The IT in Science book of
Data logging & control

Roger Frost

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The IT in Science book of
Data logging and control

Roger Frost

A compendium of ideas for using sensors in science teaching with pupils aged from 11 to 18

The companion guide to The IT in Secondary Science Book and Data logging in Practice

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Software for science teaching
About this book

This book aims to show how useful sensors can be in teaching science to pupils aged between 11 and 18. You can, at last, do virtually all of the experiments in this book on any brand of school computer.

The ideas here come from many science teachers and especially those in the London Borough of Bromley who through their MAPOSE project, first showed what could be done. Extra thanks are due to Keith Hemsley, Rosie Kentish for editorial help, David Palmer of LogIT and Alan North and Alison Bilsborough for technical advice and loans of equipment, Craig Eccleston of Data Harvest, US for encouragement.

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Resources and information for science are available on the Internet at:

www.rogerfrost.com

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About data logging and control

Scientists are forever looking for better ways to study the world. Information technology comprises many tools, including measuring tools, which help them to do this. Spreadsheets, CD-ROM databases, database programs and word processors help in various ways. Sensors and control technology help in unique ways. They provide not just better methods of measurement but also the means to help students understand and explore science. In particular, we can

- Monitor unique changes and even very fast events, for example the speed of a falling weight or the discharge of a capacitor.
- Measure with more precision and therefore have a greater certainty about our results.
- See our results immediately gaining a better feel for changes and quantities as well as using this to improve our experimental technique.
- Analyse our data and test our ideas more readily.
- Explain the workings of our automated world through project work with control technology.

Over the years the software and the hardware for data logging and control have improved to make all the above a practical reality in the classroom.

This book is a not-too-technical, technical guide to activities with sensors in the classroom. It shows what can be done and provides many starting points to introduce pupils to tools which they can use to understand and investigate science better than they ever have before.

See:

A curriculum Pages 8-9
Sensing glossary Page 10
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**Index**
Quick overview

This book is a catalogue of ideas for using computer-linked sensors to enhance the teaching of science.

1 Introducing data logging and control
This section describes how sensors help teaching and how pupil skills might develop as students move through the education system. The glossary here describes the data logging technology you might meet.

2 Ideas for data logging and control
This is a compilation of ideas organised by subject.

3 Introducing data logging
Example worksheets for starting out to use sensors.

4 Exploring science with sensors
Sensors allow us to investigate science and this is another approach you can try.

5 Control
Ideas and examples for control projects or demonstrations.

6 Sensing for age 14 +
All-purpose experiment guides using sensors

7 Sensors and software
About the available sensors and software.

Index
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The following table is a guide to the way pupils might progress with their use of sensors and control technology.

<table>
<thead>
<tr>
<th>Progression in measuring and controlling things</th>
<th>What the pupils do in science (or technology)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognise that everyday devices respond to signals and commands and they can make them respond in different ways.</td>
<td>Talk about how to use a video recorder.</td>
</tr>
<tr>
<td>Control devices purposefully and describe the effects of their actions.</td>
<td>Technology: introduce robots.</td>
</tr>
<tr>
<td>Understand how to control equipment to achieve specific outcomes by giving a series of instructions.</td>
<td>Technology: control a robot.</td>
</tr>
<tr>
<td>Use IT to control events in a predetermined manner, to collect physical data and display it.</td>
<td>Technology: control a robot and make it perform a set routine. Use sensors to make measurements and display readings.</td>
</tr>
<tr>
<td>Create sets of instructions to control events, and become sensitive to the need for precision in framing and sequencing instructions.</td>
<td>Technology: control a robot and make it perform a set routine.</td>
</tr>
<tr>
<td>Develop, trial and refine sets of instructions to control events, demonstrating an awareness of the notions of efficiency and economy in framing these instructions. Understand how IT devices can be used to monitor and measure external events, using sensors.</td>
<td>Technology: control a robot, make it perform a set routine and not be content with just getting it to work. Use sensors to make measurements, for example, use digital sensors to measure their reaction time.</td>
</tr>
<tr>
<td>Use IT equipment and software to measure and record physical variables.</td>
<td>Use sensors to make measurements in experiments. Use a data logger to record the room temperature and light level over a weekend. Display readings as time graphs.</td>
</tr>
<tr>
<td>Select the appropriate IT facilities for specific tasks, taking into account ease of use and suitability for purpose. Design successful means of capturing and preparing information for computer processing. When assembling devices that respond to data from sensors, they describe how feedback might improve the performance of the system.</td>
<td>Use sensors to make measurements in experiments. Select appropriate sensors and recording parameters. Use the data in the data logging program or export it to a spreadsheet or word processor. Develop a control system to run a biofermenter, an aquarium or fire alarm. Discuss and document the work to a high standard.</td>
</tr>
</tbody>
</table>
Learning to use sensors

Progression is no less important in using computers and sensors than any other part of the curriculum. How then might pupil’s skills develop as they move through school? This list is one answer.

Age 5-7

Use sensors to show whose hands are hottest. Show, using graphical or bar displays, which things are hot or which sound is loudest or which place is darkest? For a primer on control, they might learn to use video recorders, programmable toys or robots.

Age 8-11

Use temperature sensors instead of thermometers to investigate the cooling of a drink. Use other sensors as opportunities arise. Consider the advantages of sensors over human sensors and suggest some uses for them around the home. Use control technology to power models (just on/off to start with) and develop this further (move left/right, fast/slow). Do a control project that combines the use of sensors with control.

Age 11-13

Develop the use of sensors - starting with some initial demonstrations - moving onto investigations. Introduce different sensors, show what they measure and how they are used at home. Pupils might also learn to use a data logger to say, compare indoor and outdoor temperatures over the day. Use digital sensors for measuring their reaction time or things sliding down a slope. Build a control system such as an air conditioning system or a baby incubator.

Age 14-16

By this age, pupils should be using sensors as scientific tools in investigations and projects. They should develop the skill to use two different sensors at once and plot one value say, pressure against temperature. They should examine data critically and if the data logging software is rather limited, they might learn to put the data into a spreadsheet. Combining data, graphs and text in a word processor report is another important skill. For control work pupils might develop a control system using sensors (push switches or light sensors) and output devices (heaters, buzzers, lamps). In some courses, they would be expected to plan, design, make, test, evaluate and document their project.

Age 18-

Pupil’s skills should be put to full use at this age, although sooner would be much more useful. They should be able to choose their measuring tools, analyse data, criticise and document their work on the computer.
**Sensing glossary**

**Analogue to digital convertor** - part of a computer interface which converts an analogue reading from a sensor into a digital reading which the computer can interpret.

**Analogue Port** - a socket on a computer which you may connect analogue sensors to directly.

**Analogue sensor** - a more useful sensor which has many states and can provide readings over a wide range of change.

**Digital sensor** - a sensor or switch which has two states, on or off.

**Data logging software** - software which is designed to record and display the readings from sensors. Usually supplied specifically for your data logging kit.

**Data logging** - collecting data from sensors. To do this away from the computer you need a ‘data logger’.

**Data logger** - a self-contained device to collect readings from sensors away from the computer. When all the readings have been taken you connect the data logger to the computer to transfer the readings.

**Interface** - a device to connect the sensors to the computer.

**Light gate** - (or timing sensor) a light sensor which responds rapidly to light changes. Used for timing events with great accuracy.

**Light sensor** - measures the light level. Use for monitoring sunshine or measuring the reflection of light from a surface.

**pH sensor** - measures the acidity and requires a glass pH electrode. Use for monitoring titrations or reactions causing a pH change.

**Position sensor** - measures the angle of movement - in contrast to a distance sensor which works like a Polaroid camera’s electronic rangefinder.

**Serial Port** - a socket on a computer where you may connect an interface. Data loggers also use other ports, such as USB or SCSI or Bluetooth.

**Sound sensor** - measures the sound level. Use to study sound travel and sound proofing. Sound is measured in decibels.

**Temperature sensor** - measures how hot something is. Use to study cooling, heating, insulation and the weather.

**Time graph** - a way of showing how sensor readings change over a period of time.
Ideas for data logging and control

An overview of the many applications for sensors in science, first listed by subject and then, alphabetically, by topic. Other sections of this book take many of these ideas and work them through in greater detail.

- Biological topics Page 12
- Chemical topics Page 21
- Physical topics Page 23

See also:
Introducing data logging Page 33
Exploring science with sensors Page 52
Sensing for ages 14+ Page 73
Sensors and software Page 120
Index
Adaptation: keeping warm

Animals huddling in cold weather, the size of elephants’ ears and the size of a dog’s tongue are examples of animal adaptation to adverse temperatures. These can be investigated using temperature sensors.

Huddling: make a bundle of test tubes and fill them with hot water. Place temperature probes in tubes near the centre and the edge. Then monitor how fast they cool. Repeat with the test tubes arranged separately.

Elephant / dog: fill two cans with hot water, make ears or a tongue out of foil and attach this to one can. Place these in front of a fan, put a temperature probe in each and compare the rates at which they cool.

Animal behaviour

Some animals are nocturnal or they show a regular pattern of activity. Sensors can harmlessly monitor animal activity overnight or over several days. Place any of the above probes in an animal cage and monitor the animal’s activity over time. The temperature sensor will indicate when a nest is occupied, the sound sensor will pick up movements or bird song. The light sensor might show how often an exercise wheel is used.

The light sensor can also be used in an aquarium showing (in two separate attempts) whether fish prefer one side of the tank to the other. Since the light sensor gives an indication of when it is day or night it can be used (perhaps with the temperature sensor) to show if the animals are busier during the day or the night.

For an extracurricular activity: use an infra-red sensor to monitor the movements of the cat going through the cat flap during the night.

Water Pollution

The biochemical oxygen demand, or BOD, is an indicator of water pollution. Place a sample of river or pond water in a flask. Push the oxygen probe through a bung which fits the flask. Then place this in a water bath and measure the oxygen level overnight.
Bird feeding

Birds respond to the appearance of food no less than we do. If we set out some dyed food on a position sensor we can monitor how often they visit it. Connect the position sensor to a remote data logger. Fix the sensor on a stand with a spring and a bag of bird food. Set the data logger to record (i.e. count) an event each time the sensor reads above a certain value. When the data is transferred to the computer a bar graph will show how often the sensor was triggered. Repeat this using bird food dyed different colours.

Breathing

A spirometer is a ‘breathing box’ where the lid rises and falls as you breathe. It can be used to show the rate and depth of breathing, the tidal volume and maximum expiratory volume. It normally connects physically to a chart recorder which records the breathing movements. However, a position sensor has a lever arm which can replace that chart recorder. The computer graph can be the subject of some interesting work.

Breathing air

The air we breathe out contains only a fraction less oxygen than the air we breathe in. An oxygen sensor can show this, as well as showing what happens when we re-breathe the same sample of air. Allow an oxygen probe to stabilise at room temperature. Get a steady graph of the oxygen level on-screen and breath on the sensor. Place the probe in a carrier bag and take readings whilst re-breathing the air in the carrier bag. Fill another bag with nitrogen or carbon dioxide and take an oxygen reading from this to show the reading of 0% oxygen. Another idea: place a pH probe in lime water and show the effect of breathing into it.

Breathing locust

Cold-blooded animals use more oxygen as their temperatures increase. Place a locust (or earthworms, maggots although this isn’t very friendly) in a flask with the oxygen probe in a bung. Use Soda-Lime/Potassium hydroxide to remove the carbon dioxide. Place the solid or KOH soaked cotton wool under a mesh. Note the steady drop in oxygen level as you record, then increase or decrease the temperature slightly and note the effect on oxygen consumption. Alternatively use a manometer sensor to monitor the volume changes as the locust breathes.
Breathing movements

Pressure or breathing sensor

Monitoring breathing movements before and after exercise shows us how our lungs can increase their intake of air. Strap a breathing sensor around the chest. Or use a stethograph with a firm plastic tube to connect it to a pressure sensor. Chest movements cause a change in volume/pressure which is recorded and shown on screen. Usually a great success, but it is hard to control the position of the belt. Use an exercise cycle as this doesn’t disturb the position of the belt round the chest. Make graphs during resting, exercise and recovery. Look for changes in breathing rate and depth. Show (semi-quantitatively) the tidal and maximum expiratory volumes.

Energy release from seeds

Temperature sensors

Seeds use and release energy as they grow. By placing seeds in a vacuum flask we can ensure that this energy is not lost to the environment but instead produces a noticeable temperature rise. Place temperature probes in two vacuum flasks, one with live germinating seeds and one with killed seeds. Monitor the temperature over several hours. Use a data logger if you wish.

Energy release from food

Temperature sensor

We release energy from food by oxidising it to carbon dioxide and water. If we burn food we perform a similar chemical reaction. If we use the energy released to heat a measured amount of water we can, in turn calculate the energy content of food. Set up a temperature probe in a boiling tube with a measured amount of water. Burn a measured amount of food (a biscuit, a peanut) and monitor the temperature rise. Even if the food extinguishes prematurely, there will still be a clear graphical record of the total energy rise provided by the food. Use the program to read off temperature values from the graph. Calculate the energy released.

Energy & microbial activity

Temperature sensors

Bugs use and release energy as they respire. By placing cultures in vacuum flasks we can ensure that this energy produces a noticeable temperature rise. Place temperature probes into yeast cultures (one culture has been boiled) in 2 vacuum flasks. Monitor the temperature over several hours using a data logger. Monitor the temperature of a hay stack, a compost heap, a beehive or ant-hill. Use a data logger and place a temperature probe in the sample and another in the open air.
**Environment**

Light, sound, rotation, pressure etc.

Sensors make the job of monitoring the environment an easy one. The applications are as diverse as the environment itself. Connect the sensors to a remote data logger. Check the conditions inside a greenhouse or monitor the weather. Measure the light reaching the ground and relate this to the amount of vegetation there. Use oxygen and pH probes in a pond or aquarium to study the changing oxygen and (indirectly) carbon dioxide levels. Use a rotation sensor to measure the water flow at the middle and at the banks of a stream. Use a sound sensor to find when the road traffic is busiest, or to find when the birds start to sing. Use a position sensor as a makeshift 'anemometer'. (Connect the sensor to a spring and a plastic wind vane.)

Energy conservation is good for the environment - so let a data logger monitor the heating or heat loss from the school buildings. You might even use an air pressure sensor on a school journey to a mountain centre - it can show changes in pressure with altitude.

Use a pH sensor to study the pH of stream water, soil or rain.

