Practical Work in Primary Science

Foreword

Photograph by Dave Pratt

What do I really remember about doing science at school? Making a cardboard aeroplane in physics, colourful and explosive experiments in chemistry, looking at the intricate structure of plants and bodies down a microscope in biology. Above all, science is a practical subject. Most of what we know about how the world works was discovered, not by sitting in a chair and thinking hard, but by getting hands-on: pulling things apart, putting them back together, testing out ideas. Practical science is all about 'learning by doing'. Students achieve a deeper level of understanding by finding things out for themselves, and by experimenting with techniques and methods that have enabled the secrets of our bodies, our environment, the whole universe – to be discovered.

So – brains on, hands on, get practical!

Dr Alice Roberts
Anatomist
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"Practical work mirrors the pioneering investigative and exploratory nature of science"

Teacher response to SCORE questionnaire

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Biology Chemistry Physics

Introduction

Hands-on learning experiences are key to the development of skills and the tying together of practical and theory. Good quality practical work can not only engage students with the processes of scientific enquiry, but also communicate the excitement and wonder of the subject.

This booklet has been designed to illustrate a range of reasons why you might do practical work, and to direct you to sources of high quality practical activities for you to use in your classroom. Whilst the focus of this booklet is practical work in primary science, a few secondary level activities have also been included to highlight the importance of transition. The lower secondary activities will be useful for teachers in schools where the age of transition is later than 11, e.g. middle schools. Many primary schools enhance their curriculum provision through links with colleagues in secondary schools, and this can be valuable in helping students through the transition from Key Stage 2 to 3.

There is a wide range of possible purposes for including practical work in science lessons. Any particular piece of work should have its purposes made explicit to pupils if they are to benefit fully from it. If not, there is a danger of pupils seeing practical work merely as a break from the more routine activities of speaking, listening and writing.

The activities chosen here illustrate a range of purposes and highlight different types of practical activity that could be used to teach various topics in the science curriculum. The selections are purely illustrative and we recommend that you take a look at the original sources (particularly www.practicalprimaryscience.org) for further examples, and use the directory at the back of the booklet to help you find an activity to suit your needs.

The experiments have been categorised into Lower Primary (age 4-7), Upper Primary (age 8-11), and Lower Secondary (age 12-14). Often, however, activities can be adapted for use with more than one age group. The activities have also been categorised by purpose, and as you will see in the table, many of the activities fall into more than one category: Investigations including teamwork, Extended enquiry, Challenging existing ideas, Out of the classroom, Use of ICT, The 'messiness' of real data, Stimulating demonstrations, and Developing skills.

We would encourage Science Coordinators to look at what is being offered in terms of practical work within their own institutions and ensure that the full range of purposes are covered. A blank table has been provided that could be photocopied and completed.

"Science without practical is like swimming without water."

Teacher response to SCORE questionnaire

Activities categorised by level and purpose

	Lower Primary	Upper Primary	Lower Secondary	Investigations inc. teamwork	Extended enquiry	Challenging existing ideas	Out of the classroom	Use of ICT	The 'messiness' of real data	Stimulating demonstrations	Developing skills
Primary Science											
Make friends with a tree: Living things	X			X	X		X				
Peace at last: Sound	X			X							
Making sandcastles: Materials	X	X		X					X		
Curtains: Light		X		X				X			
Bone mystery: Living things		X		X	X			X	X		
Design a seed: Living things		X			X		X				
Paper towel magic: Materials		X				X				X	
Bishops can fly: Forces		X		X	X				X		
Colour mixing: Materials		X	X								X
Biology											
No stomach for it			X		X			X			
Biodiversity in your backyard			X	X	X		X	X	X		X
Chemistry											
A matter of balance			X			X				X	
Red cabbage indicator			X		X				X		
Physics											
Bolt from the blue			X				X		X		
Feeling the pressure			X	X	X	X					

Complete this table with your own activities, and assess their purposes

	Lower Primary	Upper Primary	Lower Secondary	Investigations inc. teamwork	Extended enquiry	Challenging existing ideas	Out of the classroom	Use of ICT	The 'messiness' of real data	Stimulating demonstrations	Developing skills

General health and safety guidance

See the health and safety notes in each experiment. The following is general guidance.

Health and safety in school science affects all concerned: teachers and classroom assistants, their employers, pupils, their parents or guardians, as well as authors and publishers.

These guidelines refer to procedures in the United Kingdom. If you are working in another country you may need to make alternative provision.

Health & safety checking

As part of the reviewing process, the experiments in this booklet have been checked for health and safety. In particular, we have attempted to ensure that:

- all recognized hazards have been identified,
- suitable precautions are suggested,
- where possible, the procedures are in accordance with commonly adopted model (general) risk assessments,
- where model (general) risk assessments are not available, we have done our best to judge the procedures to be satisfactory and of an equivalent standard.

Assumptions

It is assumed that:

- pupil behaviour is properly managed,
- schools follow the guidance in ASE '*Be Safe*', 3rd Edition, 2001,
- hand-washing facilities are readily available.

Teachers' and their employers' responsibilities

Under the COSSH Regulations, the Management of Health and Safety at Work Regulations, and other regulations, employers are responsible for making a risk assessment before hazardous procedures are undertaken or hazardous chemicals used or made. Teachers are required to cooperate with their employers by complying with such risk assessments. However, teachers should be aware that mistakes can be made. Therefore, before carrying out any practical activity, teachers should always check that what they are proposing is compatible with their employer's risk assessments and does not need modification for their particular circumstances. Any local rules issued by the employer must always be followed, whatever is recommended in this booklet.

Reference material

Model (general) risk assessments have been taken from, or are compatible with:
ASE Be Safe, 3rd Edition, 2001
CLEAPSS Guide L5p Safe Use of household and other chemicals
And other relevant **CLEAPSS** publications (www.cleapss.org.uk)

Procedures

Clearly, you must follow whatever procedures for risk assessment your employers have laid down. As far as we know, almost all the practical work and demonstrations in this booklet are covered by the model (general) risk assessments detailed in the above publications, and so, in most schools, you will not need to take further action, other than to consider whether any customisation is necessary for the particular circumstances of your school or class.

Special risk assessments

Special risk assessments are unlikely to be needed in primary science. However, only you can know when your school needs a special risk assessment. But, thereafter, the responsibility for taking all the steps demanded by the regulations lies with your employer.

Primary level activities

Introduction

Practical work lies at the heart of primary science. Children need opportunities to develop practical and enquiry skills in order to engage with the world in a scientific way and to make sense of what they are learning about living things, the environment, materials and physical processes. Hands-on experience promotes curiosity and engagement and provides opportunities for the discussion and questioning which develop understanding. Practical work can take place inside or outside the classroom, and can happen at any point in a unit of work or lesson. It may be a five minute demonstration, a short activity to practise using an unfamiliar piece of equipment or an extended enquiry. What it must be is a varied and integral part of the learning process which promotes thinking as well as doing.

Upper primary activities:

Make friends with a tree: Living things
Peace at last: Sound
Making sandcastles: Materials
Curtains: Light
Bone mystery: Living things
Design a seed: Living things
Paper towel magic: Materials
Bishops can fly: Forces
Colour mixing: Materials

"Practical work is doing things with stuff."

11 year old pupil

Make friends with a tree:
Living things

Introduction
This outdoor activity for younger children encourages them to make observations using their senses and respond to the natural world. It develops the vocabulary for describing and comparing which leads to sorting, identifying and classifying living things. It can be developed into an extended study.

It could also be used as an introductory activity for older children.

Lesson organisation
Children work in groups with an adult per group. Older children who can work independently could work in pairs.

For this activity you will need an area with a number of trees of different sizes and species in fairly close proximity to each other. Mixed woodland is ideal but parks or school grounds may also be suitable.

Equipment and materials
- Blindfolds, 1 per group or pair is generally sufficient (see note 1)

Optional:
- Small bags or other containers for collecting leaves, twigs etc
- Crayons or graphite sticks and paper for making rubbings
- Digital camera(s)

Very young children may forget by the end of the activity which tree is theirs. A sketch map or simple way of temporarily labelling the trees will enable the adults to keep a record.

Technical notes and safety
1 If any children show signs of an eye infection they should be given an individual blindfold. Many eye infections are not infectious but those caused by bacteria or viruses are. Note though that such eye infections can be transmitted by one pupil rubbing their eye and transferring infectious organisms to another person on their hand. The school will probably already have procedures in place to avoid any casual transfer from an infected child.

2 When carrying out fieldwork with primary age children follow the guidance and safety code on p32 and 33 of *Be Safe!*

Be aware that some plants are poisonous and others may cause skin irritation if touched. (See *Be Safe!* p31).

Children should not explore their tree using the sense of taste and should avoid smelling blossom if they suffer with hay fever.

Children should wash their hands as soon as possible after the activity and before eating.

3 Explain to the children how to lead a blindfolded child steadily and carefully so that they do not accidentally bump into objects or trip over.

Procedure
a One child in each pair or group is blindfolded and another child leads them, by a roundabout route, to the trunk of a tree.

b They explore the tree by feeling the texture and shape of the trunk and hugging it to feel its size. If there are leaves, blossom or fruits within easy reach these can also be explored.

Their partner or group members can guide them to touch distinctive features which may be useful for recognising / identifying the tree later. Encourage children to describe what they can feel. Children may also notice if any part of the tree has a distinctive smell and can consider the sound made by the wind or their hands moving the leaves. Other children can be helped to prompt them with questions about what they can feel, hear and smell.

c The blindfolded child is then returned to the starting point (again by a roundabout route) and, when the blindfold is removed, is challenged to identify the tree they 'made friends with'. They will do this first by looking at the nearby trees and then by repeating the actions they performed when blindfolded to confirm they have identified it correctly. Encourage the children to describe what they are looking for e.g. 'My tree is thin enough for me to get my arms all the way round and has a knobbly trunk.' 'I am looking for a tree with smooth bark. I had to open my arms very wide to hug it so it is big and fat.'

d When children have found their tree encourage them to add to their previous description by talking about what they can observe.

e Repeat the activity until all children have a tree friend. Children who struggle with the descriptive vocabulary may gain confidence if taken to a tree that another member of their group has already described.

f Practise using the descriptive vocabulary by choosing individuals to describe their tree to the whole class in enough detail that the children who were not in their group can identify the tree.

g To extend the activity back into the classroom children collect leaves, seeds etc preferably from the ground around their tree or, if picking them, carefully and in small quantities so as not to damage their 'friend'. They can also take photographs and bark rubbings. These can be used for further describing, sorting, grouping and discussion activities to extend vocabulary and observation skills. They can also be used to identify the species of tree, although describing rather than naming is the focus of this activity. Children who are working with the same tree can collaborate to make and record further observations.

