Soil Teachers' guide

Background information

The study of soils is a vital yet often overlooked part of the study of our environment. Soil is the basic substrate for most plant growth and is a major part of the water, carbon and nitrogen cycles. It is here that mini-beasts and micro-organisms work to break down the enormous quantities of dead vegetation deposited on the soil surface each year. GLOBE scientists are particularly interested in soil characterisation as soil affects water quality, it affects our ability to grow plants to eat and it determines where we can build our homes.

Useful comparisons can be drawn between contrasting locations in the UK and around the world. You could choose to compare your data with a contrasting school.

What is soil?
Soils are made up of three main ingredients:

- **Minerals** of different sizes
- **Organic materials** from the remains of dead plants and animals
- **Open spaces** that can be filled with **air** and **water**

A good soil for growing most plants should have about
45% minerals (with a mixture of sand, silt and clay)
5% organic matter
25% air
25% water

Soil formation
Soil formation (pedogenesis) and the properties of the soil are the result of five key factors. These are:

1. Parent material
Parent material is what the soil is made from. It might be the underlying rock, deposits blown in by the wind or washed in by the sea or plant material, for example the moss that formed peat soils.
2. Climate
Weather acts on the parent material and breaks it down. Climate affects how quickly a soil is formed.
3. Organisms
Plant and animals living in the soil help break down waste, they move around the soil adding air and when they die they become organic matter enriching the soil.
4. Topography
This is simply the position of soil in a landscape, whether on the side of a hill, banks of a river, facing the sun or in the shade. This will affect how the soil forms.
5. Time
Soil may take from just a few years to hundreds or thousands of years to form.

Soil Teachers' guide

Due to the interaction of the five soil forming factors, soils vary greatly. Each section of soil on a landscape has its own unique characteristics. The *face* of a soil, or the way it looks if you cut a section out the ground, is called a *soil profile*, just like the profile of a person's face.

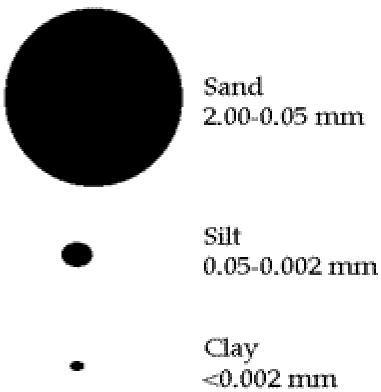
Soil Characterisation
In the field, soil horizons can be distinguished from each other within a soil profile by differences in their structure, colour, consistence, texture and amount of free carbonates. pH and soil fertility can also be measured.

Structure
Structure refers to the natural shape of groups of soil particles or aggregates (*peds*) in the soil. The structure affects how big the spaces will be in the soil through which roots, air and water may move.

Colour
The colour of the soil changes depending on how much organic matter is present and the kinds of minerals it contains (such as iron which usually creates a red colour, or calcium carbonate which colours the soil white in dry areas). Soil colour also differs depending upon how wet or dry the soil sample is and can indicate if the soil has been saturated with water.

Consistence
Consistence relates to the firmness of the individual *peds* and how easily they break apart. A soil with firm consistence will be harder for roots, shovels, or ploughs to move through than a soil with *friable* consistence.

Texture:
The texture is how the soil feels. It is determined by the amount of sand, silt, and clay particles in the soil. The particles range in size.



The relative sizes of sand, silt and clay particles.

Human hands are sensitive to this difference in size of soil particles, so we are able to determine the texture or "feel" of the soil. Sand is the largest particle size group, and feels gritty to touch. Silt is the next size group, and feels smooth or *floury*. Clay is the smallest size group, and feels sticky and hard to squeeze. The actual amount of sand, silt, and clay size particles in a soil sample is called the *particle size distribution* and can be measured in the laboratory or classroom.

Carbonates *Free carbonates* are materials that coat soil particles in soils that are above pH 7, especially in arid or semi-arid climates. They are salts of calcium or other elements that accumulate in areas where there is not extensive weathering from water. Also, carbonates can come from the parent material (e.g. limestone), can be caused by additions of carbonates to the soil, or can be the result of carbonate formation within the soil. In GLOBE, this test is performed by squirting vinegar on the soil. If carbonates are present, there will be a chemical reaction between the vinegar, which is an acid, and the carbonates, which are bases, to produce carbon dioxide. When carbon dioxide is produced, it bubbles or *effervesces*. The more carbonates that are present, the more bubbles or *effervescence* you will observe.