**Enzyme activity I**

Light sensor

The light sensor can be used to monitor a change in colour or turbidity. For example, amylase acts on starch in the presence of iodine to give a colour change from blue to colourless, trypsin acts on casein protein to produce a change from cloudy to clear. Similarly both pepsin and the proteases in biological washing powder act on albumin to produce a change in turbidity.

Use the sensor to assess the effect of different concentrations and temperatures on enzyme activity. Find out just how heat-stable washing powder enzymes are. Finally, if you are doing an enzyme extraction this technique is better than most for assessing the yield.

The reaction mixture is placed in a glass container, and the light transmitted through the solution is measured continuously. The enzyme activity is related to the slope of the graph. It helps if you split the reaction mixture into two - one part goes in the ‘cuvette’ the other can be placed where everyone can see the change taking place.

You can use postal tubing or aluminium foil to make a colorimeter cell. This ensures that light passes through the solution. I’ve not heard of anyone going as far as using a filter to produce a monochromatic light source - but it’s an idea to follow up.
Enzyme activity II

The pH sensor can be used to monitor the speed of changes involving pH. For example, urease acts on urea to produce ammonia, lipase acts on lipid to produce fatty acids. The reaction mixture is placed in a container, and the pH of the solution is measured continuously. The enzyme activity is related to the slope of the resulting graph - but use the initial rate of reaction for your measurements (that's the first part of the graph). There is an inherent problem with the technique - the pH change decreases the enzyme activity - but that is a good teaching point.

Repeat the measurement at different concentrations and temperatures as required. If you are extracting the enzyme this technique is better than most for assessing the yield.

Fermentation

During microbial respiration, acids are produced as waste products. Lactobacilli turn lactose to lactic acid, yeast turns sugar into alcohol and the alcohol in wine is oxidised to ethanoic acid (though this is not necessarily due to microbial activity). Set up a culture such as milk and live yoghurt, or yeast and sugar. Monitor the change in pH or oxygen level over several hours or overnight. Use a flask in a water bath, and suspend the electrodes in it. Seal the neck of the flask with polythene and an elastic band. Repeat at a different temperature.

Food: cooking and freezing

Some temperature sensors can record the very high temperatures while cooking food in an oven. You can use one to answer the question: does putting foil on jacket potatoes make any difference to how they cook? Use a high temperature probe to show temperatures at the top and bottom of the oven or in parts of a cooking cake.

Investigate how long you need to leave a frozen sausage to thaw or compare the effectiveness of different vacuum flasks. For this you can use ordinary temperature probes. For the sausage experiment, place one probe in the middle of the sausage, and the other near the edge. Freeze the sausage and probes together, and then allow them to thaw. If you use a data logger, you can easily monitor both the freezing and thawing process.
Homeostasis

Medical technology such as kidney machines, lung machines and baby incubators involve control technology. Models of these devices can be made using appropriate sensors and devices.

**Lung machine:** use an oxygen sensor and a device to pump air from a large bag of ‘oxygen’. E.g. use an aquarium pump powered via a mains controller. Use control software to write a program which switches on the pump when the oxygen level falls and switches off the pump when it rises again.

**Baby Incubator:** use a temperature sensor, a heating device and a cooling fan. (The fan and heater can be powered with a mains controller or relay). Use control software to switch on the heater when the temperature falls and switch off the fan when it rises.

Study how effective a control system is with just a fan and then with just a heater. How will the system behave in summer and in winter?

See the Control section for further ideas and worked examples.

Lung / blood pressure

The pressure sensor can be used to compare our lung pressures. You can also connect a sphygmomanometer cuff to the sensor to give a graphic display of what happens when a blood pressure measurement is taken. For this, set the pressure sensor to its high range. Start the software recording then put a stethoscope on the arm and inflate the cuff until the pulse stops. Adjust the sensor to bring the reading on screen. Next deflate the cuff slowly until you hear the pulse just coming through - the screen should show this. Finally, release the cuff pressure. Use the data logging software feature to zoom in on the arterial pulse wave eg adjust the time axis.

Microbial growth

Microorganisms respire and use up oxygen. Their rate of respiration is affected by temperature. Set up a culture such as milk and live yoghurt or yeast and sugar. Monitor the change in pH or oxygen level over several hours or overnight. Repeat at different temperature or sugar concentration.
Osmosis

During osmosis, water moves through a semipermeable membrane from a hypotonic solution to a hypertonic solution. The resulting volume change can be measured using sensors. An electronic manometer consists of a U-tube filled with liquid. A pressure sensor, although less sensitive, can also respond. Set up a dialysis bag filled with sucrose solution and place it in a beaker of water. Connect the opening of the bag to an electronic manometer or pressure sensor.

Photosynthesis

Put some Elodea or a Chlorella culture in a flask of water. Fit an oxygen probe through its bung. Measure the oxygen level over a period of an hour or so. Adding 5% sodium hydrogen carbonate provides extra carbon dioxide for photosynthesis.

I investigate the effect of different light levels by taking measurements with the light source some distance away. Every 15 minutes, move the light closer by the same distance. Alternately, show the effect of light of different colours by placing filters in front of the light source.

Plant growth / Tropism

A position sensor can be made to move as a plant grows and this movement can be recorded. Tie a piece of thread to a fast growing plant. Connect the thread to the position sensor. It may be possible to see if a plant grows faster during the day or during the night - so set up a light sensor at the same time. It is also possible to show phototropism by measuring how fast a plant takes to respond to a change of light direction.

The position sensor can be mounted upside down to get the graph to rise, rather than fall, as the plant grows. A data logger is particularly useful here - it will allow you to record over an extended period of time.

The sensitive plant, *Mimosa Pudica* makes an interesting subject using similar apparatus. For this investigation touch the plant's leaves and the graph on screen will show how long it takes for the plant to recover. Repeat this in the dark and attempt to explain the slower speed of recovery.
Pulse

Study the effect of exercise on the pulse rate. Show how quickly the pulse returns to normal after exercise.

The pulse sensor has a probe which clips to the ear lobe and gives a continuous read out of the pulse rate. The sensor may have an outlet which provides a trace of the pulse itself. In other words, rather than showing the pulse rate, it shows the blood flow through the ear.

**Reaction time**

The computer can start its own ‘stop-clock’ when an object passes in front of a light sensor and stop the clock as it passes a second sensor. This requires software especially designed for timing. To measure reaction time, give two students a light sensor each. Ask one to place their hand in front of the sensor and get the other to do the same immediately after they see this happen. Take a series of readings to show if the reaction time improves with practice. As a variation on the idea, get the second student to turn away so that they have to react when they hear a sound.

It may be possible to measure the speed of the ‘knee-jerk’ reflex and it is certainly fun to try. Place one light sensor near the knee to ‘see’ when the knee is hit. Place another sensor near the foot to ‘see’ when it reacts.

Soil and pond temperature

The life forms at different levels in the ground or in a pond need to adapt to greater or lesser temperature changes during the course of a day. Connect temperature sensors to a remote data logger. Monitor the temperature of the ground at different depths - both during the day and overnight. Expect the deeper probes to show a slower and shallower temperature change.

Using the same set up, monitor the temperature gradient in a pond over a 24 hour period. It is possible to show the temperature gradient in a pond. This simply involves measuring the temperature continuously whilst slowly pulling the temperature probe up from the bottom of the pond. Alternatively, set the data logger to take a reading each time a key is pressed. Then position the probe in the pond, press the key, move the probe, press the key and so on.

Extend the investigation to show how light levels vary with depth in the pond.
Transpiration
Humidity sensor / Balance

Plants transpire - evaporating water at the leaves to draw water and minerals in from the roots. This can be monitored using a humidity sensor. Simply, place a humidity probe in a polythene bag with a plant and monitor the humidity. It would be nice to be able to show which side of a leaf loses the most water - but to date I’ve not found out how to do it. Using an electronic balance attached to the computer it becomes possible to monitor the loss of water by transpiration. It can also show the effect of room temperature on this and the effect of placing the plant in a sealed polythene bag. You will need a balance designed to link to your computer, a cable and compatible software.

Weather
Temperature, light, rotation, humidity, pressure sensors

Sensors make the almost impossible job of monitoring the weather an easy one. Dedicated weather monitoring kits are available and they do the job effectively. They may however, be in excess of your occasional need to ‘do weather’. Connect the sensors to a data logger. Use a position sensor as a makeshift ‘anemometer’. Connect the sensor to a spring and a plastic vane. (Alternatively, fit a vane to a rotation sensor to measure the wind speed). The light sensor records the occurrence of day / night and furthermore shows the amount of sunlight and cloud cover. See if you can record a cold front blowing over.

A key part of monitoring the weather is the analysis of the data, so if you can get the data you collect into a spreadsheet or database file, the whole group can work on it - presenting it in various graph formats and looking for patterns. For example, find out if it is always cold when it is wet or windy or see whether it really does get cooler before it starts to rain.
The pH sensor replaces a pH meter and can monitor the progress of acid-base reactions. In an acid-base titration the acid is dripped into alkali from a burette and the pH is monitored. There are two approaches to this - the semi-quantitative approach simply involves monitoring the pH against time as the acid drips from a burette. This makes the assumption that the flow rate of the acid is constant. Or there is the quantitative approach where you enter the volume of acid using the keyboard. During the titration, you add acid bit by bit and type in the amount added at each point. The pH is measured for you. In this way, it is quite easy to prepare a set of impressive acid-base titration graphs.

**Chemical change**

Is there an energy change when plaster of Paris sets? Or: which mixture of lime and sugar makes the best heat source? The computer display of rising temperatures provides graphic evidence of these exothermic reactions.

**Combustion**

Oxygen, humidity, temperature and light sensors.

During combustion oxygen is used, water is produced and heat and light energy given off. All these changes can be monitored electronically. So you can place probes in a bell jar with a burning candle and record for a few minutes. Then, when the candle extinguishes, re-admit air to the bell jar and note the increase in oxygen level.
Conductimetry

Conductivity sensor

Change in a solution’s conductivity is used as a measurable feature in some reactions. For example when barium chloride is added to sulphuric acid a precipitation occurs with a consequent decrease in the conductivity of the solution. This can be monitored using a conductivity sensor with the production of a very good graph.

The conductivity sensor also provides a measure, if non-specific, of water purity or salinity of rock pools.

Energy from fuels

Temperature sensor

During the combustion of a fuel, heat energy is given off. In the activity illustrated, the energy released heats a measured amount of water - allowing you to calculate the energy content of the fuel. Set up a temperature probe in a boiling tube with a measured amount of water. Burn a measured amount of fuel (a candle, a spirit burner, metaldehyde, wood) and monitor the temperature rise. Read off temperature values from the graph and calculate the energy released. A high temperature probe would allow you to compare the combustion temperatures of fuels.

Gas in fizzy drink

Position sensor or balance

How much gas is there in a can of fizzy drink? How does temperature affect the loss of gas? Does keeping an opened can in the fridge help to keep it fizzy?

Use a position sensor to investigate. Place the position sensor on the plunger of a gas syringe and monitor the loss of carbon dioxide from a fizzy drink. You can also use a balance to monitor the change in mass. You will need a balance designed to link to your computer, a suitable cable and software.

Gasometry

Position or manometer sensor

Place a position sensor on the plunger of a gas syringe and use it to monitor the progress of any gas evolving reaction. As examples try the reaction between marble and acid (e.g. acid rain), the decomposition of hydrogen peroxide and the loss of carbon dioxide from say, a fizzy drink.

For reactions involving much smaller volumes of gas, a pressure sensor can be used. For example you can use one to monitor the use of oxygen by rusting iron.
Gravimetry

Electronic balance

The rates of some reactions can be monitored by the change in mass that occurs due to gas evolution. You need a balance designed to link to your computer, a cable and software. You can study the reaction between marble chips and acid; the decomposition of hydrogen peroxide; the water uptake by silica gel or the specific latent heat of vaporisation of water. Explore the factors which affect the rates of reactions such as different catalysts, the amount of catalyst, particle sizes and concentrations of reactants.

Thermometry

Temperature sensor

The computer display of rising and falling temperatures provides graphic evidence of exothermic and endothermic changes. Use a temperature sensor to monitor a thermometric titration, measure heats of solution, the heat evolved in polymerisation or in the hydrolysis of organic halogen compounds.

Absorption of thermal radiation

Temperature, thermocouple or IR sensor

Different surfaces, black, white and shiny absorb heat radiation differently. The subtle changes in temperature are fairly easily shown using electronic sensors. The three kinds of ‘heat’ sensor available are used slightly differently:

Temperature sensors: place the probe in a black painted calorimeter with water. Use a second probe in a similar but white painted calorimeter. Start recording and allow the temperatures to equilibrate. Finally move a radiant heat source into position, mid way between them.

Thermocouple: use differential temperature probes - place one probe in a black painted calorimeter with water. Place the other probe in a similar but white painted calorimeter. Set the sensor range to a low setting. Start recording and allow the temperatures to equilibrate. Finally move a radiant heat source into position, mid way between them. As a simpler alternative, place the two probes under black and white painted metal surfaces.

Infra Red Sensor: Use the sensor to take readings of radiation at various distances from the source. Alternatively, take readings of radiation reflected from the surfaces.
AC ripple

The fast data capture ability of the computer and fast data loggers can pick up the flickering of a fluorescent lamp. Point the sensor at a fluorescent strip lamp. Set the data logger to record as fast as possible. The graph will show the flicker and a simple count will indicate its frequency.

Battery life

Different electrical cells exhibit quite different deterioration characteristics. For example, nickel-cadmium cells work steadily and suddenly stop dead. Others decay steadily to the end. This data is useful for matching battery types to their final application.

Set up a circuit with a battery discharging through a lamp. Connect a voltage sensor across the lamp. Monitor the p.d. as the battery discharges. Try again using other cells such as Nickel-Cadmium, Alkaline, Lithium and Lead-Acid. Some people say they can revive a battery by placing it under their pillow overnight. Investigate this idea.

Capacitor discharge

The charging and discharging characteristics of a capacitor can be shown very clearly using electronic voltage and current sensors. The computer captures this fairly rapid event, and displays it as a graph for further study.

Set up a circuit with a power supply, switch, resistor and capacitor in series. Connect the voltage sensor across the capacitor and put the current sensor in series with it. Monitor the p.d. and the current as you charge and discharge the capacitor.

Cooling Curves

As a pure substance changes from liquid to solid there is a loss of heat. However, at the melting point, the temperature hardly changes. Monitor the cooling of stearic acid, benzophenone or wax in a test tube with a temperature probe. You can use a second probe - placing it in a small beaker of water with the above apparatus. In this way you will see how the beaker of water warms as the substance in the test tube cools. This provides evidence to help explain the latent heat of fusion.

