds), *Analysing Exemplary Science Teaching.* Maidenhead: Open University Press. pp. 63–70.

Alex Corry describes an 'apprenticeship' approach to developing pupils as scientists who use their existing knowledge to explore and enquire about science. He follows this with a helpful reflection on the process.

Useful websites

Live links to these websites can be found on the Companion Website www.sagepub.co.uk/secondary

Documents relating to the national curriculum can be found via the QCA website at www.qca.org.uk/

The CLEAPSS website is at www.cleapss.org.uk/startfr.htm