Soil particle size
The amount of each particle size group in the soil. Knowing the particle size distribution of a soil helps scientists to understand many soil properties including how much water, heat and nutrients the soil will hold and how water and heat will move through the soil.

pH
The pH influences what can grow in the soil and is the product of the kind of parent material, the chemical nature of the rain and other water entering the soil, land management practices, and the activities of organisms (plants, animals and fungi) living in the soil. For example, needles from pine trees are high in acids, and as they decay over time, they lower the pH of the soil. Soil pH is an indication of its chemistry and fertility.

Just like the pH of water, the pH of soil is on the same logarithmic scale (see the *Introduction* of the *Hydrology Investigation* for a description of pH). It is important to know the pH of the soil because it affects the activity of the chemical elements in the soil, and so affects many soil properties. Different plants grow best at different pH values. Farmers often add substances to change the pH of the soil depending on the kind of plants they want to grow. The pH of the soil also may affect the pH of ground water or of a nearby water body such as a stream or lake.

Infiltration
The rate that the water flows into the ground. Infiltration rate depends on many of the soil properties that students measure. Infiltration rates vary from less than 20mm/hr for clays and compacted soil to 60mm/min for loose, dry sand. The rate also changes depending on how saturated the soil is already.

Unsaturated flow – the initial flow rate is high as the dry soil pores fill with water

Saturated flow – the flow rate is steady and water moves into the soil at a rate determined by soil texture and structure

Ponding – the flow rate approaches zero when the ground becomes totally saturated and is no longer able to conduct water through its pores

Fertility

The fertility of a soil is determined by how many nutrients it has stored. Nitrogen (N) in the form of nitrate, phosphorus (P), and potassium (K) are three soil nutrients important for the growth of plants, and need to be maintained in the soil at a suitable level. Each also has the potential to leach from the soil into groundwater. By testing the soil for N, P, and K, we can determine how much of each is present in the soil horizons at your sample sites. Soil fertility information can help to explain why and how well certain plants grow, and can also be related to the water chemistry measured in the *Hydrology Investigation*.

Soil temperature

Useful insights can be made when comparing atmospheric, surface water and soil temperature.

GLOBE activities

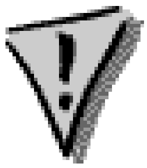
The protocols for Soil Characterisation should be done once at a site. However, you may have as many sites as you wish.

There are three ways of examining the soil.

1. A hole or pit to a depth of 1m is preferred

The site of the soil pit should be relatively undisturbed, at least 3m away from buildings, roads, paths, playing fields or other places where the soil might have become disturbed. You must check with utility companies and maintenance staff that you do not dig into or disturb wires or pipes etc. Try to find an area with relatively natural vegetation.

Keep the deep soil separate from the surface soil. They will usually be a slightly different colour. When you fill the soil pit back in, the deeper soil should be returned to the bottom of the pit and the topsoil to the top of the pit.
The flat soil face should, if possible, face the sun.



Consider safety around the soil pit. Clearly mark the edges and manage access to the pit. The pit should be filled in immediately after use or made safe.

2. An auger can be used to remove a core of soil to a depth of 1m

With this technique, students display the vertical soil profile on a horizontal surface (the ground). Identify an area where you can dig four auger holes where the soil profiles should be similar.

Assemble a profile of the top 1m of the soil by removing successive samples from the ground with the auger and laying them end-to-end on a plastic sheet, board or other surface on the ground
Wherever possible, students should fill in the hole with the original soil once the activity is complete.

3. Surface 10cm. Near Surface Sample Technique

In situations where it is not possible for you to expose the top meter of soil, an additional option is to use the top 10cm of the soil as a single horizon sample for soil characterisation using a garden trowel.

Treat this sample as a horizon and proceed to characterise its properties.

Soil Teachers' guide

All the following are done with the soil profile. Students identify different layers (horizons) and characterise the soils' properties.

- **Structure**

It is common to see more than one type of structure in a soil sample. Students should record only the structure type that is most dominant.

- **Colour**
- **Consistence**
- **Texture**
- **Roots**
- **Rocks**
- **Carbonates**

- **pH**

By mixing distilled water and a sample of soil students can measure the pH. This can be done in the classroom or in the field

- **Soil particle size**

Students need to collect three soil samples from each horizon which then need to be air dried overnight before they can complete this activity in the classroom. It takes a whole lesson to complete the settling out process.
For drying soil samples, allow at least 10 hours for drying at 95 - 105 ° C, 24 hours for drying at 75 - 95 ° C, or two days for air drying.