A high temperature sensor would allow you to study the melting points of metals.
Physics

Ohm’s Law

Set up a circuit with a power supply, rheostat and resistor. As the current through the resistor alters, the p.d. across it also changes. If the various current values are plotted against the p.d. we obtain the relationship called Ohms Law. Other electronic components show different behaviour. These relationships are shown easily, rapidly and graphically using sensors.

Set up a circuit - as above. Connect the voltage sensor across the resistor and the current sensor in series with it. Monitor the p.d. and the current as you move the rheostat slider. By plotting p.d. against current you should obtain a graph corresponding to Ohms Law. Try again using a resistor (with twice the value), a lamp, a Silicon diode and a Germanium diode.

Results: for the second resistor the gradient of the p.d. v current graph will be different. The lamp will ‘break the law’ indicating that its resistance changes with temperature. The diodes will only conduct above a certain voltage - but take care not to overload them.

If you have a fast data logger use its fast recording feature to measure the current surge when you switch on a lamp.

Interference patterns

The light sensor can be used to prepare a graph representing the diffraction and interference patterns. A laser is directed through a slit and the position of the light probe is altered steadily. The experiment can be repeated using a multiple slit.

Direct the laser at the light probe. Start recording and move the probe at a steady speed across the pattern. The experiment can be extended so that you measure the distance the probe is moved. The position sensor monitors the movement of the light probe. (You will, of course, have to calibrate this movement first.) Attach the light probe to the position sensor with a stiff piece of wire. Start recording and move the probe as before. After the recording, you should be able to plot the light intensity against the distance moved.

Elasticity

A position sensor can be attached to various kinds of thread and masses attached to measure the elasticity of the thread.
Do different metals expand at the same rate? Get metal bars of the same dimensions. Fix one end in a bench vice and let the other end rest on the lever arm of a position sensor. Start recording when you begin to heat the metal bar. This should produce a graph showing the expansion of the bar. Repeat using other metals.

The position sensor can also show the expansion of the air in say, a balloon. Place a filled balloon in a fridge to cool. Remove it and place it on the bench with a position sensor attached to it. Start recording - the graph will show the expansion of the air in the balloon.

**Distance - time**

The distance or motion sensor is a powerful tool for measuring distance and exploring distance-time relationships, acceleration, and kinetic energy. Intriguing investigations to try include designing and evaluating a model ski jump and studying stopping distances under different conditions.

Why do they put salt on the roads?

Investigate the effect of salt on the melting of ice. Take two beakers of ice and place a temperature probe in each. Start recording the temperature and add salt to one of the beakers. Does the ice melt faster? Does the temperature change?

**Gas (oxygen) solubility**

The solubility of oxygen in water decreases with increasing temperature. This is of special significance to life in water. The response of an oxygen electrode itself varies with temperature so your sensor will need to compensate for this.

Place the thermistor, oxygen probe and temperature probe in a flask of water. Place the flask in a water bath and monitor the temperature and oxygen level. Increase the temperature of the water and then allow it to cool. If the solubility of oxygen decreases with increasing temperature, does the oxygen level increase again as you let it cool?
Forces

Light gates for timing

The computer can start an internal ‘stop-clock’ when an object passes in front of a light sensor and stop the clock as it passes a second sensor. This requires software especially designed for timing.

Free fall: To measure the time an object takes to fall, use clamps to fix one sensor at a high point and one at a low point. Set up the software to record and then drop the object. Get the software to calculate the acceleration due to gravity.

More forces: There are numerous science experiments using ramps and the linear air-track. Ticker-timers have been used in the past but the Timing sensors are a welcome replacement. Use clamps to fix the timing sensors at each end of a ramp. Run a dynamics trolley or model car down the ramp and time the event. Study the effect of altering the angle of the ramp, of altering the height the trolley is dropped from or of changing the load on the trolley. You can also use this set up to show friction - measure the time take for objects, such as trainers/shoes, to slide down different surfaces.

Using timing sensors you can investigate which is the best shape for a boat. Use a length of plastic guttering filled with water. Attach thread to a boat and pass this to a pulley and weight at the far end of the gutter. Fix up the timing sensors to see how fast different boats travel.

At a higher level, you can show Newton’s second law of motion. Use slotted masses and a pulley to pull a trolley along a ramp with a slope sufficient to compensate for friction. First measure the acceleration of an unloaded trolley with say 250g hanging from the pulley. Then repeat the measurement, each time moving a mass from the pulley to the trolley. This keeps the total mass the same. A range of other advanced investigations with timing sensors will allow you to show the conservation of momentum, elastic collisions and recoil.

Other investigations: If you give the trolley a push, does it continue to accelerate after you let go? If you drop a book and a pencil at the same time, which would land first? Does the shape of an object affect how fast it falls? What makes a good parachute? Which elastic band makes the best ‘engine’?

Gravity

Position / force sensor

A position sensor can play the part of an electronic balance or ‘force sensor’. The sensor is connected to a data logger and the assembly taken to a passenger lift to show the effects of going up and down. Attach a spring with hanging masses to the position sensor. Start recording as the lift rises and comes to rest. Continue recording as the lift goes down. A force sensor (a modified bathroom scale) can do this more elegantly.
Gas laws

Temperature & pressure

We can show how pressure varies with temperature: Place a temperature probe in a water bath. Place an empty flask with a bung and a plastic tube in the water bath. Connect the tube to the pressure sensor. Increase the temperature of the water bath as you monitor the temperature and the pressure. Continue monitoring and allow the water bath to cool. When finished, plot the pressure against the temperature to show the relationship.

A simple variation on this theme involves comparing the pressure from a balloon moved from a cold room to a warm room. Place the balloon in the fridge to cool. Later, connect the balloon to the pressure sensor and start recording as the balloon gradually warms up.

Heat transfer

Temperature sensors

Most conduction, convection and radiation experiments can be radically improved by using temperature sensors. It is quite easy to adapt the numerous experiments on this theme for the computer.

Conduction along strips of metal: tape the probe to the end of a metal strip and heat the other end in hot water or a Bunsen flame.

Conduction: compare the cooling of a large saucepan of water with a small saucepan of water. Similarly, compare how fast they heat up. Suppose you are making a cup of coffee, the water boils and the phone rings. Should you pour the water now or after the call?

Convection in liquids: use two temperature probes, place one at the bottom of a beaker of liquid, the other at the top. Heat the beaker and monitor how the temperature of each probe changes.

Conduction/convection in air: a good context for this is ‘keeping your house
warm’. Get a cardboard model house and place temperature probes high up / low down in the house.

Insulation: Use two temperature probes to compare insulating fabrics, different socks or gloves, containers for keeping drinks hot and containers for keeping a picnic cold. Does a carrier bag help keep your take-away warmer? How do different vacuum flasks compare?

Radiation: see Absorption of thermal radiation.

**Cooling by evaporation:**

Compare the cooling effects of water and alcohol. You can compare the cooling curves of evaporation of different liquids in contexts such as: do after-shave and perfume really make your skin cold - or does it just feel cold? Or: should you feel colder out of the swimming pool than you did in it? Or, what good does sweating do? Should wet gloves really feel so much colder? Would plastic gloves keep our hands warmer? In this last example, compare the cooling of wet gloves, dry gloves and wet gloves covered in a plastic bag. Place temperature probes in the gloves and use a fan to simulate a cold breeze.

**Heat and electric current**

Voltage, current and temperature sensors. IR sensor.

You can investigate the temperature change when a measured amount of water is heated by a measured amount of current. Set up a circuit with a power supply and low voltage heater unit in a beaker of water. Connect a voltage sensor across the heater unit and a current sensor in series with it. Record the temperature, the p.d. and the current. You can stop after very short period of time, since the computer will have taken many readings. Get the program to read values off the graph.

You can also check the efficiency of a solar cell - relating its output to the temperature. The setup would be similar to the above - less the heater unit and beaker.

The special sensitivity of an Infra Red sensor can be used to monitor the heat given off when a fairly small current passes through a wire.
Magnetic field

A magnetic field (or magnetic flux density) sensor features a sensitive Hall probe. This can be used to study the strength of a magnetic field with distance, to compare magnets and electromagnets and to show the change in magnetic field as the Hall probe passes through a coil. Three kinds of measurement can be attempted. Firstly a simple ‘spot’ measurement of the magnetic field. Secondly a measurement of the field against distance. You type the distance in at the keyboard. (For this you set up the software keyboard entry.) Thirdly a measurement of the field while you move the probe steadily through a coil. (For this you record the magnetic field against time.)

Induction

Connect a Helmholtz coil to a voltage sensor. Set up a data logger to record as fast as possible and to start recording only when there is a change in voltage. Finally, drop a magnet through the centre of the coil. You may need to add a negative bias to the sensor input to allow a negative voltage to be recorded.

Light energy

Investigations to try: Compare the brightness of different light sources - which would be best to read by at night? How does the light level change with distance from a light source? Which pair of sunglasses appears to be the most effective? How fast do photochromic lenses change? Compare the light reflected from different fabrics - which would be safer for a cyclist to wear at night? Compare the light transmitted through different materials - which of them would be best for a window blind?
Oscillation of a spring or pendulum

Monitor the oscillation of a spring or pendulum by attaching a moving spring or pendulum to a position sensor. This will allow the study of simple harmonic motion. You can show how the frequency is unaffected by the amplitude of the movement or by damping. Using the mathematical utilities of the data logging program you can derive further graphs to show the velocity and the kinetic energy of the moving mass.

An interesting extension involves forcing the mass to vibrate by using a coil powered by a signal generator. The mass in this case will need to be a magnet and the investigation can show the system’s resonant frequency.

Radioactivity

Radioactivity sensors use a Geiger-Muller tube. You can quickly, and safely prepare a decay curve using a protactinium generator. You can study the statistics of decay, calculate half-lives and show the effect of distance on the count rate (inverse square law). For this last investigation, you need to get the software to accept distances typed at the keyboard.

You can achieve a very good demonstration of radioactive penetration by getting the computer to display a graph whilst you place different materials between the source and the GM tube.
Sound and sound travel

The sound sensor allows a range of investigations into sound travel, sound pollution, sound proofing and sound decay with distance from a sound source. Using fast recording options on the computer you can prepare a graph of the attack, decay, sustain, release characteristics of different sounds. When you use a data logger and record as fast as possible, the sound sensor can show the sound wave and also record voice patterns.

Solar Power

Build a solar collector using an umbrella lined with foil. Use the temperature sensor to monitor its effectiveness. For out-of-doors work plug the sensor into a data logger. Position the temperature probe tip at the focus of the collector and record the temperature change. Compare the effects of different reflective materials. You’ll need to reposition the umbrella if you wish to record throughout an afternoon.

Spectrum

Ultra-Violet / infra-red sensor

Use the infra-red sensor to detect the infra-red at the end of the visible spectrum. Use the ultra-violet sensor to detect UV, to compare the transmission of UV through glass, plastic and quartz or to compare sunglasses and sun creams.

Sound sensor

Temperature sensor

Ultra-violet sensor
Introducing data logging to ages 10-13

In this section there are a number of introductory ‘investigations’ using sensors. Investigations are an entirely suitable kind of activity for using sensors. Each activity is a double page spread, one side with teaching notes, the other with a guide that is set out as a worksheet. The details and questions are provided purely as a ‘jump-start’. Clearly, if your students are already fairly skilled in investigative work you will want to cut-out or cover some of this detail to avoid giving the game away. In all cases, the pages are intended as starting points to be used as appropriate. The activities are widely applicable including use with the most basic software.

The first side of the spread is the teacher’s guide:
- Information on the science in the activity.
- Requirements - a detailed equipment list.
- Introducing the Activity - some talking points.
- Investigate - some practical advice.
- Results and outcomes - expected results.
- Apply - extension activities.

The second side of the spread sets up a context for the activity, lists the things needed and suggests a method of investigating. Wherever appropriate you will find an example table to record the results and some questions to interpret them. Finally, the apply section sets new tasks using the skills developed so far.

Temperature sensor activities
Keeping baby warm. About heat transfer.
How can we keep warm? About heat insulation.
Making your hot drink cool. About heat travel.

Sound sensor
Can you trust your ears? About loud and quiet.
What can sound travel through? About sound travel.
What’s the best way to stop sounds? About sound proofing.

Light sensor
Which light is the brightest? About light sources.
What should a cyclist wear? About reflection of colour.
Stopping light from a window. About light transmission.

See also:
- Ideas for datalogging Pages 11-32
- Exploring science with sensors Page 52-61
Human beings, babies and adults alike are warmer than their surroundings and constantly lose heat to it. Other things being equal, the speed at which they lose heat depends on shape, the layer of fat beneath the skin and the surrounding temperature. The more skin in contact with the surroundings the faster the loss of heat. Animals can stay warm longer by huddling or curling up into a ball which has a smaller surface area. A baby is more prone to heat loss: it has a greater surface area for its size compared to an adult. Insulating materials, such as blankets, slow down the baby's loss of heat.

**Requirements**

- Large and small metal containers - decorate them as 'baby' and 'adult'.
- Temperature sensor, interface, computer cable, software.
- Computer, printer and monitor. Safety note: use hand hot water, place the containers in a bowl or tray. Also: aluminium foil.

**Introducing the activity**

Ask the group how they would dress a small baby for a visit to the park. Would the baby need to have more covering than themselves? Is a baby more sensitive to cold? Does a baby get colder faster than an adult? How might we investigate this?

**Investigate**

The investigation compares the cooling of containers filled with hot water. Dress the containers like a baby and an adult. You may need to do two separate runs, one for each container. To help compare the two time graphs, ensure that both starting temperatures are similar and record for the same amount of time. 15 minutes should be fine.

**Results and outcomes**

Place or trace one of the two time graphs over the other. The smallest container of hot water will cool faster than the largest container and show a lower final temperature. Note the steeper fall in the time graph.

**Apply: more to do**

How do elephants keep cool? Elephants use the surface area of their large ears as heat radiators. In hot weather elephants increase the blood supply to the ears and flap them about to lose body heat. Use aluminium foil to wrap a can of water and to make two large elephant ears. Measure how fast it cools. You might also use a spreadsheet as a calculator to show how surface areas change with size.
Have you noticed that small babies always get wrapped up well. Do they need more covering than you do?

In this activity you will compare a small 'baby' and a larger person. Who do you think will get colder first?

You need

Care! You will be using hot water. Make sure it does not get knocked over.

Hot water, a large and a small container, a 'blanket'. Computer, printer and the temperature sensor.