Teaching notes

This activity can stimulate creative responses through language and art. Children who have made detailed observations and comparisons of colour, texture and shape should be able to respond to the experience by writing poems or with a variety of art media e.g. by using a range of drawing materials, making collages, painting and making plaster casts.

If the trees are in a location which can be visited regularly children can develop their understanding of seasonal change, growth and plant reproduction by observing their tree over the course of one (or more) years.

When working with older children measured data can be collected. Height can be calculated from a photograph of the tree which includes an object of known height (using a metre stick makes the calculations simple) or by use of a clinometer. Younger children can estimate height using printouts of a digital photograph of themselves with their tree. If they cut themselves out of several copies of the picture they can use the cut-outs to estimate how many times taller than themselves the tree is.

Further information

The Woodland Trust www.naturedetectives.org.uk/, Field Studies Council www.field-studies-council.org/ and Science and Plants for Schools (SAPS) www.saps.org.uk are all good sources of identification charts and keys.

Instructions for making and using a clinometer can be found at http://nrich.maths.org/public/viewer.php?obj_id=5382.

Peace at last:
Sound

Introduction
This activity uses a story about all the sounds that keep Mr Bear awake at night to introduce a problem for the children to solve. They identify loud and quiet sounds and find ways to stop sounds from entering their ears. The activity gives young children the opportunity to carry out a simple investigation with a degree of independence.

Lesson organisation
The practical activity is carried out in groups of six. Three children in each group will be the testers, covering their ears with each object in turn. The other three will together make the sound of Mrs Bear snoring. When each tester has evaluated all the objects the children swap roles and repeat the procedure.

Equipment and materials
- A selection of suitable items for covering the ears (1 of each per group) *e.g.* small cushions or bath sponges, hats with ear flaps, ear muffs, headphones, coats with hoods. Children may also want to suggest items.

Technical notes and safety
1 Warn children that it is dangerous to put objects into their ears (except for ear plugs which are made for this). Do not have small objects, which children might use in this way, available during the activity.
2 Children should only cover their own ears not each others.
3 Be aware of children who have any hearing impairment and may have difficulty in participating fully in this activity.

Procedure
a Read the story *Peace at Last* by Jill Murphy. Encourage children to join in with the sounds. Discuss pleasant and unpleasant sounds and times when the children are noisy and when they want peace and quiet.
b Talk about what Mr Bear does to try and find peace e.g. moving from room to room, covering his head with the pillow.
c Ask the children what they can do if a loud sound is bothering them. Suggestions are likely to include various ways of covering the ears.
d Tell the children that Mr Bear would prefer to sleep comfortably in his own bed so he needs something to put over his ears so he is not disturbed by Mrs Bear's snoring. Explain that they are going to test some different ways of covering their ears so they can tell Mr Bear a way which is best for keeping the sound out.
Show the children a collection of objects and materials. Is there anything easily accessible that the children would also like to test?
e Children then work in groups to carry out the investigation.
A demonstration of how to make a realistic snoring sound may be needed.
f When each group has reported their findings write a letter to Mr Bear (individually or as a piece of shared writing) telling him the solution to his problem.

Teaching notes

This activity develops children's understanding that we hear sounds with our ears and that covering them will stop all or some of the sound from going into the ears.

Depending on the age and attainment of the children they may be expected only to identify the best way to shut out the sound or to order the items tested from best to worst.

Fair testing can be introduced by considering whether the children make the snoring sound the same loudness each time.

To make links with music children could use percussion instruments to make the snoring sound.

Making sandcastles:
Materials

Introduction
In this investigation children mix sand and water to find the ideal proportions for making a sandcastle. It promotes discussion as they agree on their criteria for identifying the best mixture. The activity can be used across the primary age range: younger pupils can make observations and simple measurements in a familiar context while older children are challenged by finding more sophisticated ways to collect and present measured data.

Lesson organisation
This activity could be completed in one lesson but may be extended, particularly with older children, to provide the time to explore and try different ideas for data collection. Children work in small groups.

Equipment and materials
Each group will need:
- Tray of dry sand, 1
- Jug of water, 1 (more may be needed if there is not an accessible tap for refilling)
- Small containers for making sandcastles
- A range of equipment for measuring volume e.g. beakers, measuring cylinders
- Other equipment such as a camera, timers / stopwatches and masses may also be requested by the children.

Technical notes and safety
1 Fine sand may blow or be rubbed into the eyes. Sand should be handled sensibly and pupils should be reminded not to touch their eyes.
2 Wash hands after the activity.

Procedure
a Introduce the activity by attempting to demonstrate making a sandcastle using dry sand. Children should recognise that you are unsuccessful because you have not added water. Ask the children how much water you need to add. There is unlikely to be a consensus so the challenge for the class is to investigate 'What is the best mixture of sand and water for making sandcastles?'
b Provide each group with a tray of sand and jug of water. Other equipment should be available for the children to choose. The group will need to discuss how they will judge which is the most successful sandcastle, in order to determine which mixture is best. They will also need to consider how to present their findings clearly to the rest of the class
c Compare the results from each group and discuss the reasons for any differences.

Teaching notes
The investigation question is open enough to stimulate discussion and allow groups of children to make their own decisions about what criteria they will use and what measurements or observations they will make.

Responses may range from a simple ranking of the sandcastles based on appearance, which could be recorded by sketching or using a digital camera, to measurements of how much weight each sandcastle can support. Some methods of data collection will be more successful than others and children should be encouraged to evaluate different methods suggested by the group.

Curtains:
Light

Introduction
This activity encourages children to investigate and find a solution to an everyday problem. They are presented with a letter from an individual, who works nights and is having trouble sleeping through the day, as his curtains do not block the sunlight entering the room. Using the knowledge that an opaque material would be the best for replacement curtains, the children test a collection of different samples, analysing the shadows formed and then recording the light levels with a data logger.

Lesson Organisation
This activity can be carried out in an hour and is differentiated to three ability levels.

The children for all levels work in pairs or small groups and are supported by class teacher and support staff if available.

Equipment and Materials
Each pair or group will need:
- Letter from individual
- Selection of different materials labelled A – H, extras for more able (see note 1)
- Torch (see note 2)
- Shoebox without lid, one end cut away and a white paper screen, stuck inside at the opposite end
- Data logger and probe, if available (see note 3)
- Access to a computer

Technical Notes and Safety
1 Do not make material samples too large, check a complete shadow can be made on the shoebox screen.
2 Check that all torches have working bulbs and strong battery power.
3 Refer to data logger manuals for operating instructions. When recording light levels with the light probe of the data logger the torch, material and sensor must be positioned close to one another, if not touching, depending on strength of torch and sensitivity of the probe.
4 Make classroom as dark as possible by blackening out all windows and switching off lights.
5 Ensure children are aware that they must not shine torchlights directly into other children's eyes.

Procedure
a With the whole class, explain how a letter has been received that morning from an individual of your choice, asking for some help. Go on to read the letter to the class explaining how this individual has a new job working as a security guard at a supermarket on the night shift. Identify how this means he has to sleep during the day. Highlight how the noise is not causing him any problems because the children are at school and his wife is at work, but the light of the spring sunshine is keeping him awake. Explain that he wants to resolve the problem, as he is very sleepy, and thinks the best way is to change his curtains, but he doesn't know what to buy. He has asked that, together, the class investigate the best way to block out the light coming into the bedroom.

b Recall how light is unable to pass through opaque materials and that a shadow is formed. Using this knowledge, discuss how the best type of material for blocking out light at his window would therefore be opaque. Identify how a dark shadow is a sign of an opaque material as no light is passing through. Reveal to the children a selection of different labelled materials that they will be testing. Encourage them to predict which materials they believe will be suitable to block out the light and, of these selections, those they believe will be opaque, or at least translucent.

c Explain to the class that they will work in pairs or small groups to test the different materials, by placing a sample in front of a torch and shining the torch into a shoebox. **Less able** will then record whether they can see a shadow on the screen. **Middle** ability will then record the darkness of the shadow created hitting the back wall of their box (visual judgement not measured data). **More able** will record the darkness of the shadow created hitting the back wall of their box (visual judgement). Then, for the samples which create a lighter shadow, they will go on to experiment by increasing the number of layers of the material to a total of three, to see whether they are able to increase the darkness of the shadow.

d For each of these tests the children can then support their findings by using a data logger to record light levels passing through the sample. All data can be downloaded onto the computer. Pairs can compare their own results for the most opaque material and then all results can be considered for patterns and accuracy. Children should return to their predictions made at the beginning of the lesson and compare these with their findings.

Teaching Notes

This activity relies on the knowledge that an opaque material will block all light and so create a very dark grey shadow, whereas translucent materials block only some light forming a light grey shadow and transparent materials do not stop any light and so no shadow is formed.

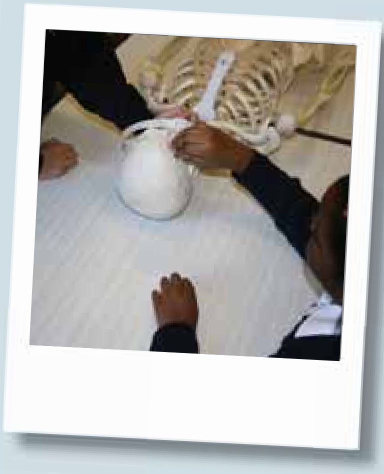
Usually, the higher the reading on the data logger the greater the light level and so this highlights that the material is allowing more light to pass through. This should be checked with the data logger manual.

Children can note their results as a postcard to the individual, highlighting what they have discovered in their tests and what he should put up at his window in order to gain a good day's sleep! This writing can be differentiated according to ability using cloze procedure for less able, questions for middle ability and free writing for more able.