- **Fertility**

Students need a test kit in order to measure Nitrate, Phosphate and Potassium.

- **Infiltration**

Students will measure the rate at which water soaks into the ground as a function of time.
Take two tin cans and remove the bottom to form metal rings

- **Soil Temperature**

Soil temperature is measured at the Soil Moisture Study Site, which should be within 100 m of the Atmosphere Study Site. If your school is not taking soil moisture measurements, take soil temperature measurements within 10 m of the Atmosphere Study Site. Measurements are particularly useful if taken at regular intervals (2 hrs) throughout a day.

If you are interested in collecting soil moisture data please contact GLOBE UK as teacher and pupil information can be provided. It is not however, included here.

Equipment

Characterisation

- GPS
- Clinometer
- Small wooden markers e.g. golf tees or lollipop sticks
- Metre rule
- Compass
- An auger (Activity 2)
- Plastic sheeting for samples / removed soil
- Trowel (Activity 2)
- Soil colour book
- Spray bottle with water
- Squirt bottle with white vinegar (Activity 9)
- Plastic gloves (Activity 9)
- Safety glasses (Activity 9)
- Plastic bags or sealable containers to transport soil samples to the classroom

Infiltration (Activity 10)

- Metal ring diameter 5-10cm
- Metal ring diameter 10-20cm
- 8 litres of water
- small ruler
- Waterproof marker
- Stop watch
- Block of wood (approx 25cm x 25cm)
- Hammer
- Grass clippers
- Two soil thermometers

pH (Activity 11)

- pH pen
- 3 beakers
- Distilled water

Fertility (Activity 12)

- Soil test kit
- Distilled water

Soil particle size (Activity 13)

- 3 x 100ml graduated cylinders with stoppers
- Distilled water
- Spoon
- Dispersal agent (Calgon)
- Torch
- Stopwatch
- Gloves
- Goggles

Soil temperature

- 2 x soil thermometers

Extra activities

Purpose
To develop an understanding of how water flows through soils and of how the water changes as it goes through.

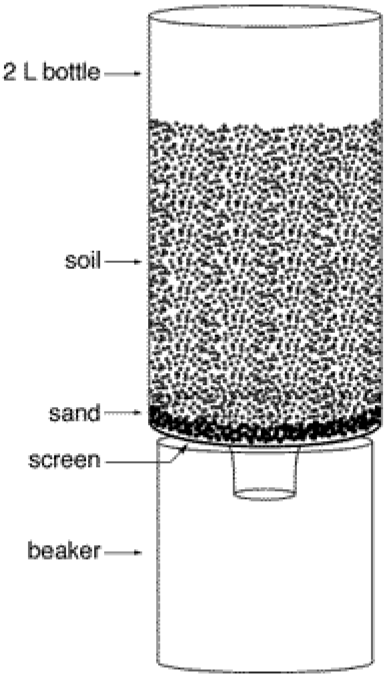
Overview
Students time the flow of water through different soils and observe the volume of water held in these soils. They will also observe the filtering ability of soils by noting the clarity of the water before and after it passes through the soil

Materials and Tools

- Transparent plastic 2 litre bottle.
- Three 500mL beakers or similar size clear containers marked off in cm to pour and catch water.
- Soil samples (Bring in samples of different types of soil from around the school or from home).
- Fine window screen or other fine mesh that does not absorb or react with water (1mm or less mesh size)
- Water
- Clock or timer

Preparation

- Cut off the base of the clear plastic 2L bottle and remove the labels and lid.
- Place a circular screen inside the bottle so that it covers the cap opening.
- Pour 3-4cm depth of sand onto the screen. The sand will keep the screen from becoming clogged.
- Place the bottle, mesh side down, on a beaker or clear container.
- Pour 1.2L of soil into the bottle over the sand.
- Copy the Work Sheets for each student.