Investigate

1. Get the computer ready to measure temperature.

2. Fill the small container with hot water. The small container is a warm baby. Take and record its temperature.

3. Get the computer to draw a time graph as it cools down.

4. Stop the recording after fifteen minutes. Now print the graph.

Now see if a larger person keeps warmer:

5. Fill the large container with hot water. The large container can be you. Take the temperature. Make sure the temperature is the same as the baby was to start with.

6. Get the computer to draw another time graph as it cools down.

7. Stop the recording after about fifteen minutes. Print the graph.

1. What was the temperature of your 'baby' at the beginning?

2. What was the temperature of your 'baby' after fifteen minutes?

3. What might happen to the baby's temperature if you left it a long time?

4. Where do you think the baby's heat went to?

5. What was the temperature of a larger person after fifteen minutes?

6. Look at your graphs. Which loses heat faster, a small baby or a larger person?

7. Can we dress a baby in 'too many clothes'?

Apply:

· Does wrapping a baby in a blanket help to keep it warm?

· How do elephants keep cool?
How can we keep warm?

Teachers notes

Clothes provide an insulating layer between the body and the surroundings. Air is a good insulator and a poor conductor of heat. The air trapped within clothing provides protection against heat loss. Depending upon how much air is trapped, bulky sweaters or many layers of thin clothing provide insulation.

Results and outcomes

Place the time graphs over each other. The most effective insulator maintains the temperature of the water longest - shown by the slower fall in the time graph and a higher final temperature.

Apply: more to do

Astronauts sometimes wear shiny suits. What do these do? Wrap a container of hot water with aluminium foil. The foil ‘suit’ should increase the rate of cooling. How do animals keep warm? Use fake fur as an insulator. Does fur still work when it is wet? Some children may have noticed that animal fur coats grow thicker in the winter. Which box is best to keep a take-away pizza hot? A variety of boxes, lined and unlined, can be compared.

More things to investigate

Do after-shave or perfume really make the skin cold? Remove the temperature probe from the after-shave to allow evaporation to begin. If you got wet in the rain, would your wet clothes really make you colder? Study the effect of a cool wind on the temperature in a wet glove or sock. Then cover the item with a polythene bag.
How can we keep warm?

When it is cold we wear extra clothing. Which would keep us warmer: one thick jumper or two thin shirts?
In this activity you will compare different clothing to keep warm with.

You need:
Hot water, container, wool, cotton, elastic bands. Computer, printer and temperature sensor. Care!
You will be using hot water. Make sure it does not get knocked over.

Investigate:
1. Get the computer ready to measure temperature.
2. Wrap a container with wool and fill it with hot water. The container can be you!
3. Get the computer to draw a time graph.
4. Stop the recording after fifteen minutes. Now print the graph.
See if 2 shirts can keep you warm:
5. Wrap a container with cotton fabric and fill it with hot water.
6. Take the temperature. Make sure the temperature is the same before continuing.
7. Get the computer to draw another time graph.
8. Stop the recording after fifteen minutes. Print the graph.

1. Does clothing help to keep the heat in?
2. What should you wear to keep warm?
3. If you wore T-shirts and a jumper what would this do?
4. How can we make our home warmer?

Apply:
Now find the answer to this question:
• What would be best to wear in hot weather?
Hot things cool because they lose heat to their surroundings. We can help them to cool by making the surroundings cooler (by blowing) or by conduction through a spoon. The greater the difference in temperature between an object and its surroundings, the faster it will cool.

**Requirements**

A plastic cup. Safety note: use hand hot water, place the cup in a tray. Temperature sensor, interface, computer cable, software.

**Introducing the activity**

Ask the group what they do if they are given a very hot drink. Do they wait or can they cool the drink down?

**Investigate**

Water should be at a safe temperature. The first activity simply involves allowing a cup of water to cool. The second involves trying to speed up the cooling. Children might try blowing on the surface, placing the cup in the draught of a fan, placing it near a window on a cold day or placing the cup in a dish of cold water.

To help compare the time graphs, ensure the starting temperatures are similar and record for the same amount of time - 15 minutes should be adequate.

**Results and outcomes**

Printed graphs should be obtained and placed over each other.

**Apply: more to do**

A spoon left in a drink will help cool it by conducting the heat into the surroundings. A lid on a container will help prevent convection and conduction. If we pour a drink between two cups we provide a bigger area for the drink to lose heat from.

**More ideas to investigate**

Does ice melt slower when wrapped up with a sweater / placed in a vacuum flask? The vacuum flask will need to allow the temperature probe to monitor the temperature. Heat eventually finds its way to the ice by conduction through the flask.
Making your hot drink cool

In this activity you will measure the temperature of a hot drink as it cools down. You will use the computer to help you do this. Later you can try to make the drink cool down faster.

You need
- A cup, hot water. Computer, printer and the temperature sensor. Care! You will be using hot water. Make sure it does not get knocked over.

Investigate
1. Get the computer ready to measure temperature.
2. Make a hot drink. Take and record its temperature.
3. Get the computer to draw a time graph as it cools down.
4. Stop the recording after fifteen minutes. Now print the graph.
Now see if you can speed up the cooling:
5. Make another hot drink. Take its temperature. Make sure it is the same temperature as your first drink was.
6. Get the computer to draw another time graph as it cools down. Try to make your new drink cool down faster by blowing on it.
7. Stop the recording after fifteen minutes. Print the graph.

Apply
See if your drink cools down faster or slower when you:
- Leave a spoon in the drink.
- Place a lid on the drink.
- Pour the drink between two cups.

What is the temperature of a hot drink that is just ready for drinking?
Sounds originate from the vibration of some material which set up vibrations in the air. These air vibrations are little ‘puffs’ of higher air pressure followed by gaps of lower air pressure. The loudness or quietness of a sound is the size of these ‘puffs’ or in other words, the amplitude of these vibrations. Loudness is measured with a sound meter or sound sensor. The unit for measuring sound is the decibel, named after Alexander Graham Bell the inventor of the telephone. A ‘Bel’ is too large a unit for everyday use so the decibel is more commonly used. The pitch of a sound, which is how high or low a sound is, must not be confused with loudness. To measure the pitch of a sound you need an oscilloscope or frequency meter.

**Investigate**

Get the software to show a bar gauge ‘picture’ of how loud sounds are. Measure how quiet the group can be. Show the sound level in decibels. Two points are worth considering: The sensor is very sensitive and picks up most sounds in the room. How can they be sure they are measuring the sound from the sound maker and not something else in the room? Where should the sound source and sensor be placed? Experiment to find a best position.

**Requirements**

Musical instruments, a ticking clock, elastic bands, spoons, scissors, tuning forks, containers filled with rice or paper clips, blocks of wood, a drum, a radio and so on. Aim for a balance of percussion, string, wind and electronic sound makers. Interface, cable, Sound sensor, software.

**Introducing the activity**

Ask about being asked to ‘turn the noise down’ by an adult. Can adults and children agree on how loud is loud? Is anyone right? Does it depend on what the sound is? Explain that they will be testing various sound makers to find out which are the loudest and the quietest. Ask how they will agree on what is a loud and what is a quiet sound? They might rate the sound level on a scale of 1 to 5, 5 being loudest.

**Results and outcomes**

How do the estimates of loudness compare with the Sound sensor? Estimates of the loudness of a sound can contrast wildly with the sensor. Sudden, shrill or piercing sounds appear loud even though they may not be. Is this what adults object to? The importance of using measuring instruments rather than a guesswork is a key idea here.

**Apply: more to do**

**Do the shapes of ears help us to hear better?** Place the sound sensor at one end of a tube and make a sound at the other. Try again with a paper funnel or model animal ears. Try using a model satellite dish - place the sensor at the centre of an opened umbrella lined with metal foil.
Can you trust your ears?

Which sound makers make the loudest sounds?

Can you trust your ears to decide? Can you measure the sound level?

In this activity you will use the computer to measure how loud sounds are.

You need

Sound makers. Computer and the sound sensor.

Investigate

1. Which sounds will you test? Will you play the sound makers 'hard' or 'soft'?
2. Try the sound makers and decide which sounds are quiet and which ones are loud.
3. Decide how you will record your findings.
4. Test each sound using the sound sensor.
5. Record each Sound level in your table.

<table>
<thead>
<tr>
<th>Type of sound</th>
<th>How sound is made</th>
<th>Quiet or Loud</th>
<th>Sound level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flute</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Guitar</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Talking</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ticking clock</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Did you and the others agree on what was 'loud' and 'quiet'?
2. How far away was the sound maker from the Sound sensor?
3. Sort the sound makers into order, loudest first
4. What sound level would you say is loud?
5. Make a sound level scale with the numbers from 0 to 100. Mark it to show Quiet, Loud, and Very loud.
6. Do your ears and the sound sensor disagree?

Apply

Use the sound sensor to find who has the noisiest shoes.

If you drop something, does it make more noise if you drop it from higher up?

Does the shape of your ears help you to hear better?
What can sound travel through?

Introducing the activity

Ask the group how the sound from next door gets to their ears. Is it through the air? If all the air in the classroom was replaced with water could they still hear? Has anyone heard sounds underwater? Can sea creatures such as whales and dolphins hear underwater? Can we hear through walls? Does anyone know of a way to hear things through a wall?

Investigate

Ask the group what they might test to find if sound can travel through them. Will the tests be affected by the noise in the room? Two levels are recorded - to compensate for the background noise. This idea may well confuse and is worth going over first.

Results and outcomes

Sound is carried through solids and liquids - it travels faster through solids and liquids. The particles that make up solids and liquids are more closely packed together than in air so there are more particles for sound to travel through. The fact that sound travels through solids and liquids can be useful or annoying. Prisoners in jail can communicate by tapping on pipes; trapped miners can tap on the walls in a mine to help us find them. We can hear the dentist drilling our teeth, the noise from a washing machine, from traffic or a building works; sea divers can talk by touching their helmets and doctors can hear and see an unborn baby womb using sound.

Requirements

A ticking clock, doorbell or electric buzzer. A tank or bowl of water, glass (a window), wood (a broom), metal (furniture), plastic pipe, a wall, a door, a string telephone. Sound sensor, interface and software. The Sound sensor is electrically safe but do not put it in water.

Sound needs a medium to travel through. The medium can be a solid such as wood, liquids such as water or gases such as air. Sound travels because sound vibrations cause solids, liquids and gases to vibrate and carry the sound. Sound travels faster through solids and liquids than it does through air. The speed of sound in air is 330 metres per second, in water it is 1400 metres per second. This is why whales can communicate with each other quickly even when they are miles apart. Sound does not travel through space or a vacuum. Astronauts have to talk to each other using radio. They would also hear each other if their helmets were touching, the vibrations are carried through their helmets.

What can sound travel through?

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Requirements

A ticking clock, doorbell or electric buzzer. A tank or bowl of water, glass (a window), wood (a broom), metal (furniture), plastic pipe, a wall, a door, a string telephone. Sound sensor, interface and software. The Sound sensor is electrically safe but do not put it in water.
What can sound travel through?

Can sound travel through the air? Or water, wood and metal?
In this activity you will use the sound sensor to find out what sound can travel through.

You need
Glass, wood, metal and plastic pipe; a wall, a door, a string telephone. Computer and the sound sensor. Keep the computer away from water and wet hands.

Investigate
1. Choose a sound maker. It must make a sound that the sound sensor can hear.
2. Can sound travel through a door? Place the clock on the door. Press your ear against the door and listen.
3. Move the clock away from the door. You should no longer hear the clock through the door.
4. Place the clock on the door again. Press the Sound sensor against the door and record the sound reading.
5. Move the clock away from the door. Record the sound reading.
6. Find out if sound can travel through other things.

<table>
<thead>
<tr>
<th>Material</th>
<th>Sound level (touching)</th>
<th>Sound level (not touching)</th>
<th>Difference in sound level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Metal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water balloon</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plastic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>String</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. List the things that you found sound can travel through.
2. Does sound travel better through wood or air?
3. Give an example of where sound travelling through metal is useful.
4. Give an example of where sound travelling through water is useful.

Apply
Does sound travel through string? Make a string telephone to find out.
Who can make the best string telephone? Use the sound sensor to test your telephones.
Do sounds get weaker with distance?
Sound proofing a building is extremely difficult. This is because all sorts of materials in the home vibrate and transmit the sound. Having plenty of sound absorbers, such as carpets, curtains and soft furnishings in a room help to absorb sound. When a sound is made the vibrations in the air cause surfaces to vibrate and to reflect sound. Materials such as insulating felt and foam do not vibrate very well nor do they reflect sound well. In contrast a sheet of metal or wood does vibrate well and does not insulate sound well.

Requirements

A consistent sound source such as a buzzer or bell. Sound proofing material: cotton wool, foam, cork, newspapers, card, wood, polystyrene, an inflated balloon, a cushion, a blanket, thick or padded clothing; cardboard egg-boxes. Computer, monitor, Sound sensor, interface, cable and software.

Introducing the activity

What is sound for? Ask the group to consider how sound is useful. Get examples of useful sounds: speech (communicating); music (comforting, enjoyable, exciting). Sounds warn us about danger or danger to come. Useful sound is about communicating. Is an old noisy car trying to ‘tell us’ something? When is sound called music? When is sound called noise? Noise is sound being a nuisance or causing ear damage.

Investigate

Ask the group how they shut out sound when there’s a lot of noise next door? Would closing the window or the curtains help? Use a buzzer or bell to make a steady sound. Measure its sound level with the sensor covered with different materials in turn. Different thicknesses and mixed layers of say, foam and polystyrene should also be tested. Alternatively, place the sound sensor in a ‘shoe box’ to represent a room and line the box with various materials.

Results and outcomes

Good sound proofing depends on the material used. Sound insulation usually involves thick air-containing materials, such as felt.

Sound can ‘leak’ around a sound insulator.
Sometimes sound is a nuisance. Sound from traffic and the room next door can stop us getting to sleep. Sound can also distract us from what we are doing.

How can we stop sounds? To find out you will use the sound sensor to find the best way to stop sounds.

### You need

A sound maker. Materials to stop sound such as clothing, a blanket, a cushion, egg boxes, cork, polystyrene. Computer and the sound sensor.

### Investigate

1. Decide which sound maker you will use. It needs to make a fairly loud steady sound.
2. Make a sound and measure the sound level. Record your result.
3. Choose a material that might stop sound, for example use a blanket.

<table>
<thead>
<tr>
<th>Material</th>
<th>Sound level (before)</th>
<th>Sound level (after)</th>
<th>Difference in sound level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blanket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Folded blanket</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Egg boxes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Put the material around the sound sensor.
5. Make a sound, measure the sound level.
6. Try the other materials. Record your results.
7. Fold the blanket to make it thicker and try again.