Further Websites

Log It manufacture the Log It Explorer data logger which has internal and external light probes which catch data and are easy to use by children in Key Stage 2.
http://ccgi.dcpmicro.plus.com/DCPMICRO/productt1.php?pr=1

Bone mystery:
Living things



Introduction
This activity presents children with a mystery to be solved when a skeleton is discovered during renovation work at a local site of historical interest. It requires children to make decisions about what data to collect, to measure accurately and to find patterns in their data. They will use their knowledge that the skeleton grows until adulthood.

Lesson organisation
This activity takes place over two lessons: one for planning and obtaining data, the second for presenting the data and drawing conclusions.

Measurements will need to be taken from children of different ages and from adults. Arrangements will need to be made with colleagues to ensure minimal disruption of lessons.

Children work in pairs to make the measurements. You may wish them to work in larger groups when planning the investigation so that 2 or 3 pairs can combine their data into a larger total sample.

Equipment and materials
- Letter / news report
- Model skeleton or ICT / paper images of a skeleton (see note 1)
- Selection of rulers, metre sticks and tape measures, enough to allow a choice for each pair of pupils. Calipers may also be useful if available
- Spreadsheet or graphing software (optional)

Technical notes and safety
1 If a model is not available an archaeologists report, with data about the skeleton, should be used.

Procedure
a Introduce the activity with a letter or news report about the discovery of a skeleton buried at a local historical site. It is clearly ancient but, as yet, archaeologists have very little information about it. The task for the class is to try to determine what age the individual was when they died. In order to answer the question the children will need to make comparisons between the skeleton and people of various ages in their school. The bones have been disturbed and have not yet been reassembled into a whole skeleton so children will have to make measurements of individual bones. No measurements are available yet but assure the pupils that the archaeologists will send these by the time of their next lesson.

b Using a model skeleton or suitable images discuss what measurements it would be possible to take from a living person in order to make comparisons with the skeleton. Pairs or groups of children decide what measurement to take and plan their investigation. They then make and record the measurements.

c In the second lesson the data is presented as a bar chart grouped by class or age or as a scattergraph with age plotted against bone measurement. This can be done using ICT. Discuss patterns in the sets of data.

d Reveal to the children that the archaeologist's data about the skeleton has now arrived. This will either be in the form of measurements on a table or diagram or, if a suitably sized model skeleton is available, as a reconstruction of the actual skeleton.

Children compare the measurements of the skeleton with their own findings and decide on the likely age range of the mystery individual. Older or more able children can use combined evidence from different measurements to report an overall conclusion to the archaeologist.

Teaching notes

When planning their investigation you may want to prompt pupils to consider and justify some or all of the following decisions (depending on age and ability):

- What measuring equipment to use
- Where exactly to measure to and from on each person
- Which year groups to sample – do they need to choose all years to find a pattern
- How many people in each year group to measure
- Whether they need the same numbers of boys and girls
- How they will choose which children in a class to measure – the tallest, the shortest, a random selection
- Which adults to measure.

If doing this investigation for the first time, without a model skeleton, you will need to look at the data collected by your pupils in order to choose suitable measurements to include in the archaeologist's report for the second lesson.

Children may also consider evidence that people in the past were, on average, shorter than we are now. How might this affect their conclusion?

The mystery can be further extended into cross curricula work by introducing evidence which allows children to draw further conclusions about when the person may have lived and who they might have been.

Design a seed:
Living things

Introduction
This activity involves designing a seed, which has come from a newly discovered plant. It stimulates discussion on how the seeds are dispersed as well as providing a link to the topic of germinating and growing seeds. It requires some creative thinking and also gives opportunities for developing literacy and presentation skills.

In order to be successful pupils will draw on knowledge and understanding gained through fieldwork, making close observations and drawing conclusions. They will have:
- observed and collected fruits and seeds from local habitats;
- learned about the reason why seeds need to be dispersed away from the parent plant and the main groups of dispersal mechanisms (animal, wind, water and self-dispersal);
- made careful observations of fruits and seeds and used these to decide how each one is dispersed.

(see website references for sources of further ideas for the activities above)

Lesson organisation
Children work individually or, to promote discussion and reduce the resource demand, in pairs.

Equipment and materials
- A range of junk and modelling materials which may include small boxes and other containers, a range of papers and card, components for technology projects, fabric, feathers and other trimmings, pipe-cleaners, hooks, Velcro, balloons, plastic bags, bubble wrap etc
- Tape, glue, string etc
- Scissors and other tools as required

Technical notes and safety
Although nothing in the activity suggests eating seeds, and berries, the activity does provide an opportunity to remind pupils that fruits, which birds and other animals enjoy eating, may be very poisonous to humans. Nothing must be eaten without the permission of the adult in charge. A list of commonly found hazardous plants can be found on p31 of *Be Safe!*.

Procedure
a Suggest to the children that they are going on an expedition to look for new plants and bring back some seeds from these plants. Ask the children to make a drawing of the plant they discover and give its name. (You can let them discuss how scientists name new plants when they are found.)

b Review the different ways in which plants can disperse their seeds. Then ask the children to make a magnified drawing of a seed from their plant and explain how they think it is dispersed.

c From their design, let them make an enlarged version of their seed, using junk materials.

Teaching notes
This provides an opportunity for extended enquiry if, as children are designing and making their seeds, they are encouraged to carry out further observations and investigations using the seeds collected in previous lessons. However, children need not necessarily be constrained by the examples they have observed; their expedition may take them to places where seeds fly, walk or appear to roll on wheels. The possible outcomes of this activity are limited only by the children's imagination and the range of materials available. Some examples of seeds designed by children can be found in the original source publication for this activity (see below).

Further information
Adapted with permission of Science and Plants for Schools (SAPS) and Field Studies Council (FSC).
(See www.field-studies-council.org/publications/pubsinfo.aspx?Code=OP107 *and for further information of what SAPS offers* www.saps.org.uk

Paper towel magic:
Materials

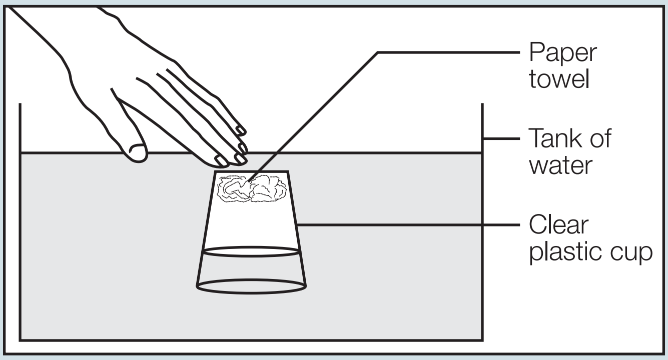
Introduction
This is a demonstration to help pupils understand, as part of an introduction to gases, that there is air occupying all the 'empty' spaces around them and that it has volume.

Lesson organisation
This is a short introductory activity. Depending on the prior experiences of the pupils it can be demonstrated as a 'magic trick' or presented as a 'challenge activity' with the 'trick' as the solution. You may also wish to give pupils the opportunity to try the activity for themselves afterwards.

Equipment and materials
- Clear plastic cup(s)
- Paper towels (or similar)
- Transparent bowl or tank of water, deeper than the cup

Technical notes and safety
Make sure the paper towel is pushed securely into the bottom of the cup and the cup is vertical as it is lowered into and lifted out of the water.

Procedure
a Show the tank, cups and paper towels to the pupils. Challenge the pupils to put a scrunched up paper towel into the water and bring it out dry. Let them demonstrate some of their ideas.
b If anyone is successful proceed with the discussion. Otherwise, scrunch a paper towel into the bottom of a dry cup. Invert the cup and lower it into the water until it is completely submerged. Lift it out and ask pupils to check that the towel is completely dry.
c Ask the pupils to talk with a partner and then discuss as a class how the 'magic trick' was done. Repeat the demonstration as necessary during the discussion to support further observation and explaining.



Teaching notes
Some pupils will realise quite quickly that the air in the cup is stopping the water from reaching the towel. Others will need to see the cup being tilted, releasing bubbles of air, and watch the water rise to replace the air inside the cup before they can explain how the 'magic trick' works. A small amount of water rising in the cup before any air has been released demonstrates that air can be compressed

Possible questions:
What is in the cup?
Is anything else in the cup?
What can you see when the cup is underwater?
Can you see any water in the cup?
What is stopping the water going into the cup?
How can I show there is air in the cup?
or What will happen if I tilt the cup?
What has happened to the towel now?

Bishops can fly:
Forces

Introduction
The initial problem solving challenge to make a piece of A4 paper float across the classroom leads to the systematic exploration of the physical and material phenomena of balance, friction, forces, gravity and the properties of common materials. The activity starts with a problem solving approach and then with further exploration leads to the identification and testing of trends and patterns, followed by the communication of the processes used and tentative explanations developed.

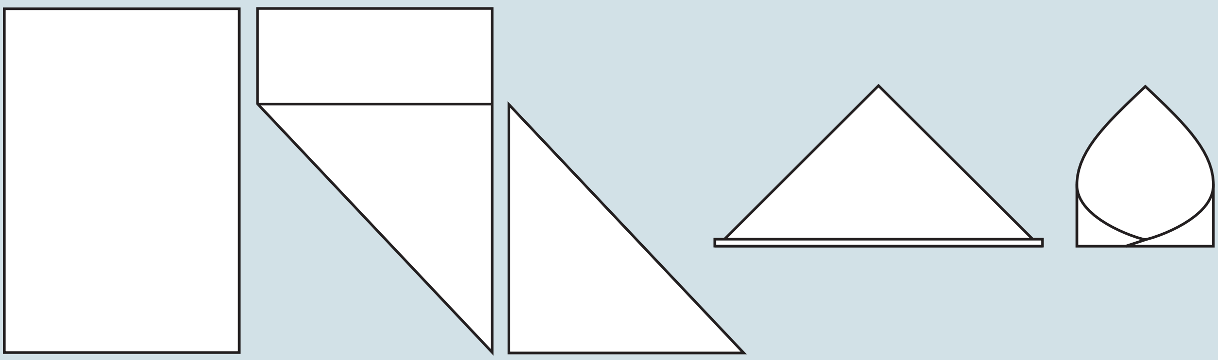
Lesson organisation
The introductory activity and exploration involve students working individually with their own paper model. This leads to an investigation where they work in small groups of not more than three.