What To Do and How To Do It

1. Choose a soil (a sandy soil works best) to use for the demonstration and place 1.2L of the soil into the 2 litre bottle.
2. Have students look closely at the soil. What do students notice: Colour? Plant matter? Does it feel light or heavy? Granular (like biscuit crumbs) or blocky (chunky)? Record their observations about the soil on the board.
3. Pour 300mL of water into a 500mL beaker or other clear container for pouring. Have students notice the clarity of the water.
4. Use a black marker to draw a line showing the height of the water in the pouring container. Have students count the cm lines to reach the top of the water. Record this number on the board.
5. Ask the students "*What will happen if you pour the water onto this soil*"? Ask students to explain why they think the soil and water will behave this way Some possible questions to ask are:
    - *Will the water run out through the bottom of the bottle?*
    - *Will all of it run out? How much will run out?* Make a mark on the pouring container with a red pen to show how much of the water the students think will flow out.
    - *How fast will the water pass through the soil?* Older students may time with a clock or stopwatch. Younger students can time by marking the minutes off on a timer (like in the Work Sheets) as the teacher times.
    - *What will the water look like when it comes out the bottom? Clear? Murky? Very Dirty?*
6. Record the class 'hypotheses' on the board.
7. Pour the water onto the soil and begin timing. Ask students to describe what is happening as you pour the water:
    - *Is all the water staying on top?*
    - *Where is it going?*
    - *Do you see air bubbles at the top of the water?*
    - *Does the water coming out of the soil look the same as the water going in?*
    - *Does the soil look different where the water has gone?*
8. Record the class observations on the board. Also record how long it takes for the water to pass through the soil.
9. Ask students to compare their hypotheses and the results of the experiment.
10. Once the water has stopped dripping from the bottom of the bottle, remove the soil bottle and hold up the beaker of water that has passed through the soil. Ask students:
    - *Is this the same volume of water that we started with? How can we tell if it is the same volume?*
    - Pour the water back into the original container. Compare the volume left with the black line on the container. *How much water is missing? How could we measure how much is missing?*
    - Compare the water level to the red line on the container. *Is there more or less water left than we thought there would be? How could we measure the difference? Why did you think there would be more or less?*
    - *What happened to the water that is missing?*

- *Is the water more or less clear than before it passed through the soil? Why?*

11. Keep the water that was poured through for comparison.
12. Using the bottle of saturated soil, ask students what will happen if you pour another 300mL of water into the soil. Record the class hypotheses on the board.
    - *Will the same amount, more, or less water stay in the soil this time?*
    - *Will it move through faster or slower or at the same speed?*
    - *How clear will the water be? The same, more clear, or less clear than before?*
13. Pour the water through the saturated soil, keep the time, observe the results, and compare with the hypotheses. Ask students:
    - *Did the water flow through faster than before? How do you know?* Compare the two times.
    - *Did more of it flow through than before? How can we find out?* Compare the volumes in the beakers.
    - *Is the water as clear as the first time?* Compare the colour of the water in the two beakers.

Student experiment

Observation and Hypotheses

1. Give each student the Look and Guess Work Sheet.
2. Ask the students to fill in the **Colour** of their soil (in words or with a crayon).
3. Ask the students to circle the **Structure** which looks most like their soil.
4. Ask students to look for leaves or **Organic matter** in their soil. Circle YES if they find organic matter. Circle NO if they do not.
5. **Time** Remind students of the observations, which they made during the demonstration. Ask students to guess the time it will take water to flow through their soil. Circle the time on the timer, then write the number in the blank.
6. **Volume** Ask students to draw a RED line on the container showing the volume of water they think will flow through their soil.
7. **Clarity** Ask students to put an X on the container which will look most like their water after it flows through their soil.

Experiment and Report

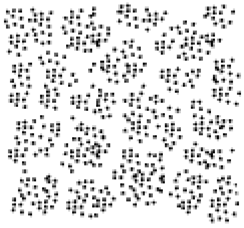
1. Explain that when you say 'GO' everyone will pour their water in together.
2. You will begin to time when the water is poured.
3. Have students fill in the Experiment and Report Work Sheet for their soil.

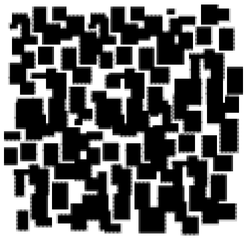
Soil Teachers' guide

Just Passing Through Work Sheet

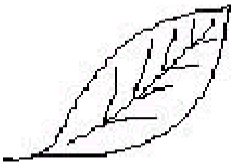
Observe, Predict and record

My soil is ___________________________ colour

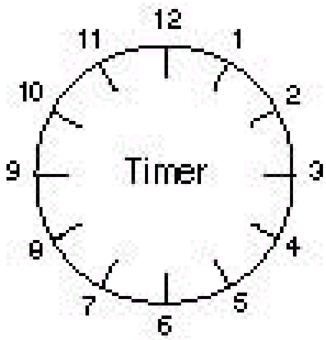




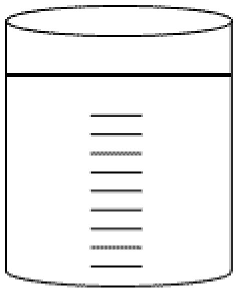
My soil looks granular blocky

My soil has  leaves. Yes No

Time ____________



How much water will come out? Make your line RED



What will the water look like? (CIRCLE)