1. Which material is the best at stopping sound?
2. Which material is useless at stopping sound?
3. Does twice the thickness of the material stop the sounds any better?
4. Do the sound proofers have anything in common?
5. How would you sound proof your room at home?
Which light is the brightest?

Requirements
A candle, some torches, a torch without a reflector, tungsten lamp, fluorescent strip light and daylight. Light sensor, interface, cable, software. Computer and monitor.

Introducing the activity
Ask the group to list as many ways as they can of getting light. Try to put them in order of brightness: a torch can seem quite bright - is this brighter than the sun? Which is the brightest, the lighting in the room or the sun outside? The business of science involves measuring how bright things are rather than guessing. Show how it can be used to give reliable readings of light levels. It uses a scale of zero to 100. Where should the light sensor be placed in relation to the light source when taking readings?

Investigate
Use the light sensor at a metre, or always at the same distance from the source. Stray light will affect the readings obtained. To avoid this, place a tube made of card or foil around the sensor.

Results and outcomes
Sunlight is the brightest and candlelight is the weakest. Fluorescent strip light is much brighter than tungsten light and both are suitable for reading at night. Other factors can be taken into account - such as the warm colour of tungsten light compared to fluorescent light, safety and convenience. Use the electricity tariff to work out how much it would cost to provide say, 10 hours of tungsten light and fluorescent light. The price depends on the wattage of the bulb, but typically tungsten bulbs need to have a wattage 3 times as high to produce anywhere near the brightness of fluorescent lights. Estimate how many sets of batteries would be needed to obtain 10 hours lighting and how much this would cost. Finally, find out the burning time and cost of a candle.

Apply: more to do
Does light come from the back and sides of a light source? Place a candle in the middle of a circle and take readings at intervals around it. Light spreads out in all directions from a light source. This is why we have to use reflectors and lamp shades.
Which light is the brightest?

You need light to see things. How many ways of getting light can you think of? Which way of getting light would give you the most light? The light sensor can measure how bright the light is. In this activity you will use it to test different light sources to find which is the brightest.

You need

A candle, some torches, a torch without a reflector, tungsten lamp, fluorescent strip light and daylight. Computer and the Light sensor.

Investigate

1. Should you hold the light sensor very close to the lights? Should you hold the light sensor far away from them?
2. Can you stop light in the room from getting to the light sensor?
3. Get the computer to measure the light level.
4. Test each of the light sources.
5. Record your light level readings in a table.

Apply

Does light come from the back and the sides of the candle?
Does light come from the back and the sides of the other lights?

<table>
<thead>
<tr>
<th>Light Source</th>
<th>Light Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torch</td>
<td></td>
</tr>
<tr>
<td>Strip light</td>
<td></td>
</tr>
<tr>
<td>Sunlight</td>
<td></td>
</tr>
<tr>
<td>Tungsten light</td>
<td></td>
</tr>
<tr>
<td>Candle</td>
<td></td>
</tr>
</tbody>
</table>
Most substances reflect some light and that is why we can see them. White light is a mixture of many colours mixed together. When white light shines on say, a blue fabric, the fabric reflects blue and absorbs every colour except blue. Similarly a red fabric reflects red and absorbs all other colours. Fluorescent fabrics, often worn by cyclists, temporarily store and emit the light shining on them.

**Investigate**

A light source such as a desk lamp or strong torch can be used to illuminate the fabrics. The sensor should be directed at or be very close to each fabric tested. Ideally the light sensor should be clamped into a fixed position.

**Requirements**

Fabrics of different colour, foil, other reflective materials, shiny and dull fabrics in the same colour. A desk lamp, light sensor, interface, cable, software.

**Introducing the activity**

Discuss the road safety aspects of walking and cycling in the evening. Many accidents happen at this time. What can we do about this? If wearing bright clothes is an answer, what colour clothes are the most noticeable?

Can we compare the colours of clothes by eye? Is there anything we can use to help us make a good comparison? I introduce the light sensor for measuring the light reflected from clothes.

Ask the group to consider how they will test the fabrics. Will they need to shine a light on the fabrics? Will they press the light sensor against them or hold it away from them? How can they make their investigation into a fair test?

**Results and outcomes**

A black fabric absorbs all the colours of white light and reflects little light back. A white fabric absorbs little white light and reflects most colours back. Shiny and fluorescent fabrics reflect even more light back and are likely to be even better choices for a cyclist.

**Apply: more to do**

Children can use their skills to find whether fabrics look as bright in the evening. They should test their fabrics under poor lighting conditions. The results table should be extended by one column for this second set of results. They may well find some fabrics change their position in the 'league table'. For example, a shiny fabric will not reflect much light under poor lighting.
Cyclists need to be seen. What colour do you think the cyclist should wear? The light sensor can measure the brightness of fabrics. In this activity you will test coloured clothing. Can you use the light sensor to help you choose the best one?

**You need:**
Fabrics of different colour, foil, shiny and dull fabrics in the same colour. Computer and the Light sensor.

<table>
<thead>
<tr>
<th>Fabric</th>
<th>Light level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black</td>
<td></td>
</tr>
<tr>
<td>Yellow cotton</td>
<td></td>
</tr>
<tr>
<td>Yellow plastic</td>
<td></td>
</tr>
<tr>
<td>Day-Glo plastic</td>
<td></td>
</tr>
<tr>
<td>White</td>
<td></td>
</tr>
</tbody>
</table>

**Investigate**

1. How will you test the fabrics? Will you shine a light on the fabrics to test them? Will you press the light sensor on the fabrics to test them? Will you just point the sensor at the fabrics to test them?
2. Get the computer to measure the light level.
3. Test each of the fabrics.
4. Record your readings in a table.

**Apply**

Suppose you were riding a cycle in the evening. Do you think your clothes would look as bright? Test all your fabrics again in dim light.
The light sensor works a bit like the eye. Light enters the eye in much the same way as it enters the light sensor. In the eye the light is focused and absorbed by the retina. Here nerve cells respond to light and then transmit electrical impulses to the brain. The brain interprets the signal as light.

In the light sensor are devices that focus and respond to light. When the sensor responds it sends an electrical message along the wire to the computer. The computer interprets the signal and displays it in a variety of ways.

Glass is a good material for a window pane. Glass has little effect on the passage of light so we call it transparent (or clear). Materials, such as obscured and ground glass, also reflect and absorb very little light. They break up the image passing through them and we call them translucent. Materials which absorb or reflect all the light reaching them are called opaque.

**Requirements**

Polythene, wood, card, foil, light source, thin paper (or fabrics) in a spectrum of colours, black polythene. Glass or plastic: clear and obscured types. (Wrap tape around the edges of glass.) Light sensor, interface, computer cable, software. Computer and monitor.

**Introducing the activity**

Talk about curtains and blinds at home: are there places where they need an opaque blind that cuts out all the light? Are there other places where a blind which lets light through and just stops people seeing through would be better?

Examine the materials you collected together. Which would be suitable for a blind? What are their reasons? Can a light sensor help make the choice?

**Investigate**

Stray light will affect the readings obtained, so place a short paper tube over the end of the sensor. The light sensor will now have a narrower range of view.

In the absence of sunlight, use a desk lamp or spot light.

**Results and outcomes**

From their results, they will be able to make their choice of material for two kinds of window blind a) the opaque kind needed to stop the morning light or useful for a photographer’s darkroom b) the translucent kind that would be useful in a bathroom.

Most materials can be described as transparent, translucent or opaque.

**Apply: more to do**

Do some colours let less light through than others?

A dark coloured material absorbs more of the light trying to pass through it than a light coloured material.
You often need to stop the light getting into a room. What would you use to do this? If you chose curtains would you use thick fabric or thin fabric? Would the colour make any difference?

The light sensor can measure how much light can pass through fabrics. In this activity you will test some fabrics.

You need:
Polythene, wood, card, foil, light source, thin paper (or fabrics) in different colours; black polythene. Glass: clear and translucent. Computer and the Light sensor.

Investigate
1. Get the computer to measure the light level.
2. Use the light sensor to see if glass lets light through it.
3. Can you find a way to stop light from the room reaching the light sensor?
4. Test your materials.
5. Record your readings in a table.

<table>
<thead>
<tr>
<th>Material</th>
<th>Light level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polythene</td>
<td></td>
</tr>
<tr>
<td>Thin paper</td>
<td></td>
</tr>
<tr>
<td>Thin fabric</td>
<td></td>
</tr>
<tr>
<td>Translucent glass</td>
<td></td>
</tr>
<tr>
<td>Clear glass</td>
<td></td>
</tr>
</tbody>
</table>

1. Put the materials into order.
2. Which material is the best for stopping light?
3. Is thick material or thin material best for stopping light?
4. Which material would you use as a window blind?
5. Which material would be best for a bathroom window?

New words: transparent, opaque, translucent.

Apply
Do some colours let less light through than others?
A catalogue of explorations

The use of a computer and sensors can short cut many of the steps in exploring or investigating science. For example, sensors allow pupils to think more about their experiment than the business of recording. And the 'real-time' display gives them valuable feedback on their work.

This section catalogues a number of opportunities for more open-ended tasks.

Do your hands become hot when you exercise?

How can you stop an ice lolly from melting?
Exploring science with sensors

Temperature sensors

Amy took her hot tea to the bathroom but she fell asleep in the bath. When she woke up the tea was cold and the bath was warm. How come?

Why do astronauts wear shiny suits? Would one keep you warmer?

Does fur really help keep an animal warmer? Does fur still work when it is wet?

While making coffee you are called away just as the kettle boils. Should you pour the water now or leave it till you get back?
Exploring science with sensors

Temperature and light sensors

Which flame heats things fastest - the blue flame or the yellow flame?

How can you keep your take-away food hot?

Do wet gloves really make your hands cold?

Does it get warmer when the sun comes out?
Exploring science with sensors

Temperature, light and timing sensors

How long is the day? Will today be shorter or longer than yesterday?

Who has the least slippery shoes?

Do babies get colder more easily than adults?

Does your reaction time improve with practice?
Exploring science with sensors
Temperature, pressure and humidity sensors

How does the pressure on you change with depth?

How does your breathing change after exercise?

Does sweating make you hotter or colder?

Do you breathe out more, or less moisture when you exercise?
Exploring science with sensors

Temperature and light sensors

Wouldn't it be better to leave the heating on all day and all night, instead of heating the building up from cold twice a day?

Do all candles give off the same amount of light?

Is the central heating coming on and off at the most sensible times?

Which fabric would be best for a parasol?
Exploring science with sensors

Light sensor

How fast do photochromic glasses change?

- photochromic sunglasses darken in the sun.

Which is the best pair of sunglasses?

Is light lost when it is reflected off a mirror?

Which light source would be best to read by?
Exploring science with sensors

Sound sensor

If you drop something, does it make more noise if you drop it from higher up?

What can sound travel through?

Who has the noisiest pair of shoes or boots?

What makes the most noise during the day?
Exploring science with sensors

Section 4

Investigate

60

What is best at stopping sounds from travelling?

Which can you hear best, high sounds or low sounds?

Do sounds get quieter the further away you are?

How could you make a really loud drum?
Exploring science with sensors

Timing sensors

If I dropped a large ball and a small ball which would land first?

Does a toy car keep speeding up after you stop pushing it?

How fast is your Karate chop?

Do smaller hands chop faster?

How does the steepness of the hill affect the speed of a car?

Section 4

Investigate 61
Why control?

Control technology involves the study of automated systems in a world increasingly driven by technology. In control technology activities, children identify a need and create a solution to fulfil it. Through this they will analyse situations, form hypotheses, make predictions and evaluate their work.

But computer control activities can also be the focus of many new, absorbing and practical experiences for children. In the course of this, children will learn about automation, sequencing computer instructions and about the logic of control systems.

Control is interesting to both science and technology curriculum areas - although clearly the balance, and the benefits, are in favour of technology.

See also:

Control (homeostasis)  Page 17
Control glossary

Digital sensor - a sensor or switch which has two states, on or off.

Light switch - a digital light sensor which responds to something covering it. This might be used to sense when dusk occurs and then turn on a light. It might also be used to sense objects on a supermarket conveyor belt.

Push Switch - a switch that responds to momentary pressure. Use as a bell push or to control a pelican crossing.

Toggle switch - a two-position switch like the switch used to turn on a television. A type of digital sensor.

Pressure mat - a switch that responds to momentary pressure. Put under a mat for a shop or burglar alarm.

Proximity switch - a switch that responds when close to another object. One brand of proximity switch is a reed switch which is triggered when brought close to a magnet.

Control box - an interface (or 'Buffer box') which allows you to switch and power lights, motors and buzzers. The box will have inputs for digital sensors and may take analogue sensors.

Barnet Box - virtually the same as a Deltronics Box or TTS box. A brand of control box with 8 output box and 8 digital input sockets.

Smart Box - a brand of control box with outputs, digital and analogue sockets.

Lego Interface A/B - a brand of control box. Lego have replaced their 'Interface A' with the 'B' control box that provides analogue sensing.

Control module - an alternative to a control box and part of the First Control system. There are several modules to extend children's experience of output devices.

User Port - a socket on a computer or an interface where you can connect control boxes.

Serial Port - a computer socket where you connect a control box or other interface.

Control software - the programs used to read information from sensors and switch devices on and off.

Control language - each control program has its own language. You use this language to write programs for control systems.
Choosing control kit

For control technology work, you'll need three ingredients. You'll need models and devices to control. Secondly, you'll need a computer interface to connect them to the computer. Thirdly, you'll need software to give commands with.

The models and devices can be built from ‘junk’ or puka kit. Systems such as Plawco and Lego or the sophisticated First Control mains module. While you will have your own criteria for selecting from the range, consider using a mixture of them.

The interface should allow the easy and reliable connection of sensors, motors and other devices. You'll appreciate a tidy integration of sensors and output devices - allowing you to measure, for example, the temperature and then control a fan.

Your choice of software is tied to the interface you use as most software is written to work with its corresponding interface. You will want a control language which is as close to normal English as possible. The software should avoid the use of obscure punctuation marks in commands, e.g. Switchon [1 2] or Repeat 3 [Switchon [1 2] Switchoff [1 2]]. That kind of software is well past its 'sell by date'. The software could provide a menu of commands and offer helpful messages if a command is entered incorrectly.