Equipment and materials
- A4 paper, several sheets per pupil
- Scissors
- Paper clips
- Rulers

Technical notes and safety
If students are investigating releasing their model from above their own height (not essential but may be part of exploratory activities) they should stand on PE or playground equipment and not classroom furniture. (Refer to *Be Safe!* p12)

Procedure
a Setting the problem
Quite simply the students are challenged to make a piece of A4 paper float across the classroom. They are allowed to cut and fold the paper in any way they wish but are not allowed to apply any force when releasing the paper. The only forces that can act on the paper as it falls are gravity and the resistance caused by air particles. The students spend at least 5 minutes exploring a number of options but invariably admit they need help.

b Making the model
The students are shown how to make a Bishop's hat by folding and cutting the paper to form an isosceles right angle triangle and then folding the hypotenuse twice inwards thinly like folding a scarf, before joining the ends to form a mitre or Bishop's hat.



All the students are required to make a model that works. The model is held horizontally near the tail with the tail on the underside of the model and released. As it falls the Bishops hat will gently glide across the classroom.

c Exploring the model and its flight pattern

Time needs to be spent making a range of Bishop's hats exploring ways to improve the flight pattern, direction and distance, by changing the centre of balance, by adding paper clips or the flow of air, by folding the tail up and down. Following this exploration a discussion of what is involved when the paper floats across the room is conducted including:

- Talking about the movement through the air /and resulting air flow
- Identifying the manner in which the model moves.
- Identifying some questions using the lead, I wonder what will happen if …?
- Making a list of questions that could be investigated.
- Identifying one that the whole class can complete.

d As a class investigate

"I wonder what will happen to the flight pattern if I change the way the air flows over the tail by changing the shape of the tail?"

Depending on their experience the students, in small groups of no more than three, can plan a simple investigation to identify the effect changing the tail has on the flight pattern. It may be appropriate to introduce the notion of multiple testing when looking for patterns and the use of symbols to communicate what has been observed. For example the students could draw symbols to show the fold in the tail and a curve to show the glide path. The students will test their models a number of times and as a class build up a table to highlight patterns.

The teacher could use one group's results and record them in pictorial form on the white board or large sheet of paper. (See example in teaching notes).

In a class discussion ask the student to identify inferences that can be drawn from these patterns that can retested or evaluated and then turn the inferences into explanatory statements like "when the tail is folded down the flow of air is changed and it causes the flight pattern to change" or "with our models it makes the model fall directly down". If the students have not made the connection to aircraft and birds this would be a suitable time to link this experience to other similar situations.

e Finally discuss the activity from a science perspective; 'What makes this activity a science activity?', 'What conventions of science activity have been applied as we have completed this exploration?'. For example, a scientific idea is an idea where the evidence supporting the idea has been tested and this testing can be replicated and scientist use symbols to record and communicate data and ideas.

Teaching notes

Example results table:

Exploring flight patterns / glide paths of Bishop's hat when tail shape is changed				
Tail shape	**Test 1**	**Test 2**	**Test 3**	**Test 4**
				

Colour mixing:
Materials

Introduction
This activity presents a simple 'interview challenge' which requires the scientific skill of measuring using a graduated cylinder.

It is designed to develop the children's ability to measure volumes of liquid, interpret data and follow directions. Although this activity for older pupils develops measuring to a high level of precision it can be adapted for younger children by scaling up quantities and using larger containers or measuring cylinders with larger divisions / graduations.

Lesson organisation
Children work in pairs.

Equipment and materials
For each group of 2:
- Challenge sheet (see note 1)
- Red, yellow and blue liquid (see note 2)
- Beakers, 3 (to hold red, yellow and blue liquid)
- Large test-tubes (boiling tubes) (50 ml), 6 (see note 3)
- Test tube rack
- Graduated measuring cylinder (25 ml) (see note 4)
- Graduated measuring cylinder (10 ml) (see note 4)
- Plastic pipette, 1 (see note 5)
- Plastic cup, 1, for rinsing between colours
- Water wash bottles (optional)

(Some equipment may be borrowed from a local secondary school)

Technical notes and safety
1 The challenge sheet is the student worksheet. It has the 'challenge', procedure, and results table. See the procedure for details.
2 Fizzy colour tablets, like those from TTS are good as they do not stain.
3 For younger children, or if large test-tubes (boiling tubes) are not available, use small plastic cups. Test tubes and boiling tubes are glass but are generally robust. However, explain to the children what to do if a tube becomes broken e.g. by being dropped onto a hard floor. Explain that they must not try to pick up any broken glass themselves but must report the breakage to the teacher.
4 Use plastic graduated cylinders.
5 Inexpensive disposable type plastic pipettes can be washed.

Procedure
a Children are read the 'challenge' from the challenge sheet:
'I would like to take this opportunity to welcome you to the Southside Medical Technology Company.
If you pass this stage, you will be offered employment at SMTC. As part of our selection process to find the very best candidate possible for employment in our company, we give each applicant who reaches the third round in our selection process a test. This test is based on a person's ability to *measure different substances, interpret data and follow directions*. Below you will find the directions to this test. We wish you the best of luck and hope you have the abilities we are looking for in our employees.'

(OPTIONAL – if you have water wash bottles:)
'Any time you want to "rinse" a piece of equipment use a water wash bottle. Your teacher will tell you how. Contaminated liquid is disposed of in the plastic cup.'

b Pupils then follow the procedure (also on the challenge sheet):

1 Label 6 test tubes in order: A, B, C, D, E & F.
2 Measure 22 ml of RED liquid from the beaker and pour it into test tube A.
3 Measure 14 ml of YELLOW liquid from the beaker and pour in into test tube C.
4 Measure 18 ml of BLUE liquid from the beaker and pour in into test tube E.
5 From test tube C, measure 3 ml and pour into test tube D.
6 From test tube E, measure 6 ml and pour into test tube D. Swirl test tube D.
7 From test tube E, measure 3 ml and pour into test tube F.
8 From test tube A, measure 6 ml and pour into test tube F. Swirl test tube F.
9 From test tube A, measure 7 ml and pour into test tube B.
10 From test tube C, measure 2 ml and pour into test tube B. Swirl test tube B.
11 Record the colours you have made on the worksheet table.
12 If time permits measure each coloured liquid and record in the table.

c The children record their results in a table where they can record the final colour and the amount of liquid in each test tube.

Data Table: Test Tube Observations (don't forget units)

Test-tube	Final colour	Volume of liquid (ml)
A		
B		
C		
D		
E		
F		

Teaching notes

Pre-lesson:

Before starting the scientific skills challenge children need to become familiar with graduated cylinders and the various scales on 25 ml and 10 ml graduated cylinders. Scale markings can be drawn on the board. Children also need to know how to use a pipette.

Simple challenges can help children develop the skills to use a pipette: making a line of single drops on a plastic container lid or piece of cling film, picking up drops using the pipette, adding one drop to an existing drop.

Similar challenges can be set using graduated cylinders: using the 10 ml cylinder can they make exactly 25 ml using 10 ml +10 ml +5 ml (the amount in the 25 ml cylinder will act as a self check), can they fill the 25 ml cylinder with 17 ml of water (the pipette can be used to take away or add liquid and this will be useful in the main activity)?

During the main activity:

How will they label their test tubes (small pieces of paper on the table)? Why is marking or covering the test tubes with paper labels not a good idea (labels could hide the contents)? What strategies can they use to keep track of where they are in the challenge (mark off numbers as they go)?

Children collect the equipment they need but are not allowed to start until the teacher does an equipment check. Read through the list and when finished let groups get anything they are missing.

Children work independently to complete the challenge. Encourage rinsing of equipment to decrease cross contamination of colours.

At the end the teacher can do a quick accuracy check, each test tube should end up with the same amount, 9 ml. A more precise ‘quick check’ can be done by pouring all the colours in a graduated cylinder. The total should add to 54 ml. Alternatively, the teacher can get the children to check each others test tubes and totals.

Biology

The science of the life processes and habits of all living things, from tiny single cells to whole organisms and how they interact with each other and their environment.

Introduction

Students come to understand how living things behave through opportunities to engage in practical activities. Biology involves making sense of complex systems at the level of cells, organisms and whole ecosystems. Often biologists have to devise models that isolate individual processes for closer study, have to control the many variables in a system to see the effect of each more clearly, or have to study changes over long time scales. A successful biologist will master key ideas in chemistry and physics, and use mathematical tools for interpreting and analysing data. Much of what students learn in biology is directly applicable to their own lives, as a growing understanding of other living things helps them to learn about the human body and the wider environment.

Secondary biology experiments:

No stomach for it:
Modelling the effect of antacid medication
Biodiversity in your backyard:
Fieldwork using your school playing field

"We enjoy science when it's practical and we get to do stuff rather than just sit there, I learn more because we've done it ourselves rather than just reading about it"

Y9 students taken from *'Learning to Love Science: Harnessing children's scientific imagination – a report from The Chemical Industry Education Centre, University of York; Cliff Porter and Joy Parvin*

No stomach for it:
Modelling the effect of antacid medication

Introduction
This practical has been developed with support from the British Pharmacological Society and the Physiological Society. Pupils monitor the changing pH of a sample of dilute hydrochloric acid as doses of over-the-counter antacid preparations dissolve. Typical doses of a range of over-the-counter antacid preparations (powders, tablets and liquids) are added to a volume of dilute hydrochloric acid that models the volume and concentration of our stomach contents. Pupils monitor the changing pH, and compare the effects of different preparations and discuss the short and long-term consequences of using each medicine.

Lesson organisation
Organisation may depend on the number of pH probes and meters you have, or the range of antacids you want to try. Students working in pairs would each be able to investigate one or two antacids.