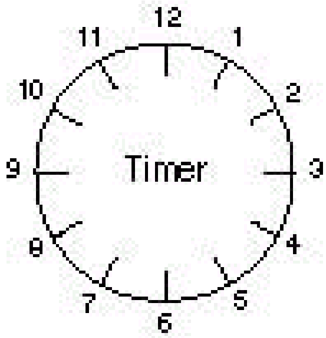
www.globe.org.uk

Soil Teachers' guide

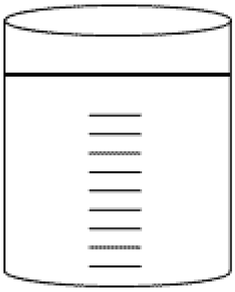
Just Passing Through Work Sheet

Experiment and report

Time ________



How much water came out?



What did the water look like?

My Report

Soil Teachers' guide

Soil: The Great Decomposer

Purpose

To introduce students to the role that soil, under different environmental conditions, plays in the decomposition of organic materials

Overview

Students will simulate a variety of environmental conditions to determine which conditions facilitate the decomposition of organic material in soil. Variables will include temperature, moisture, and light conditions. Students will use "bottle" experiments to observe changes in the decomposition of vegetable scraps.

Materials and Tools

- 12 glass jars or beakers or 2litre plastic bottles (more for additional studies)
- Marking pen or labels
- Enough dry soil to fill each jar to a depth of 10cm. Use the same soil (loam or potting soil) for each jar.
- Enough chopped vegetable or fruit scraps (carrots, cucumbers, apples, etc.) to cover a depth of 2-3cm in each jar (use the same fruit or vegetable scrap mixture in all jars). Other sources of organic material include leaves (broken up), grass clippings, flowers, etc. *Do not use animal scraps*.
- Graduated cylinder or measuring cup to add specific volumes of water to the soil.
  For further studies:
- Soils with sandy and clayey textures.

Preparation

Have the soils, bottles, and vegetable scraps available. Ask students to bring in vegetable scraps on the day of the experiment.
Locate areas in the classroom that will provide variable conditions required for the experiment (warm, sunny site; cool, sunny site; warm, shaded site; cool, shaded site).

Background

Light, temperature and water content largely determine the rate of decomposition in the soil. Soil holds the moisture and heat required for micro-organisms to thrive and perform the decomposition process, changing organic materials into soil material called humus. Soils have different abilities to hold moisture, heat, and to support organisms. If the soil is too wet, too dry, or too cold, decomposition will be slow. Energy from the sun will warm the soil and also promote evaporation, which will affect the moisture content in the soil. Students will be asked to investigate what conditions contribute to rapid decomposition of organic material in soil.

What To Do and How To Do It

Set out 6 jars or beakers on table. Label each as follows:

1. Dry and sunny
2. Moist and sunny
3. Wet and sunny
4. Dry and cool
5. Moist and cool
6. Wet and cool

Talk about climates across the globe, which would have these conditions, and compare them to the climate in your local area.

Add equal volumes of soil (about 10 cm) to each jar.
Add equal depths (about 2-3 cm) of vegetable material to each jar and evenly mix the soil and vegetable material. Use the same type of vegetable material in all jars.
In each of the jars marked "wet," saturate the mixture with water (allow water to cover the surface of the soil).
In each of the jars marked "moist," moisten the mixture with water.
Leave the mixture to dry in the jars marked "dry."
Place one wet, one moist and one dry jar in a warm sunny place (as marked).
Place one wet, one moist and one dry jar in a shaded, cool place.
(as marked).

Cover the jars but poke small holes in the top for air to circulate.
Every other day, saturate soils in jars that are marked "wet," and moisten soils in jars marked "moist." At this time, stir the soil/vegetation mixture in each jar.

For a period of two weeks, observe the jars daily (or every other day) and record observations. Note changes in water content and the condition of organic matter.
Discuss with the class how light, temperature, and water content affected the amount of organic material left in the soil after 2 weeks. Which conditions enabled greatest decomposition? Which jars show the least decomposition? Can you rank the jars from the least to most decomposition after 2 weeks?