Many control programs have tied themselves to the LOGO language. An advantage of this approach is that it enables children to progress painlessly from turtle robots and LOGO into control work. The idea is a valid one but the disadvantage is that it hasn’t made control as easy as it should be. LOGO is fine but when combined with the clutter of a control kit things start to get difficult. It feels like a lead weight hanging off you. My preference is for the easiest software available - avoiding LOGO - hoping that, one day, LOGO itself will become easier. Instead look for something which is easy - it will not require much capability to achieve most ‘science’ purposes.

Starting out with control

Children need to develop a familiarity with the school’s computer control kit. As their familiarity develops we hope that they will see the kit as a tool they can use for their own purposes. The following examples show some of the possibilities in science contexts.

Computer control activities can find a place in science topics - particularly when children design methods of measuring and controlling.
In a **weather** topic devices can be made which measure wind speed or collect rain water. They may develop a device, say a solar ‘panel’ which can turn to face the sun.

In a **living things** topic children can make devices which monitor birds arriving at a bird table. They can test which bird food is preferred, they may even devise a machine to meter out bird food.

In an **ourselves** topic they may use sensors and control equipment to mimic the control systems of the human body - such as moving in response to sound and light. They may show how a hospital baby incubator can be kept at a steady temperature - by using a fan and/or heater.

In a **machines** theme they can develop numerous systems using lights, motors, drive belts, levers and gears. This could be a buggy, a washing machine, a bridge that opens and closes, a pelican crossing or a car park barrier.

In an **electricity** or **electronics** topic they can extend their knowledge of circuits as they wire up systems e.g. traffic lights and thermostatic control.

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**About the control activity sheets**

In the following sheets there are problems, questions and solutions. They start ‘from scratch’ and they exemplify writing control programs using a typical control language. When some familiarity with the equipment develops, the detail can be cut out. For example, you might copy only the top half of the sheets - and use them as problem cards.
Automatic porch light

You want a light to come on at your front door whenever it is dark and switch off when it gets light.

Questions

What will you use as a light?
What will you use to detect whether it is day or night?
At what light level will the light switch on? Above 60? Above 40? Test it to find out.
At what light level will the light switch off? Below 60? Below 40?

Solution

- Use a 12v car lamp as a light. Power it using a power pack and connect a relay to your Control box output. Alternatively, dispense with the relay and connect a lamp directly to your Control box.
- Connect a light sensor and the Control box to the sensor interface. Use a light sensor to find out whether it is day or night. A test with the sensor will find the most suitable on/off light level.

Apply your skills

- Welcome Home: Your automatic light is wasting electricity! You want a light to come on at your front door when you arrive home at night. Obviously it doesn’t come on during the day.

Using a control language

When you have finished setting up, your control language program might be typed in like this.

Type the following:

```
REPEAT
  ENTER
  IF LIGHT IS ABOVE 50 THEN SWITCH ON 1
  ENTER
  IF LIGHT IS BELOW 50 THEN SWITCH OFF 1
  ENTER
AGAIN
END
```

To run this procedure type:

```
DO porch
```

Test the porch light system. Repeat all this, but build a procedure called `porch`:

```
BUILD porch
REPEAT
  ENTER
  IF LIGHT IS ABOVE 50 THEN SWITCH ON 1
  ENTER
  IF LIGHT IS BELOW 50 THEN SWITCH OFF 1
  ENTER
AGAIN
END
```

To run this procedure type:

```
DO porch
```
Bath water tester

Make a bath water tester which tells you if the bath temperature is OK, too hot or too cold.

Questions

What temperature is your ideal bath?
What can you use as a warning if the water is too hot?
What can tell you if the water is too cold?
What can tell you if the water is OK?

Solution

- Use 3 painted lamps and connect them to outputs 1, 2 and 3 on your Control box. Some control boxes have built-in coloured LEDs.
- Connect a temperature sensor and the Control box to the sensor interface.
- A temperature of around 50 degrees might be suitable for a bath. A red light could be used to show that the temperature is too hot. Use yellow for cold, and green for just right.
- If the temperature is above 55 degrees the red light should be switched on. If the temperature is below 45 degrees the yellow light should be switched on. If the temperature is above 45 degrees and below 55 degrees the green light should be switched on. Remember that each light needs to be switched off - otherwise there may be two or more lights on at the same time.

Apply your skills

- Bath time. Improve your bath tester so that it also tells you when the bath is full. You might use a light sensor to detect this.

Using a control language

When you have finished setting up, your control language program might be typed in like this.

Type a procedure which we’ll call bath:

```
BUILD bath
REPEAT
SWITCH OFF 1 2 3
IF TEMPERATURE IS ABOVE 55 THEN
SWITCH ON 1
ELSE IF TEMPERATURE IS BELOW 45 THEN
SWITCH ON 2
ELSE IF TEMPERATURE IS ABOVE 45 AND TEMPERATURE IS BELOW 55 THEN
SWITCH ON 3
AGAIN
END
```

To run this procedure type:

```
DO bath
```
Sound controlled alarm

Make an alarm clock which switches on at dawn and switches off when you shout at it.

Questions

How will the computer know that it is morning?
How will the computer detect that you have shouted at it?
How loud do you need to shout to stop the alarm?
What can you use to set the alarm when you go to bed?
How could you tell if the alarm has been set?

Solution

- Connect a sound sensor, a light sensor and the Control box to the sensor interface.
- When the light reaches a certain level the alarm should be switched on. When the shout achieves a certain level the alarm should be switched off. The level at which this happens should be set high enough so that it is not switched off by the alarm itself. Use a push switch to set the alarm - you might also use a green light to indicate it is set.
- When the push button is pressed the green light shows that the light sensor is waiting for the light level to reach a certain value. When it does, the buzzer sounds and the sound sensor waits for the shout. The buzzer is then switched off and the whole cycle can begin again.

Apply your skills

- Turn it down! Make an alarm which tells you when you’re playing your music too loud.

Using a control language

When you have finished setting up, your control language program might be typed in like this.

Type a procedure we’ll call alarm

BUILD alarm ENTER

REPEAT FOREVER ENTER

WHEN INPUT 1 IS ON THEN

SWITCH ON 3 ENTER

WHEN LIGHT IS ABOVE 40 THEN

SWITCH ON 6 ENTER

WHEN SOUND IS ABOVE 80 THEN

SWITCH OFF 6 ENTER

SWITCH OFF 3 ENTER

AGAIN ENTER

END

To make this procedure run type:

DO alarm ENTER
It is a hot day and the temperature in the room is rising. Make a cooling fan which only works when it gets too hot.

Questions
What temperature would you say is "too hot"?
What can you use to sense the temperature?
How will you test if the temperature is too hot?
What should happen if the temperature is too hot?
What will you do when the fan cools the room to the temperature you want?

Solution
- Connect a temperature sensor and the Control box to the sensor interface. Connect a motor and vane (fan) to the Control box.
- A temperature of 25 degrees might be considered too hot. Use the temperature sensor to measure the temperature. Test the temperature using the 'IF TEMPERATURE IS ABOVE ...' command. If the temperature is too hot switch on the 'fan'. When the temperature drops, switch off the fan.

Apply your skills
- Keep Warm! Make a system you can use for keeping warm. A fan heater or hair-dryer might be used as a heater.

Using a control language
Ensure that the set-up can blow air over the tip of the temperature probe. If the weather is cool have a hair-dryer nearby to warm the probe. The fan will start and stop when the temperature rises above 25 degrees or falls below 25 degrees.
When you have finished setting up, your control language program might be written like this.
Type in this procedure we'll call coolme
BUILD coolme ENTER
REPEAT ENTER
IF TEMPERATURE IS ABOVE 25 THEN SWITCH ON 1 ENTER
IF TEMPERATURE IS BELOW 25 THEN SWITCH OFF 1 ENTER
AGAIN ENTER
END
To run the procedure type:
DO coolme ENTER
How could you make an ordinary electric kettle into an automatic kettle which keeps your water permanently hot.

Questions
What can you use to sense when the kettle is boiling?
What should happen when the kettle boils?
What should happen after the kettle is switched off?

Solution
Connect a humidity sensor and the Control box to the sensor interface. Connect a relay, power supply and low current heater (a car accessory for example) to the Control box.
Use a humidity sensor to respond to vapour from a manually operated kettle. Test the humidity using the ‘IF HUMIDITY IS ABOVE ...’ command. Get the system to switch off when the humidity level reaches the test value. When the humidity level falls below the test value again switch the kettle back on.

Apply your skills
Cook it, don’t burn it! Make a thermostat for a controlled oven. Use a hair dryer as a heat source and choose a suitable sensor.

Using a control language
When you have finished setting up, your control language program might be written like this.
Type in the following mini-program or procedure which we’ll call boilme:

BUILD boilme
ENTER
REPEAT
ENTER
IF HUMIDITY IS ABOVE 80 THEN
SWITCH OFF 1
ENTER
IF HUMIDITY IS BELOW 80 THEN
SWITCH ON 1
ENTER
AGAIN
ENTER
END

To run the procedure type:
DO boilme
How might all this equipment keep the baby cool?

Solution

Baby incubators, central heating, air conditioning and greenhouses are examples of control systems. For this exercise we will build a model of a thermostatic control system. There is a temperature sensor, a heater and a fan. When the temperature rises above a certain level the fan is switched on. When it falls a heater is switched on. How successfully the temperature is controlled is monitored on a graph.

The heater can be a 12v car lamp which is powered by a relay. Alternatively, use a hair dryer or an electric kettle powered by a mains controller.

The fan, or cooling device can be a desk-fan powered by a mains controller.
A solution using icon driven software (examples Lego Robolab, Flowol, Junior Control Insight, Logicator, SOFTLAB, Investigate)

When you have built your control system on the SoftLab 'benchtop' hold SHIFT and click the top Gate box. Set the gate to open when the temperature goes below 30.

Hold SHIFT and click the lower Gate box. Set the gate to open when the temperature rises above 30.

Hold SHIFT and click the lower Switch box. Choose switch number 2 (the fan)

Double click the Meter to open the window and re-position it on the screen.

Double click the Graph to open a window then re-position it if necessary.

Choose Run, Check & Start.
This section illustrates the scope for using sensors in experiments with students aged 14 to 18. You’ll find details of the science, the sensors, the apparatus and how it all fits together.

The experiments were written for in-service training sessions, but with a teaching use in mind. They were also written to be used with any of the hardware and software you might find in school. So whether your temperature sensor is home-made or the very latest multi-range device, you should find something useful here.

The experiments are organised by subject:

- Biological topics Page 74
- Physical topics Page 91
- Chemical topics Page 107

Older systems

Modern sensors are recognized by your software - you will not need to tell the computer which sensor is connected. You may have some older equipment, which although it is hard to use by today's standards, still can have some good use extracted from it.

- You can make use of your older sensors, such as the 'Blue Box' variety, by using an adaptor supplied by the interface supplier. However, these sensors do require you to tell the computer which sensor you have connected. If you forget, you’ll find that the graph displays in the wrong units - for example, a pulse rate of 100 bpm might display as 0.5 volts. The actual recording is unaffected.
- In most systems, the sensors plug into your interface and then into the computer's USB or 'serial port'. You can still use the older systems which plug into the analogue port using a connecting box. Mentally substitute it for the interface illustrated in the following pages.

See also:

- Introducing data logging to ages 10-13 Page 33
- Exploring science with sensors Page 52-61
- Sensors & software Page 120-
Pulse: measuring the pulse rate

The pulse sensor provides a direct measurement of the pulse rate. Using it you can see the rate of change in pulse rate instead of just a measurement at a point in time.

You might use it to monitor pulse rate before, during and after exercise.

These instructions show you how to use the sensor to obtain the kind of trace shown in the Sample graph below.

**Apparatus**

Pulse sensor with probe. The probe may need some seconds to stabilise.

**Setting up**

Connect the pulse sensor to a socket on the interface.
Connect the pulse probe to the body.
Some systems recognize the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 10 minutes.

**Using the results**

How does the graph show an increase in pulse rate?
What must be happening when the graph trace rises?
How can we use this to measure the fitness of an individual?
Save your data on disk and print your graphs.

**Sample graph**

![Sample graph image]
**Pulse: monitoring the heart beat**

The pulse sensor can show the blood flow through the probe, i.e. you can see the heart beat, shown in the Sample graph below, rather than count heart beats. You should be able to monitor some of the detail of the heart cycle.

You might monitor the blood flow before, during and after exercise.

These instructions show you how to use the sensor to obtain the wave trace shown below.

**Apparatus**

Pulse sensor with probe.

**Setting up**

Connect the pulse sensor to a socket on the interface. How you get the pulse wave trace varies with the equipment you have - you may need to:

- use a terminal marked Pulse Out on the sensor. Or use another channel on the software or set a switch on the sensor itself.
- Connect the pulse probe to the body.

The software needs to know that you want to measure the pulse wave.

**Recording the data**

Record for 40 seconds.

**Using the results**

- Count the number of peaks to work out the pulse rate.
- Does the shape of the peak change after exercise? Why does this occur?
- Explain the notch on the side of each peak.
- Save your data on disk and print the graphs.

**Sample graph**

![Sample graph](image-url)
Arterial pulse / Sphygmograph

A sphygmomanometer cuff constricts the arterial blood flow through the arm. When the pressure sensor is attached to the cuff it is possible to obtain a picture of pressure changes as the cuff pressure is increased and then released.

**Apparatus**

Sphygmomanometer cuff, pressure sensor.

**Setting up**

Connect the pressure sensor to a socket on the interface and connect the cuff tube to the sensor. Attach the cuff to the upper arm.

Your pressure sensor needs to be able to work within a wide range, such as from 0 to 100kPa. Some systems recognize the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 2 minutes. If you record for longer you will lose some of the finer detail in the graph.

This can be worrying, so choose your subject carefully! Inflate the cuff until the blood flow through the arm stops. If the sensor has a zero control, use it to get the reading on the screen. Then release the pressure slowly using the cuff thumb-wheel. You may be able to record the arterial pulse.

**Using the results**

Zoom in on the part of the graph showing the arterial pulse. Explain how we normally measure the blood pressure. Save your data on disk and print the graphs.
Breathing movements

There are several ways to monitor the movements of your chest. You can get creative with a position sensor and a spirometer box - and this works well. Or you can use a custom device: there is a breathing (stretch) sensor and there is a 'corrugated chest strap device', called a stethograph, which is worn around the chest. In this example, chest movements cause (semi-quantitative) changes in air pressure which are monitored by a pressure sensor.

If you take readings before and after some exercise you should find some interesting graph patterns to explain.

**Apparatus**

Breathing sensor such as a stethograph, plastic tubing and a pressure sensor.

**Setting up**

Connect the sensor to a socket on the interface.

Attach the belt around the chest. Wear it such that it does not restrict breathing or slip off.