Apparatus and Chemicals
For the class – set up by technician/ teacher:
- Hydrochloric acid, dilute, 0.01 mol dm^{-3}, 100 cm^3 for each antacid for each working group (refer to Hazcard 47A and note 1)
- Universal indicator solution, in dropping bottles (note 2)
- Antacids, with details of dosage from packaging

For each group of students:
- Beaker, 100 cm^3, 2 per antacid to be tested
- Mortar and pestle
- Measuring cylinder, 100 cm^3

Technical notes and safety
1 Hydrochloric acid is described on Hazcard 47A as irritant at concentrations above 2.0M, causes burns and is irritating to the respiratory system. The acid used here is much more dilute and presents a minimal hazard to students.
2 Universal indicator – see Hazcard 31 and Recipe card 32. The bottled solution is highly flammable.

Procedure
SAFETY: Take care when making up the dilute acid.

Preparation by the teacher

a Make up the dilute hydrochloric acid by serial dilution (1 in 10, twice) from 1 mol dm^{-3} acid. (See note 1.)
b Copy (and enlarge if necessary) the details of typical doses of antacids from the packaging.
c Set up a few beakers of 50 cm^3 of water with indicator to show what a neutral pH would look like.

Investigation

d Measure 50 cm^3 of dilute acid into each of two beakers and add enough Universal indicator to get a clearly visible colour. (See note 2.)
e Sit both beakers on a sheet of white paper.
f Keep one beaker for comparison as small changes in the acid pH range can be hard to see.

g Add a normal dose of antacid to the other beaker and watch the colour change. If the antacid is in tablet form, crush the tablet in a mortar with a pestle before adding to the acid.
h Repeat with other antacids.
i Decide which antacid is making the greatest change, or the quickest change. Record any other observations – such as effervescence.
j If using a pH probe, plot a graph of pH against time over 10-15 minutes.

Teaching notes

The approximate relaxed volume of our stomach is 50 cm^3, but it is able to expand to nearly 4 dm^3. The lowest pH of secreted acid is about 0.8, but it is diluted in the stomach to an ideal pH of around 1.4. The stomach secretes acid to produce the optimum pH for the action of pepsin. An excess of acid is sometimes produced, which results in acid indigestion (in the short term) or could result in ulceration of the stomach lining (if high concentrations of acid persist). Antacids have been developed to treat short-term excesses. Other pharmaceuticals are used to treat long-term imbalance of acid production.

Students may be surprised how little the pH changes when the antacid is added.

It is interesting to compare liquids with powders, and to see just how slowly an uncrushed tablet reacts.

There are ingredients other than antacids in many over-the-counter preparations that have an effect on indigestion. Some include a mucilaginous component that coats the stomach lining and may protect the lining tissue from damage by acid. This could lead into a more detailed exploration of the structure of the stomach and the different tissues that make up the organ.

Discuss the issues associated with long-term use of antacid preparations. Ideas are listed below.

- Pepsin operates best at acid pHs, so using antacids before meals, or immediately after, could reduce the rate of digestion.
- The body has many mechanisms that maintain balance. Is it possible that taking antacid medication regularly would, in fact, stimulate the gastric lining to make more acid to restore normal pH?

Further information

www.rsc.org/education/teachers/learnnet/pdf/LearnNet/rsc/Kev51-60.pdf

This is from the RSC's '*Classic Chemistry Experiments*' – a formal titration of preparations of indigestion tablets with hydrochloric acid. You could use this as a more quantitative extension activity linked to the above investigation.

Biodiversity in your backyard:
Fieldwork using your school playing field

Introduction
Introduce the core fieldwork technique of random sampling with quadrats in your school grounds. Random sampling allows you to make an estimate of the populations of different species in any area. It should eliminate sampling bias introduced by the sampler selecting areas that look interesting or easier to count. Develop an understanding of plant biodiversity in the grassland typical of school playing fields. Use the Field Studies Council key *Playing field plants* to identify the species that you find. Students are often surprised by the biodiversity in an area they think of as ‘grass’. There is scope for students to develop and investigate hypotheses about plant distribution based on observations and measurements of factors such as soil, moisture, light intensity and wind speed. Observations of human or other animal activity in the area, and background information about the characteristics of common playing field plants, provide further starting points for developing hypotheses to test over short or long time scales.

Lesson organisation
Students working in groups of three (or four) can each take a role in the survey. Depending on your students, it should be possible to carry out your survey of one or two areas of the school grounds in one lesson. Then, presenting and analysing the results could be completed in the next lesson. Collecting data to investigate hypotheses might be spread over several weeks. Each time the students survey the area, they will be more efficient as they become more familiar with the technique and the species present.

Apparatus and Chemicals
For the class – set up by technician/ teacher:
- Tape measure, 20 m, 2 (or string marked into metres)
- Number cards, 1-20, in each of two bags (or bowls or buckets)
- OR 20-sided dice, 2 (ask someone who plays war games or fantasy role-play games)
- Pinboard, or sheet of cardboard (for step 1) with sticky tape or pins to attach plants to the board

For each group of students:
- Quadrat – a wire frame 0.25 m x 0.25 m, or 0.5 m x 0.5 m
- Key to plants – see links
- Clipboard, 1
- Pencil, 1
- Record sheet – devised by teacher or students

Technical notes and safety
1 Choosing your quadrat: A quadrat, not a ‘quadrant’, is a frame used for sampling an area and it is usually square. Smaller quadrats present a smaller number of species to be identified. However, groups taking 10 samples each with 0.5 m x 0.5 m quadrats will collect information about a more significant sample of the area.
2 Refer to the supplementary risk assessment (SRA 08) dated October 2006 from CLEAPSS for more details of hazards and control

measures for working outdoors. This risk assessment advises that it is important to consider the following.

a How students are likely to behave when working outdoors, and suggests that the normal ratio for classrooms or laboratories may not be adequate to ensure safe working outdoors.

b Provision for hand washing needs to be readily available whenever plants and soil are handled. You might consider the use of alcohol gels or other hand sanitisers with paper towels.

c The low risk of diseases such as toxoplasmosis and toxocariasis from plants and soil contaminated by cat or dog faeces. Covering any cuts and grazes and ensuring that children do not eat snacks or sweets while working outdoors as well as confirming thorough hand washing reduce this risk.

d The possibility of allergic reactions to substances encountered outdoors, such as pollen, plant sap, contact with leaves, insect bites and stings or some hairy caterpillars. Be alert to the development of any allergic reactions or asthma symptoms and deal with them according to your school's normal policy.

e The risk of sunburn on sunny summer days if exposed for more than 20-30 minutes.

f Risks of injury when using and carrying tools or heavy loads of unfamiliar equipment which should be assessed for each individual in the specific environment.

g Hazards such as building rubble, pot holes in the ground, unsafe structures or items such as broken glass and other 'litter' that could be hidden in grass or soil. Check the area in advance and be aware of any such risks that could cause wounds or cause children to trip and fall. Remove the hazards or identify them with warning signs and keep children away from them.

3 Sample size: You can test whether your sample size is big enough by comparing the results from two groups sampling the same area. If their results are very similar, your sample size is big enough to be a good estimate of the populations in the area.

Ethical issues

It is useful to consider how the act of surveying the area and collecting plants might damage or change the environment surveyed. Although this is probably not an issue for a school playing field (which is regularly mowed and trampled in normal use), it would certainly be an issue for a natural or 'wild' area.

Procedure

SAFETY: Make a full risk assessment for the outdoor activity and put in place any necessary control measures.

Preparation

a Check the area where you will be working for hazards.

b Make a preliminary survey yourself to identify the most common plants (other than grass).

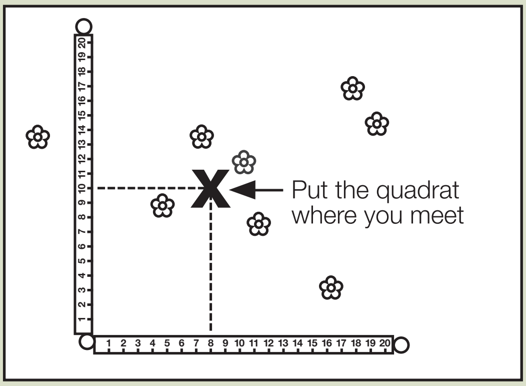
c Collect your equipment together and check it for hazards such as sharp edges. Consider attaching tags of brightly-coloured electrical tape to make it easier to locate equipment that gets 'lost' on the site.
d Organise your students in groups of three (or four) and identify their roles in the group.

Step 1: Preliminary observations

a Stand in the area to be surveyed and make a simple plan drawing of key features – the direction of north, any nearby buildings, large plants (trees and shrubs), favoured paths across the area, slopes etc. Include information about the use of adjacent land and think about whether the site is open and exposed or sheltered by a belt of trees or buildings.
b Make a note of any clearly visible features in the 'grassland' vegetation, such as areas of flowering plants, worn grass or darker vegetation.

Step 2: Identifying what species are present

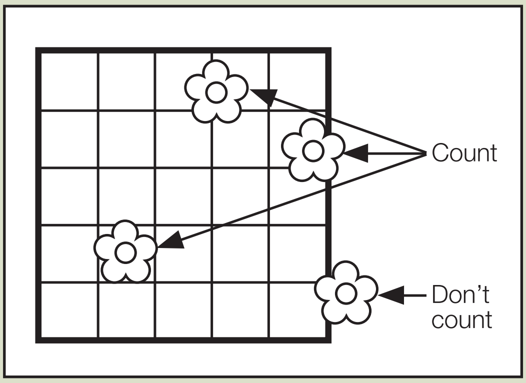
c Give the students a quadrat per group. Place the quadrat on the ground and ask students to look closely at the plants and see how many different plants they can see.
d Develop vocabulary to describe the differences between plants – for example key botanical features such as leaf veins, sepals, or the arrangement of flower clusters, and the shapes of leaves, the patterns of attachment of leaves to stems, the habit of the plant (ground-hugging, creeping, rosette etc). The table on the inside of the FSC key Playing field plants will guide such observations and allow students to use them to identify the main species of plants.
e Collect samples of the five most common plants (other than grass). Write their names on the board and ask each group to bring and attach a sample of each plant to the board.