Further investigations

- Find out where there is digging (excavation) going on nearby and visit the site, comparing what you observe there with the soil characteristics described at your school soil site.
  Remember: Safety is always your first concern.

- Using soils with "optimal conditions", place earthworms in one jar and leave a second jar earthworm-free. Observe and record earthworm activity, rate of decomposition and differences in soil properties after two weeks. You may also want to create a "worm farm." Place sand and soil in horizontal layers in a glass jar. Use this to observe worm behaviour, decomposition, and changes in soil over a longer period of time. Ensure the moisture of the soil is maintained to avoid worm desiccation!
- Do a similar experiment as above but vary the soil texture. Include jars with sandy soil and clay soil and observe differences as above.

Useful contacts and publications

British Society of Soil Science teaching materials www.soils.org.uk
Published on the Web by the British Society of Soil Science (BSSS), this resource provides access to teaching materials and reference information of use to those involved in soil science teaching and research. There are many varied reference aids available covering a wide range of topics. Most materials are provided by the BSSS but some link to external sources.

Internet glossary of soil science terms www.soils.org/sssagloss
An extensive list of soil science terms explained in alphabetical order from a to z. The list can be both browsed and searched with a keyword. Includes SI-units conversions and tables and figures for special issues and a dictionary file for MS WORD. The Glossary is maintained by the Soil Science Society of America. This February 1997 revision replaces the July 1987 edition

Soil association www.soilassociation.org
The Soil Association is the UK's leading campaigning and certification organisation for organic food and farming. They have education pages with a range of educational activities based around organic farming. The activities link to the national curriculum and provide resources for both teachers and pupils.
Free: Our colourful *Little Book of Organic Farming* (KS1-4) and *Organic Experience* activity poster (KS1-2) are free to schools. Email education@soilassociation.org to request your copy.

National Soil Resources Institute www.silsoe.cranfield.ac.uk
NSRI was newly established in August 2001 in order to create a unified Institute with the necessary scientific expertise and the research capability to focus on the long-term development of the sustainable management of soil and land resources both in the UK and around the world.

Global Soils Learning Module
www.uwsp.edu/geo/faculty/ritter/geog101/modules/soils/soils_module_contents.html
This learning module looks at different aspects of soil development – from factors affecting its properties to the different horizons that make up a soil profile. Diagrams accompany the notes. Comprehensive notes ideal for further research.

NAME THAT SOIL - UK - soil identification and visual soil map interpreter 2.0
Enables non-specialists to identify and name soils by the Soil Survey of England and Wales classification (with FAO and USDA translation). The program leads through a succession of questions about a soil, shows parent material, soil group and series, and presents a scaled and annotated colour picture of the soil profile described by your answers. Author: Dr Colin Rudeforth.

GLOBE curriculum links

Geography Encourages geographical enquiry and skill development through the collection and of data and appropriate use of fieldwork

Key stage 2	1a-c	2a-g	3a-g	4a-b	5a	6a-c	7a-c

Key Stage 3	1a-d	2a-f	3b-d	4a-b	5a	6c,e+,j	7a-c

Science Promotes scientific investigation of living and nonliving things, using equipment, materials and language appropriately whilst collecting firsthand data

Key Stage 2	1.1b	1.2a-m	2.1a-c	2.3a-c
	2.5a-f	3.1a+d	3.2a,c,d,f	3.3a-c

Key Stage 3	1.1b-c	1.2a-o	2.3a-d	2.5a-c
	3.1c,e+g	3.2d-f,h+i	3.3d-f	4.5f

ICT Uses computer technology to convey information; to interpret, analyse and check data required for specific purposes. Purposeful use of data-logging equipment.

Key Stage 2	1a-b	2b+c	3a	4a-c	5a-b

Key Stage 3	1a+b	2b	3a-c

Mathematics Uses appropriate measuring instruments to observe, record and interpret numbers and scales with a high degree of accuracy. Opportunity for data handling skills.

Key Stage 2	2.1a-k	2.2b,f,k	2.3l	3.4a,b	4.1b-h	4.2a-d

Key Stage 3	2.1g,h	2.2e	3.4a	4.1a	4.2d	4.3a-c

Literacy Finding and selecting information from various sources; use electronic communication to describe observations.

Key Stage 2	2.5f,g	3.1e	3.2a-f