Some systems recognize the sensors you attach automatically, in others you do this yourself. If you are using a pressure sensor, it needs to be set to work over a narrow range.

**Recording the data**

Do a test run, and if the sensor is adjustable you might need to adjust it to get the reading on the screen.

Record for 1 minute.

**Using the results**

Count the number of peaks to work out the respiration rate.

Zoom in on a good part of the graph.

Which part of each peak is inspiration?

Does the 'expiration' part show the same shape as this, if not why not?

Do the shapes of the peaks look different after exercise?

Does it matter where on the torso the stethograph is attached?

Save your data on disk. Print the graph.
Breathing movements

An example using SoftLab software

Some software features a continuous monitoring feature where the time axis is constantly replotted. SoftLab, an example of a fairly advanced program, does this particularly well. As on the previous page, breathing movements are monitored by a device strapped around the chest.

Apparatus
A breathing sensor: stethograph, plastic tubing, pressure sensor and interface.

Using the program

- Drop a Sensor on the Benchtop

Choose Pressure Sensor. Click OK.

- Drop a Gauge on the Benchtop

Double click the Gauge to open a window; re-position it on the screen.

- Drop a Graph on the Benchtop

Double click the Graph to open a window, re-position the window.

Choose Data, Store to store each recording.

Choose Run, Check & Start.

Start breathing! Data will be collected until the graph is complete.

To start a new run, Choose Run, Start/Stop

Results

From the graph window choose Options, Customise to alter the x-axis (time) or the y-axis (breathing).

Press \text{ALT} + \text{PRINT SCREEN} to capture the graph window to the Windows clipboard. In your word processor, choose Edit, Paste to add the graph to your report.
Enzymes: starch and amylase

Amylase catalyses the hydrolysis of starch. Iodine can be used as an indicator to show that the starch has been broken down. A light sensor can be used, like a colorimeter, to monitor this change. This experiment aims to show the effect of different temperatures on the action of amylase.

**Apparatus**

Fresh amylase and starch solutions, iodine, distilled water, a sheet of black paper, light sensor.

**Setting up**

Set up the light sensor and beaker. Add 20cm³ starch solution and 2-3 drops of iodine. (Or: use a smaller volume in a plastic cuvette - use a discarded plastic pH indicator paper box).

Use black paper to shield the beaker from changes in the light level. Try not to completely cover the chemicals - it helps if you can see the colour change.

Connect the light sensor to a socket on the interface.

Start the computer recording and look for a trace on screen. If the Light sensor is adjustable, change its range to get the trace on screen. Some systems recognize the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Add 5cm³ amylase to the beaker. Record for 15 minutes.

When the reaction is complete replace the beaker and solutions. Make a new recording, but at a different temperature.

**Using the results**

What happens to the appearance of the solution during the reaction?

What does the graph tell you about the progress of the reaction?

When was the reaction working at its fastest?

What condition did you change? How has this affected the graph?

Calculate the average gradient of the graphs. Which part of the graph should you use? What does this tell you?

Save your data on disk. Print the graph.
This experiment studies the effect of the enzyme pepsin on protein. Pepsin catalyses the hydrolysis of the protein, albumin into amino acids. As the protein solution is cloudy and amino acids are soluble the liquid changes from cloudy to clear. The light sensor can be used, like a colorimeter, to monitor this change. You can try this at different pH values.

**Apparatus**
- Water bath
- 1g/100 cm³ pepsin solution
- 1% fresh egg white
- 0.1M hydrochloric acid HCl
- 0.1M sodium carbonate Na₂CO₃
- Light sensor

**Setting up**
- Set up the light sensor and beaker containing 25 cm³ of egg white + 5 cm³ acid.
- Connect the light sensor to the interface.
- Warm the beaker in a 35°C water bath.
- Some systems recognize the sensors you attach automatically, in others you do this yourself. Start the computer recording and look for a trace on the screen. If the light sensor is adjustable, change its range to get the trace on screen.

**Recording the data**
- Remove the beaker from the water bath and place it over the light sensor. Add 10 cm³ pepsin solution to the beaker.
- Record for 25 minutes.
- When the reaction is complete, repeat the experiment using 25 cm³ of egg white and 5 cm³ sodium carbonate instead of the 5 cm³ acid.

**Using the results**
- What happens to the appearance of the solution during the reaction?
- What does the graph tell you about the progress of the reaction?
- When was the reaction fastest?
- What condition did you change? How has this affected the graph?
- Calculate the average gradient of the graphs. Which part of the graph should you use?
- Save your data on disk and print the graph.
Sensors can be used to monitor photosynthesis. They can show that as the light level increases, the oxygen level will also increase. It is also possible to show the effect of carbon dioxide levels (as added hydrogen carbonate solution) and to show the effect of coloured light.

A data logger allows readings to be taken over a period of time such as over a weekend.

**Apparatus**

Live pond weed (keep warm and illuminated before use), flask, 10g/L sodium hydrogen carbonate $\text{NaHCO}_3$ solution, oxygen probe, oxygen sensor, light sensor.

**Setting up**

Set up the oxygen sensor as shown. Switch on the sensor 15 minutes before use. Connect the oxygen sensor to the first socket on the interface. Connect the light sensor to the next socket.

You may be able to calibrate the sensor to read 21% oxygen in room air. If the light sensor is adjustable, use a Log range. Some systems recognize the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 30 minutes. Shield the plant from light for the first 10 minutes. Use ambient light for the next 15 minutes. Use bright light for the remaining time.

**Using the results**

Is oxygen produced steadily during photosynthesis? How does the light level affect the rate of photosynthesis? Does heat from the light source affect your experiment? How could you check that heat was not affecting your experiment? Save your data on disk. Print the graph.
Sensors can be used to monitor photosynthesis. They can show that as the light level increases, the pH will decrease. This happens because of the use of carbon dioxide by the plant.

It is also possible, using gelatine filters, to show how this is effected by different coloured light.

**Apparatus**

- Live pond weed (keep warm and illuminated before use), flask, pH electrode, pH sensor, light sensor.

**Setting up**

Connect the pH sensor to the first socket on the interface. Connect the Light sensor to the next socket.

You may be able to calibrate the pH sensor to read correctly in a known buffer solution. If the Light sensor is adjustable, use a Log range. The software needs to know that you have connected a pH sensor and a light sensor. Some systems do this automatically.

**Recording the data**

Record for 30 minutes.

- Shield the plant from light for the first 10 minutes. Use ambient light for the next 15 minutes. Use bright light for the remaining time.

**Using the results**

- What happens to the pH of the water during photosynthesis?
- Why does this happen?
- Does the pH change steadily during photosynthesis?
- How does the light level affect the rate of photosynthesis?
- Does heat from the light source affect your experiment?
- In this experiment, where does the plant obtain its carbon dioxide from?

Save your data on disk. Print the graph.
When living things respire they use up oxygen. This can be monitored using an oxygen sensor. The living thing can be a plant, animal or microorganism. Maggots, locusts, or yeast are often used and so can pond-weed. If you use Elodea, its container should be kept in the dark or wrapped in foil.

It is also quite easy to show how temperature affects the rate of respiration - however, in this example, the oxygen sensor should be able to compensate for its own response to temperature changes.

**Apparatus**
Live material in a flask, oxygen probe, oxygen sensor. Take care to avoid damaging the membrane tip of the probe.

**Setting up**
Set up the oxygen probe and sensor as shown. Let the sensor stabilise for around 15 minutes before use.

The software needs to know that you have connected this sensor - which some systems do for you. You may be able to calibrate the sensor to read 21% oxygen in room air.

**Recording the data**
Record for 60 minutes. Experience will give the most appropriate time for the living material under investigation.

**Using the results**
How does the oxygen level change during the experiment?
What does the graph tell you about respiration?
If you recorded for twice as long how would the graph look?
How would temperature affect your graph?
Temperature sensors can be used to measure the heat produced during seed germination. As the sensors can record very small changes, this experiment yields results in a very short period of time. Hypochlorite solution is used to kill fungal spores. A batch of seeds, killed by boiling, is used as a control.

Using very similar equipment, you can measure the heat produced by freshly cut grass.

**Apparatus**

2 vacuum flasks, cotton wool, germinating pea seeds, hypochlorite solution, bunsen burner, mat and gauze, interface, temperature sensors.

**Setting up**

Connect two temperature sensors to the first two sockets on the interface.

Soak the pea seeds, in Hypochlorite solution, for 15 minutes to kill off fungal spores. Divide the batch into two and boil one for 10 minutes to kill the seeds. Allow to cool.

Set up the two vacuum flasks with the batches of pea seeds. Put a temperature probe each and add a cotton wool plug.

Some systems recognize the sensors you attach automatically, in others you do this yourself. If the sensors have a range control, use a suitable range such as -10-40 degrees.

**Recording the data**

Record for 30 minutes or more.

**Using the results**

What does the graph tell you about heat and germination?

What does the shape of the graph tell you about the progress of germination?

Did the control show any temperature change?

If you recorded for twice as long how would the graph look?

Save your data on disk. Print the graph.
As food burns it releases energy. This energy can be used to heat up a known volume of water and so calculate its energy content. The temperature change can be easily monitored using a temperature sensor. Furthermore, if the food stops burning too soon, the graph will show how much the water cools and you can add this temperature change into your calculations.

**Apparatus**
Clamp, stand, boiling tube, balance, food (e.g. a peanut), a mounted needle, interface, temperature sensor.

**Setting up**
Connect the temperature sensor to the first socket on the interface.
Weigh the food sample and add 30 cm³ water to the boiling tube.
Some systems recognize the sensors you attach automatically, in others you do this yourself. If the sensor has a range control, use a suitable range e.g. from 0-100.

**Recording the data**
Record for 5 minutes. Heat the food in a Bunsen flame to light it. Heat the tube of water with the food until it has completely burnt, relight the food if necessary. Repeat with another food.

**Using the results**
How does the graph tell you how much energy is in the food?
Did your food extinguish before burning?
Did the water lose heat as a result?
Did you burn equal amounts of each food? If not, how will you compare the results from different foods?
Did the food give all of its energy to the water?
Use the software to read temperature values from the graph.
Save your data on disk. Print the graphs. Use a spreadsheet to help with any calculations you need to do. (The IT in Secondary Science book shows how).
Temperature sensors can be used to measure the heat produced as yeast respires in a vacuum flask. Since the sensors can record very small changes, this experiment yields results in a relatively short period of time. A second flask can be set up to show the effect of anaerobic respiration - in this case, the yeast is covered with oil.

**Apparatus**
2 vacuum flasks, cotton wool, yeast, sugar, oil, interface, temperature sensors.

**Setting up**
Connect two temperature sensors to sockets 1 and 2 on the interface.
Make a yeast suspension and divide it equally between two vacuum flasks.
Put a temperature probe each flask.
Some systems recognize the sensors you attach automatically, in others you do this yourself. If the sensors have a range control, set a suitable range e.g. to measure up to 40 degrees.

**Recording the data**
Add an equal quantity of sugar to each flask.
Pour a layer of oil into one flask to show anaerobic respiration.
Loosely plug them with cotton wool.
Record for up to 24 hours. You may get results much sooner than this.

**Using the results**
How do you know that the yeast is respiring?
What do the shape of the graphs tell you about the progress of respiration?
How can you tell which flask showed the most respiratory activity?
If you recorded for twice as long how would the graph look?
Save your data on disk. Print the graphs.
In the manufacture of foods, such as yoghurt, bacteria turn lactose into lactic acid. The acid denatures the milk protein and sets it solid. In the process, bacteria use oxygen and, of course, lower the pH of the milk. Sensors can be used to monitor both of these processes.

**Apparatus**
Flask, cotton wool, live yoghurt, milk, water bath, clamps and stands, interface, pH buffer solution, pH sensor, oxygen probe, oxygen sensor.

**Setting up**
Place 200 cm$^3$ milk and 10 cm$^3$ yoghurt into the beaker. Set the water bath to 35°C. Connect the oxygen sensor to socket 1 on the interface. Connect the pH sensor to socket 2 on the interface. Place the pH and oxygen probes in the yoghurt and milk mixture.

Some systems recognize the sensors you attach automatically, in others you do this yourself. You may be able to calibrate the oxygen sensor to read 21% oxygen in room air. You may be able to calibrate the pH sensor to read correctly in pH buffer solution.

**Recording the data**
Record for up to 10 hours.

**Using the results**
What does the graph tell you about the change in pH during fermentation?
Why does the pH change?
What does the graph tell you about the change in oxygen level during fermentation?
Why does the oxygen level change?
How do the graphs change with respect to each other? Is there a pattern here?
Save your data on disk. Print the graph.
In the manufacture of foods such as yoghurt, bacteria turn lactose into lactic acid. The acid denatures the milk protein and sets it solid. In the process, bacteria lower the pH of the milk and also use oxygen. Sensors can be used to monitor both of these processes. A data logger allows readings to be taken over a longer period of time such as over the weekend.

**Apparatus**
- Flask, cotton wool, live yoghurt, milk, water bath, clamps and stands, data logger, pH buffer solution, pH sensor, oxygen probe and oxygen sensor.

**Setting up**
- Place 200 cm$^3$ milk and 10 cm$^3$ yoghurt into the beaker. Set the water bath to 35°C. Connect the oxygen sensor to socket 1 on the data logger. Connect the pH sensor to socket 2 on the data logger.

**Recording the data**
- Place the pH and oxygen probes in the yoghurt and milk mixture.
- Press the button on the data logger that starts it recording.

**Transferring the data to computer**
- Connect the data logger to the computer.
- Get the software to transfer data from it.

**Using the results**
- What does the graph tell you about the change in pH during fermentation?
- Why does the pH change?
- What does the graph tell you about the change in oxygen level during fermentation?
- Why does the oxygen level change?
- How do the graphs change with respect to each other? Is there a pattern here?
- Save your data on disk. Print the graph.
A pressure sensor can be used to monitor the progress of osmosis. In this experiment a dialysis bag containing sucrose solution is placed in a beaker of water. Over a period of time, water enters the bag and even very small changes can be measured. Initially, the rate of osmosis is rapid, but as the concentration gradient changes the rate of osmosis decreases. A manometer sensor can be substituted for the pressure sensor.

Apparatus
Sucrose solutions, Dialysis (‘Visking’) tube, connecting tube for the sensor, beaker of water for the dialysis bag, interface, pressure sensor.

Setting up
Connect the tube from the suspended dialysis bag to the sensor.
Connect the sensor to socket 1 on the interface.
Some systems recognize the sensors you attach automatically, in others you do this yourself. If the sensor has a zero control you may want to use it when your experiment is ready to run.