Step 3: Sampling the area – a random sample

f Lay out your tape measures (or marked string) at right angles along two edges of the area to survey. Lay the two bags of numbers near the point where the tapes meet.
g With students working in threes, ask one student to hold the quadrat, a second to pick a number from the bag on one line, the third to pick a number from the other bag on the other line. Then, the students who have numbers should replace the numbers and walk to that number on their line. The student with the quadrat uses their colleagues as place markers and places the quadrat where it is in line with both of them. Then all three can work together to identify the species in their quadrat and record the results.

h Send two students back to the bags on the lines to pick more numbers and randomly select the next quadrat position. Repeat step **g**.



i Each group should assess the contents of around 10 quadrats to get a reliable estimate of the species distribution.

Step 4: What to record

j In a preliminary investigation, or with younger students, a presence or absence of each species in each quadrat may be enough information. You can then collate the results to show the percentage of quadrats in which each species was found, which will give you a relative abundance of each species.

k With older students, or to provide data you can analyse with mathematical tools, you will need to estimate and record the number of plants of each species in each quadrat or the percentage cover of each species in each quadrat.

Step 5: Analysing the results

l Use a spreadsheet to analyse the results and produce bar graphs or other plots of the data collected.

m The simplest analysis would be of the percentage of sample quadrats that each species appears in.

n If you have information about frequency (or percentage cover) you can calculate the average frequency (or average percentage cover) of each species for each area sampled.

Teaching notes

It can be very rewarding with younger students simply to open their eyes to the diversity of plant species under their feet. Developing observational skills and learning which features of plants are important when distinguishing one species from another are significant basic skills.

The detail of the data you gather will depend on the investigation you are exploring.

A 20 m x 20 m survey area covers 400 m^2. A 0.25 m quadrat covers one sixteenth of a square metre and a 0.5 m quadrat covers one quarter of a square metre. So, with 10 groups collecting data from 10 quadrats each (100 quadrats surveyed), the group will have sampled 6.25 m^2 with 0.25 m quadrats (about 1.6% of the area) or 25 m^2 with 0.5 m quadrats (6.25% of the area). (See note 3.)

A random sample will give you some descriptions that characterise an area. So it is useful if you want to compare two contrasting habitats. You could make random samples on two different areas of grassland in the school – such as the playing field and any open areas that get less foot traffic, or two different parts of the playing field to see if there are any differences.

It is possible using the method here for selecting your random sample point that two groups of students will survey the same square metre. For introductory exercises this should not pose a problem, but for more thorough investigations you could keep track of the areas sampled and ensure you do not survey any sample square twice.

There are several methods of quantifying biodiversity – apart from comparing a simple list of the number of species identified in each area. One measure is 'species richness'.

Here is an example of a simple record sheet that you could use for your field survey.

	Species present										
Quadrat number											
1											
2											
3											
4											
5											
6											
7											
8											
9											
10											
	Numbers / percentages in each quadrat										

Others include 'range-size rarity' and 'taxic richness'. See links below, or make a wider internet search.

You could survey to answer questions such as: Are there more daisies in mown or unmown grass? Is there more ribwort plantain where the grass is less trampled? Alternatively, after identifying differences in distribution of species between two areas, you can start to develop hypotheses that might explain the different distributions. These might depend on being able to collect further data about the areas. For example: Is the soil wetter where we find more buttercups?

You could collect and collate information about the plants in the field and maintain a database of distribution information (with photographs) over a number of years.

This kind of random sampling will probably not reveal any trends or changes across an area (such as differences near to or far from a regular walkway where plants are trampled). However, there are systematic sampling techniques that allow you to investigate changes along a line from one part of an area to another – such as a line transect or a belt transect. A good guide to ecological techniques will explain these techniques in more detail.

An example of a simple record sheet that you could use for your field survey is shown.

Some questions to think about:

1 What are the 5 main species in each area?

2 What do you think are the reasons for any differences?

3 How would you investigate these differences further?

4 What has surprised you most about the diversity of plants on your school playing field?

Further information

www.field-studies-council.org/publications/pubsinfo.aspx?Code=OP97

Details of the Field Studies Council key to Playing field plants. This will be a great help in identifying the main plants and provides supplementary information about the plants to support hypothesis development and suggestions for further work. (Last accessed November 2008.)

www.field-studies-council.org/outdoorscience/diy.htm

Part of the London Outdoor Science project – with details of how to make and use your own fieldwork equipment. (Last accessed November 2008.)

www.field-studies-council.org/resources/index.aspx

The index to all the Field Studies Council on-line resources. (Last accessed November 2008.)

http://internt.nhm.ac.uk/eb/homepage.shtml

This is the homepage for a project called Exploring biodiversity (dated 2001) on the Natural History Museum (London) website. It includes interactive models that explain how to calculate species richness, range-size rarity and taxic richness. You will need to log in using Internet Explorer to view these pages. (Last accessed November 2008.)

Chemistry

The science of materials, their structure, physical and chemical properties, and how they interact.

Introduction

Chemistry is about the study of atoms, how they interact, the structures they form and the materials they make. Practical activities provide opportunities for students to explore the chemistry of materials, and observe patterns in reactions. They can also be used to demonstrate the applications of chemistry, increasing its relevance to students. Practical work is vital in the development of students' skills of manipulating and handling apparatus and data, working with others, and scientific enquiry. They can also provide opportunities for students to collect their own data and use this to apply and develop mathematical skills. Chemistry demonstrations should be exciting and stimulating and some of the most memorable experiences that students will take from science.

Secondary chemistry experiments:

A matter of balance:
The combustion of iron wool
Red cabbage indicator:
Making a pH indicator

> "What was missing from my primary science experience was fun experiments to hold children's attention"

Student response to Student review of the science curriculum, 2003

A matter of balance:
The combustion of iron wool

Introduction
Iron wool is heated in air on a simple ‘see-saw’ balance. The increase in mass is seen clearly.

Lesson organisation
This demonstration takes around 5 minutes once it has been set up.

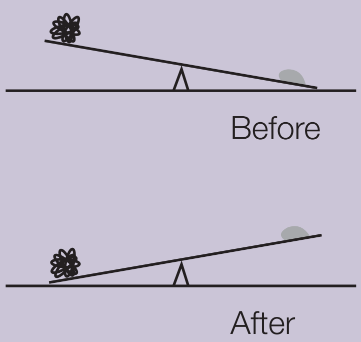
Apparatus and chemicals
For one demonstration:
- Eye protection
- Bunsen burner
- Heat resistant mat
- Wooden metre rule (see note 1)
- Aluminium cooking foil, about 10 cm x 10 cm
- Retort stand, boss and clamp
- Plasticine, few grams
- Knife edge, triangular block or something similar
- Steel wool (**Low hazard**), about 4g

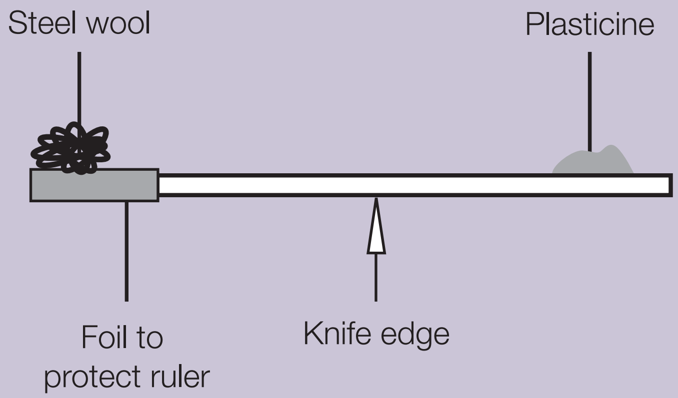
Technical notes and safety
Steel wool (**Low hazard**) Refer to CLEAPSS Hazcard 55A

1 A shallow groove cut across the width of the ruler at the 50 cm mark will help when balancing it on the knife edge. Cover the end of the meter ruler with foil to protect it from the Bunsen burner.

Procedure
a Cover one end of the metre ruler with foil to protect it from the Bunsen burner. Take about 4 g of steel wool and tease it out so that the air can get around it easily. Use a few of the strands to attach it to the end of the ruler.

b Balance the ruler on a knife edge or triangular block at the 50 cm mark. Weight the empty end with plasticine until this end is just down (see the diagram). This part is critical.





c Place a heat resistant mat underneath the steel wool.
d Wear eye protection. Light the Bunsen burner and heat the steel wool from the top with a roaring flame. It will glow and some pieces of burning wool will drop onto the heat resistant mat. Heat for about a minute by which time the meter ruler will have over-balanced so that the iron wool side is down.

Teaching notes

As you are setting up, ask the students whether they think the iron wool will go up, down or remain the same. Many will predict a weight loss.

If fine steel or iron wool is used then it may be possible to light it using a splint.

Equation:

Iron + oxygen $\longrightarrow$ iron oxide

$2Fe(s) + 3/2\ O_2(g) \longrightarrow Fe_2O_3(s)$

This demonstration could be complemented by a class experiment such as 'The change in mass when magnesium burns' which can be found at www.practicalchemistry.org.

Red cabbage indicator:
Making a pH indicator

Introduction
A pH indicator is a substance which has one colour when added to an acidic solution and a different colour when added to an alkaline solution. In this experiment pupils make an indicator from red cabbage.

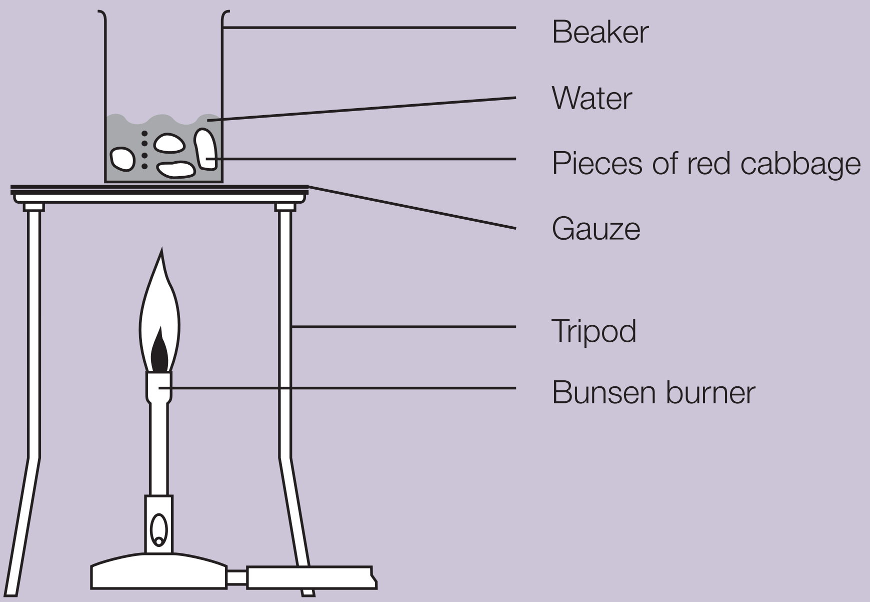
Lesson organisation
The experiment is in two parts. The first part involves boiling some red cabbage in water. In the second part the students test their indicator. Between the two parts the mixture must be allowed to cool. The first part takes about 10 to 15 minutes. The cooling takes about 15 minutes and the testing less than 5 minutes.

The cooling period could be used as an opportunity to discuss the background to the experiment – see Teaching notes below.

Apparatus and chemicals
- Eye protection for all

Each working group will require:
- Beaker (250 cm^3)
- Bunsen burner
- Tripod
- Gauze
- Heat resistant mat
- Test-tubes, 3 (see note 1)
- Test-tube rack
- Dropping pipette
- Several pieces of red cabbage

Access to (see notes 2 and 3):
- Dilute hydrochloric acid, 0.01 mol dm^{-3} (**Low hazard** at this concentration)
- Sodium hydroxide solution 0.01 mol dm^{-3} (**Low hazard** at this concentration)
- De-ionised or distilled water



Technical notes and safety

Dilute hydrochloric acid, 0.01 mol dm^{-3} (**Low hazard** at concentration used). Refer to CLEAPSS Hazcard 47A

Sodium hydroxide solution 0.01 mol dm^{-3} (**Low hazard** at concentration used). Refer to CLEAPSS Hazcard 91

1 Small test-tubes of capacity about 10 cm^3 are ideal.

2 Each group of students will need access to the hydrochloric acid and sodium hydroxide solutions. Dropper bottles are ideal. Alternatively small beakers (100 cm^3) with dropper pipettes could be used. Students need to be able to pour the acid and alkali solutions easily and safely into test-tubes.

3 Provide similar containers for de-ionised or distilled water. Label the containers 'Acid', 'Alkali' and 'Water'.

4 A good tip is to attach a pipette to each bottle with an elastic band, to avoid cross-contamination.

Procedure

SAFETY: Wear eye protection throughout. Consider clamping the beaker.

a Boil about 50 cm^3 of water in a beaker.

b Add 3 or 4 small (5 cm) pieces of red cabbage to the boiling water.

c Continue to boil the red cabbage in the water for about 5 minutes. The water should turn blue or green.

d Turn off the Bunsen burner and allow the beaker to cool for about 15 minutes.

e Place 3 test-tubes in a test-tube rack. Half-fill one of the test-tubes with acid, one with alkali, and one with distilled or de-ionised water. Label the test-tubes.

f Use a dropper pipette to add a few drops of the cabbage solution to each test-tube. Note the colour of the cabbage solution in each of the three test-tubes.

Teaching notes

Discussion points could include any or all of the following.

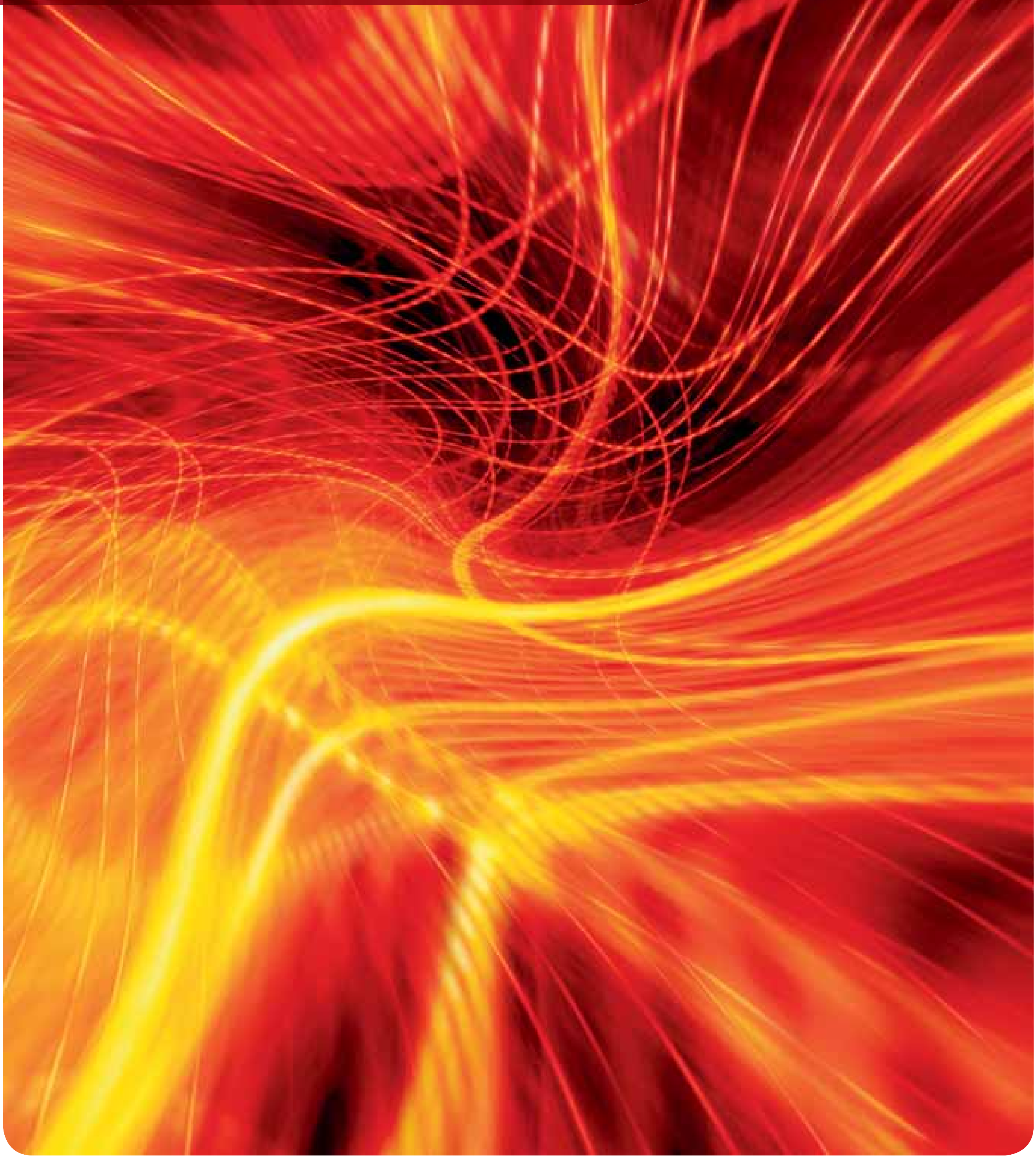
Many plant colouring materials in berries, leaves and petals act as indicators.

Some of these will not dissolve in water easily. A solvent other than water (e.g. ethanol) could be used, but it may be flammable. Discuss how the risk of fire can be reduced by using a beaker of hot water to heat the mixture.

Possible variations on this experiment might include using beetroot, blackberries, raspberries, copper beech leaves, or onion skins in place of the red cabbage.

Physics

The science of matter and its motion, as well as space and time. Concepts such as force, energy, mass and charge, and learning to understand how the world around us behaves.



Introduction

Practical work in physics is important in *showing* things to learners, as well as giving them an experience or feeling of a phenomenon, particularly an abstract one such as momentum. Experiments can sharpen students' powers of observation, stimulate questions, and help develop new understanding and vocabulary. Practical work plays a particularly important role in developing pupils' understanding of the physical world around them. Everyone remembers a number of dramatic practical activities from school – often demonstrations or activities with unexpected outcomes. These vivid memories of dramatic events can help students to retain scientific knowledge.

Secondary physics experiments:

Bolt from the blue:
Timing a 100 m run accurately
Feeling the pressure:
Investigating the effects of atmospheric pressure

"Practical work is doing things with different types of materials"

Teacher response to SCORE questionnaire

Bolt from the blue:

Timing a 100 m run accurately

Introduction

This is an exploration of issues of measurement, such as precision, range of values, uncertainty or 'error', repeat measurements and mean values.

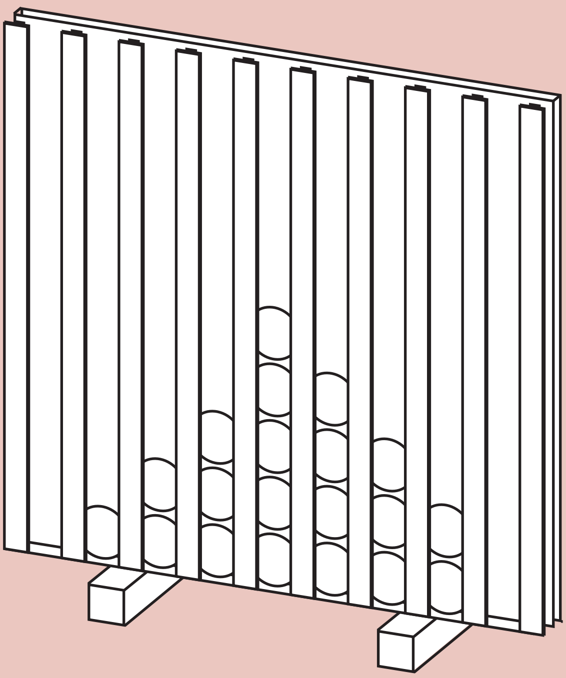
Apparatus and materials

For each student or student group:

- Stopwatch or stopclock
- String
- Statistics board (see note 1)
- Masses (50 g), 5 or 6
- Cones/Track markers, 10 (optional)
- Video camera (optional)
- Tape measure, long (at least 10 m) (optional)

Technical notes and safety

1 A statistics board is made from a piece of wooden board about 0.5 m square. 10 slotted channels are glued to it and metal (or other suitable material) discs are cut so that they fit into the channels. The board is supported vertically.



Assign values to each channel. Students drop in a disc for the value they achieve. The distribution of results grows as results are added.

2 If working outside, students must be appropriately supervised.

3 If a trolley is used in the lab, ensure that the trolley cannot land on anyone's feet or legs.

Procedure

a One student runs a distance of 100 metres. You, and other students, all independently time the run.

b Compare all of the measurements. What is their *range* (the difference between the highest and the lowest values)?

c What is the *mean* of all the measurements? A mean is a kind of average. Work this out by adding them all together and then dividing by the number of measurements.

d Did everybody make measurements with the same *precision*? For example, did everybody make measurements using tenths of seconds (0.1 second is a tenth of a second) or hundredths of seconds (0.01 seconds is a hundredth of a second).
e How certain can you be about the actual time taken for the run? You can't be perfectly certain! There must be some uncertainty in the measurements. The mean measurement could be 14.8 seconds. Perhaps you think that the 'true' time for the run is in between 14.6 seconds and 15.0 seconds. Then you can say that the uncertainty is ± 0.2 seconds.

Teaching notes

The times can be collated as lists of numbers or, using a computer, as bar charts, or using a statistics board. Bar charts enable students to understand range, mean and error visually.

Statistical treatment plays a very important part in science. In advanced experiments students are expected to treat errors with some statistical care. In kinetic theory the steady pressure of a gas is recognised as an average of innumerable individual bombardments.

Statistical methods are used to delve into details of molecular speeds or sizes. In atomic physics statistical views are of prime importance. So you might well make a gentle start now by showing how scientists look at a number of measurements of the same thing.

It is worth pointing out that there is such a thing as too much precision in a quoted value. A student who uses a stopwatch and gives a time of 14.77 seconds is crediting the timing process with more precision than it has. Answers of 15 seconds or 14.8 seconds may be acceptable (depending on the procedure and the stopwatch).

'Mean' is here used to indicate a particular kind of average – that found by dividing the sum of values by the sample size.

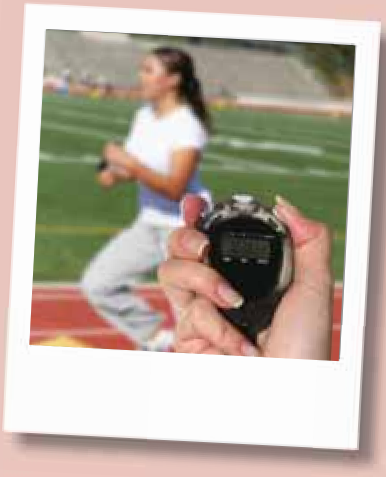
In more advanced work, uncertainty is conventionally called 'error'. Here, the word uncertainty more clearly describes the concept. You could repeat the activity for a different motion, such as for a trolley pulled across a metre distance on a table, or the fall of a mass.

Again, all students should measure the time for the same motion. Range, mean, precision and uncertainty can be compared with those for the student's 100 metre run.

You may want to compare timings for real sports races. Information on sporting records can be found on the Internet. Precision of measurement in different sports can be compared, and students can discuss the idea of uncertainty in the values.

How Science Works extension:

This experiment already covers many of the areas relating to accuracy and reliability of data, as well as experimental errors.



The scope could be increased further, as follows:

- Arrange pairs of students every 5 m or 10 m apart along the 100 m running path. Use some kind of signal (e.g. dropping a raised arm) to start both the runner and everyone's timers. As the runner passes each student, they stop their timer and record the time taken to reach them.
- Students then plot this data graphically (distance against time). This will make it easier for students to understand average speed and get a feel for the variation in measurements. A 'true' velocity can be calculated from the gradient of the best fit line.
- If you placed cones/markers along the track, you might be able to video each student running, with a stopclock also in the camera view. This would generate a second set of results that could be compared numerically or graphically to the class set. Students could comment on whether this method improves on the previous one.

Feeling the pressure: Investigating the effects of atmospheric pressure

Introduction
It is not always easy to get students to understand the effects of atmospheric pressure, but here are a couple of simple activities to challenge existing ideas and allow the development of a more sophisticated understanding of this concept.

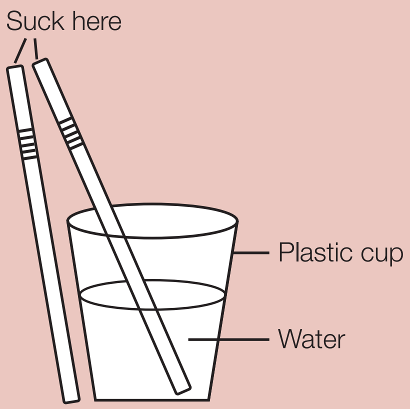
Lesson organisation
Although these can readily be done as demonstrations, the simplicity of the equipment allows the activities to be done individually or in small groups as well.

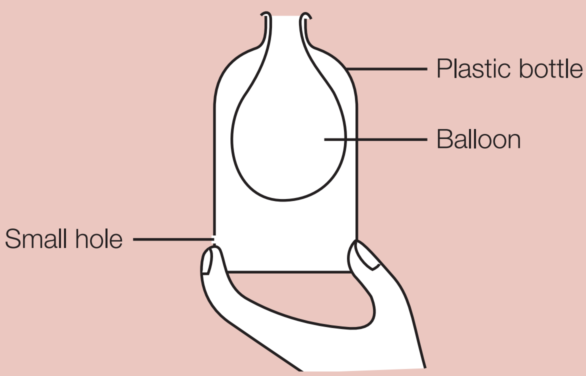
Apparatus and materials
Each group/individual will need:
- Two straws
- A plastic cup of water
- A clear plastic bottle up to 1 litre in size
- A clear plastic bottle up to 1 litre in size, with a small hole on its base
- 2 well stretched balloons
- A drawing pin to make a hole in a straw

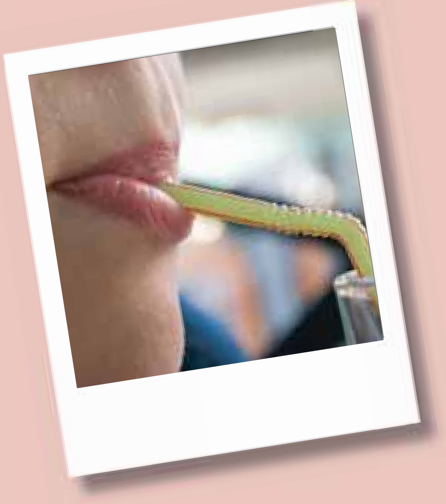
Technical notes and safety
Each student who tries the two straws activity should use fresh straws and used straws should be thrown away.

Procedure
Activity 1 – atmospheric pressure and suction

1 Put a straw in the clear cup of water.
2 Hold a second straw outside the cup as shown.
3 Try sucking the water up through the straw.
4 Now make a small hole in one of the straws with the drawing pin about 3 cm from the top and try drinking through it.







Activity 2 – balloon in a bottle

1 Place a balloon inside each bottle; spread its neck over the top of the bottle.

2 Try blowing up the balloon in each case – only with the bottle with a hole in will it work.

3 Air will exit the bottle via the small hole in the base of the bottle. Quickly seal the hole with your thumb and the balloon will stay inflated.

4 By slowly allowing air to enter the bottle, the balloon will deflate under your command.

Teaching notes

Both activities can be run after some discussion to encourage students to make predictions and attempt explanations that use the idea of a pressure difference to explain what happens.

Activity 1

The student will find it impossible to drink if one of the straws is outside the glass.

If both straws are placed in the mouth it is difficult to maintain a sufficiently low pressure to cause the water to be sucked up, because air enters the mouth through the second straw. In order for the water to be forced into your mouth, the pressure outside (atmospheric pressure) needs to be greater than the pressure inside your mouth. This means that no matter how you suck, a straw won't work if air can get into your mouth.

A similar effect is achieved by making a small hole in a straw about 3 cm from the top and putting this straw in the water.

Extension activities could include exploring how many straws put IN the water can drink be sucked through – increasing the surface area makes it harder.

By joining straws together find the longest straw it is possible to drink through.

Activity 2

Discuss why it is not possible to blow up the balloon without the hole in the bottle and why the balloon stays inflated when the hole in the bottle is covered. Encourage students to use the idea of pressure differences in their answers.

Putting the lid on the bottle, or tape over the hole, can leave the balloon inflated.

By sucking air through the hole in the bottom of the bottle it is possible to inflate the balloon.

Further information

Web resources:

General
CLEAPSS: www.cleapss.org.uk
SSERC: www.sserc.org.uk
ASE: www.ase.org.uk
ASE School Science: www.schoolscience.co.uk
ASE Primary Upd8: www.primaryupd8.org.uk
SciCast: www.planet-scicast.com
Field Studies Council (FSC): www.field-studies-council.org
Science Learning Centres: www.sciencelearningcentres.org.uk
CREST STAR Investigators:
www.the-ba.net/the-ba/ccaf/CRESTStarInvestigators/
Practical Primary Science: www.practicalprimaryscience.org
Planet Science: www.planet-science.com

Biology
Science and Plants for Schools (SAPS): www-saps.plantsci.cam.ac.uk
Survival Rivals: www.survivalrivals.org
Great Plant Hunt: www.thegreatplanthunt.org
Woodland Trust nature detectives: www.naturedetectives.org.uk
Evolution Megalab: www.evolutionmegalab.org
Practical Biology: www.practicalbiology.org
BioEthics Education Project (BEEP): www.beep.ac.uk

Chemistry
Practical Chemistry: www.practicalchemistry.org
Nuffield Re:Act: www.chemistry-react.org
RSC Classic Chemistry Demonstrations:
www.rsc.org/education/teachers/learnnet/classic.htm
RSC Classic Chemistry Experiments:
www.rsc.org/education/teachers/learnnet/classic_exp.htm
RSC Microscale Chemistry:
www.rsc.org/education/teachers/learnnet/microscale.htm
RSC Video material for teachers of chemistry
www.rsc.org/education/teachers/learnnet/videoclips.htm

Physics
Practical Physics: www.practicalphysics.org
Physics & Ethics Education Project (PEEP): www.peep.ac.uk

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