Recording the data
Record for up to 1 hour. The exact time will depend on the concentration of the solutions.
You can repeat the experiment using a different sucrose solution concentration.

Using the results
How is a change in volume shown on your graph?
What does the graph tell you about the change in volume during osmosis?
Why does the pressure change?
What would happen if you used a more concentrated sucrose solution?
Save your data on disk. Print the graph.
A position sensor can be attached to a plant to record its growth. Depending on the plant chosen this is a very slow process. Using a sensor greatly decreases the time taken before the results can be used. It is possible to compare the effects of light and dark and other factors on plant growth. Ideally, two plants and two position sensors would be used. In order to allow a longer period of measurement the experiment is best performed using a position sensor attached to a data logger as described below.

**Apparatus**
Clamps and stands, plant, such as a growing bean and thread, data logger and position sensor.

**Setting up**
Set up the position sensor and plant. Use thread to tie the plant to the position sensor. If the sensor is placed the 'other way' round, the graph will develop in the opposite direction.

**Recording the data**
Connect the sensor to socket 1 on the data logger. Press the button on the data logger that starts it recording.

**Transferring data to the computer**
Connect the data logger to the computer. Get the software to transfer data from it.

**Using the results**
How is plant growth shown on the graph? What does the graph tell you about plant growth? Is it steady - or does its rate change during the day or night? What sources of error can you see in this experiment? Save your data on disk. Print the graph.
Recording the data
Switch on the heater. Don’t let the temperature exceed 65°C. Record for 20 minutes.

Using the results
What does the graph tell you about the change in temperature during the experiment?
What does the graph tell you about the change in oxygen level during the experiment?
Why does the oxygen level change?
How do the graphs change with respect to each other? Is there a pattern here and what does it tell you about the solubility of oxygen at different temperatures?
With a graph on the screen, get the software to plot temperature on the horizontal axis and plot the oxygen level on the vertical axis.
Save your data on disk. Print the graph.

Oxygen solubility and temperature

As the temperature of water increases, the solubility of oxygen decreases. This is significant in pollution studies - for example, when factory outflow warms a river. In this experiment a sample of aerated water is warmed as the oxygen level and temperature are monitored by sensors. The software can plot the oxygen level against the temperature. The response of the oxygen probe is itself affected by temperature so a thermistor compensates for this.

Apparatus
Water, aquarium pump to aerate the water, beaker, water bath, stirrer/heater, interface, oxygen probe / oxygen sensor, temperature sensor.

Setting up
Aerate the water with the pump. Let the oxygen sensor stabilise for around 15 minutes before use.
Connect the oxygen sensor to socket 1 on the interface. Connect the temperature sensor to socket 2 on the interface.
Some systems recognize the sensors you attach automatically, in others you do this yourself. If the temperature sensor has a range control, set this to a suitable range eg to measure up to 40 degrees. You may be able to calibrate the oxygen sensor to read 21% oxygen in room air.
The radioactivity sensor is normally connected to a standard Geiger-Muller tube and can produce a radioactive decay curve in 'real-time'. This is a very convincing display of radioactive decay. Protactinium, with its half life of just 72 seconds, makes an ideal radioactive material for this experiment.

**Apparatus**

Geiger-Muller tube, clamp stand, source such as a Protactinium generator, interface, radioactivity sensor.

Connect the GM tube to the sensor and the sensor to socket 1 on the interface.

**Setting up**

Some systems recognize the sensors you attach automatically, in others you do this yourself. If you can adjust the range on the sensor, set it to around 50 cps. You may be able to get the software to calculate $\ln$(count rate) and plot this in real time.

**Recording the data**

If you are using a Protactinium generator, give it a shake and then start recording. Record for up to 10 minutes. The exact time will depend on the source.

**Using the results**

How is a decrease in radioactivity shown on your graph? Does the radioactivity change steadily or is there more to it? Use the software to calculate $\ln$(count rate) and plot this against time. How is this graph different? Use the software to perform a least squares fit on the raw decay curve. Save your data on disk. Print the graph.
Penetration by radiation

1. Clamp the Geiger-Muller tube next to the source - connect this to the sensor.
2. Connect the sensor to socket 1 on the interface.

The radioactivity sensor is normally connected to a standard Geiger-Muller tube and provides a measure of radioactivity. In this investigation the intensity of a radioactive source is compared over different distances. The investigation can be extended to show the effect of distance and penetration through various materials - in fact this is a particularly helpful demonstration.

**Apparatus**
Geiger-Muller tube, clamp stand, radioactive sources - alpha, beta and gamma. Metre rule, interface, radioactivity sensor. If required, paper, aluminium and lead of different thicknesses.

**Setting up**
Connect the GM tube to the sensor and the sensor to socket 1 on the interface.

Some systems recognize the sensors you attach automatically, in others you do this yourself. If you can, set the range on the sensor to cover 0-50 cps. The software also needs to know that you will be entering distances, of between 0 and 100 cm, via the keyboard.

**Recording the data**
Start recording - you should be prompted to enter a distance at the keyboard. Set the GM tube next to the source and type in 0 for the distance.
Move the GM tube 5cm further away. Type in 5 for the distance. Continue moving the tube and entering the distance.

**Using the results**
How is a decreasing amount of radioactivity shown on your graph?
How does the radioactivity change with distance?
Use the software to find the relationship between count rate and distance.
Save your data on disk. Print the graph.
The magnetic field sensor responds to a magnetic field. In this experiment the sensor is moved through Helmholtz coils and the variation in field is measured.

**Apparatus**

Clamp stand, Helmholtz coils, leads, power supply, metre rule, interface, magnetic field sensor.

**Setting up**

Arrange the apparatus as shown. Connect the Magnetic field sensor to socket 1 on the interface.

Some systems recognize the sensors you attach automatically, in others you do this yourself. If you can, set the range on the sensor to cover 0-10 mT. The software also needs to know that you will be entering distances, of between 0 and 100 cm, via the keyboard.

**Recording the data**

Start recording - you should be prompted to enter a distance at the keyboard. Set the probe next to the coil and type in 0 for the distance.

Move the probe 1cm into the coil. Type in 1 for the distance. Continue moving the probe and entering the distance each time.

**Using the results**

How is an increasing amount of magnetic field strength shown on your graph?

How does the field strength change with distance?

Save your data on disk. Print the graph.
The magnetic field sensor responds to magnetic fields. We can use this idea, together with a metre rule damped with a sand bag, to demonstrate how a seismometer might function. If the apparatus is ‘disturbed’ a trace on the screen can represent an ‘earthquake’ event.

A position sensor can be used instead of the magnetic field sensor, just as effectively here.

**Apparatus**

Clamp stands, sand bag, magnet, metre rule, interface, magnetic field sensor.

**Setting up**

Arrange the apparatus as shown. Connect the magnetic field sensor to the first socket on the interface. If you can, set the range on the sensor to cover 0-10 mT. The identity of the sensor is unimportant in this experiment.

**Recording the data**

Record for 1 minute. During this minute, disturb the apparatus to simulate an earthquake. If you record for longer you will lose the finer detail from your recording.

**Results**

How is an earthquake represented on your graph?

Are you able to measure the size of an earthquake using this method?

Could such a seismometer be used to predict earthquakes?

Save your data on disk. Print the graph.
In this experiment an electrical cell is tested to exhaustion. The cell might be a dry-cell, an alkaline cell or a lead-acid accumulator. The decreasing voltage is measured over a (long) period of time and the software will show this as a graph of voltage against time.

**Apparatus**

1.5V dry cells, lamp, switch, leads, voltage sensor, interface.

**Setting up**

Connect up the circuit as shown - disconnect the battery for the moment. Connect the sensor to socket 1 on the interface. Some systems recognise the sensors you attach automatically, in others you do this yourself. If the voltage sensor has multiple ranges, use the 2V range.

**Recording the data**

Connect up the battery. Record for around 48 hours. Repeat using a different type of battery.

**Using the results**

How does the graph show the decay of the battery? How do different batteries decay with time? What uses would you recommend for each type of battery? Find out if temperature affects the performance or recovery of the battery? Save your data on disk. Print the graphs.

**Using a data logger**

As an alternative, a data logger can be used to collect the data independently of the computer.

1. Set up the circuit as shown. Connect the sensor to socket 1 on the data logger. If you can, set the range on the sensor to 2V.
2. Press the button which starts the data logger recording.
3. When the cell is exhausted, get your software to transfer data from the data logger.
The temperature, voltage & current of a heating unit are measured over a period of time. This allows us to calculate the power of the heater (voltage x current), and then to plot this against the temperature. As the power increases, so does the temperature. Your software can produce the graphs quite easily.

**Apparatus**

Heater unit (e.g. 24W), smoothed 12V DC power supply, interface, temperature, voltage and current sensors.

**Setting up**

Connect up the circuit as shown. Place exactly 100 cm$^3$ water in the beaker.

Connect the current sensor to socket 1, the voltage sensor to socket 2 and the temperature sensor to socket 3.

If the sensors are adjustable, set a 2A range on the current sensor, a 10V range on the voltage sensor and a 0-100 range on the temperature sensor. Some systems recognise the sensors you attach automatically, in others you do this yourself.

You may be able to set up the software to plot the energy (V x I x time) against temperature as the experiment proceeds.
**Recording the data**

Switch on the power to the heater. Record for 20 minutes.

**Using the results**

What does the graph tell you about the change in temperature? 
What does the graph tell you about the change in current? 
What does the graph tell you about the change in potential difference? 
Use the software to calculate the energy (V x I x time). Try to plot energy against temperature. 
Save your data on disk. 
Print the graphs.
The voltage & current of a thermistor are measured as its temperature changes. Sensors allow graphs of voltage and current to be plotted against time. Not only can the resistance of the thermistor be calculated but also the relationship of \( \ln(\text{temperature}) \) against \( \frac{1}{\text{current}} \).

**Apparatus**

TH7 thermistor, smoothed power supply, heater/stirring unit, interface, temperature, voltage and current sensors.

**Setting up**

Connect up the circuit as shown.

Connect the current sensor to socket 1, the voltage sensor to socket 2 and the temperature sensor to socket 3.

If the sensors are adjustable, set a 1A range on the current sensor, a 5V range on the voltage sensor and a 0-100 range on the temperature sensor. Some systems recognise the sensors you attach automatically, in others you do this yourself.

You may be able to set up the software to plot the resistance \( \frac{V}{I} \) against temperature as the experiment proceeds.
Recording the data

Heat the beaker to almost boiling and then allow it to cool. Record for 20 minutes.
You may need to do a test run to establish a suitable voltage for the power supply.

Using the results

What does the graph tell you about the change in temperature?
What does the graph tell you about the change in current?
What does the graph tell you about the change in potential difference?
How does the temperature affect the current and potential difference?
Use the software to calculate the resistance (V / I). Try to plot resistance against temperature.
Use the software to calculate Ln(Temperature)
Use the software to calculate 1/Current. Plot this against Ln(temperature).
Save your data on disk. Print the graphs.
In this experiment the resistance of a lamp, resistor or diode is measured as the current is varied. Voltage and current sensors make the measurements while the software plots the results in real-time. After the experiment, the resistance and the power can be plotted against the potential difference.

**Apparatus**

Rheostat, dry-cells, lamp, Si / Ge diodes, resistors (e.g. 18 and 36 ohm), interface, voltage and current sensors.

**Setting up**

If the sensors are adjustable, set a 1A range on the current sensor and a 2V range on the voltage sensor. Some systems recognise the sensors you attach automatically, in others you do this yourself.

You might get the software to plot the following as the experiment proceeds rather than afterwards:

- the current against potential difference.
- the resistance \((V / I)\) against potential difference.
- the power \((V \times I)\) against potential difference.

**Recording the data**

Note that you will not be recording against time, just one variable against another.

Start recording. Move the rheostat slider to change the current in small steps. Get the software to plot a reading at each step. If no points can be seen, your readings may be out of range - in fact a test run, to check this, is recommended anyway.

**Using the results**

What does the graph tell you about the change in current?

What does the graph tell you about the change in potential difference?

What is the relationship between current and potential difference?

Use the software to calculate the resistance \((V / I)\). Try to plot resistance against potential difference.

Use the software to calculate power \((V \times I)\). Try to plot this against potential difference.

Save your data on disk. Print the graphs.
Current-Voltage relationships

Some software allows you to plot the readings of one sensor against another. Examples such as PASCO’s Data Studio, LEGO’s ROBO LAB do this particularly intuitively. As on the previous page, the resistance of a lamp, resistor or diode is measured as the current is varied.

Apparatus

Rheostat, dry-cells, lamp, Si / Ge diodes, resistors (e.g. 18 ohm), interface, voltage and current sensors. Example using Softlab

Using the program

1. Drop a Sensor on the Benchtop
2. Choose Current Sensor. Click OK.
3. Drop a Sensor on the Benchtop
4. Choose Voltage Sensor. Click OK.
5. Drop 2 Meters on the Benchtop
6. Drop a Graph on the Benchtop
7. Wire the boxes together as shown.

Double click the Meters to open their windows. Re-position the windows.

Double click the Graph to open a window. Re-position the window.

From the Graph windows choose Options, Customise to alter the x-axis to VOLTS.

Choose Data, Store to store each reading.

Choose Run, Check & Start.

Move the rheostat slider. A graph will be plotted.

To stop recording, choose Run, Start/Stop.

Results

From the graph window choose Options, Customise to alter the x-axis or the y-axis.

From the graph window choose Options, Line with symbols to change the style of the plot from a plain line to a line with symbols.

You can then use a calculator box to work out the resistance (V / I). Wire this to a separate graph box where the resistance can be plotted against potential difference.

Or you can use a calculator box to work out the power (V x I). Wire this to a separate graph box where the power can be plotted against potential difference.
The voltage & current of a capacitor are measured as it charges and discharges. Sensors allow a graph to be plotted as this happens. The effect of different values of the capacitor and resistor can easily be explored.

**Apparatus**

1000 mF capacitor, 1kΩ resistor, power supply, switch, leads, voltage and current sensors, interface. You may need to 'bias' the voltage to get your readings on screen.

**Setting up**

Connect the current sensor to socket 1, and the voltage sensor to socket 2. If the sensors are adjustable set a 100mA range on the current sensor and a 10V range on the voltage sensor. Some systems recognise the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 1 minute. Charge the capacitor and when charged, move the switch to allow it to discharge.

**Using the results**

Describe the graph you see. What does the graph tell you about the way a capacitor discharges? What factors affect this? Save your data on disc and print the graph.
How pressure changes with temperature can be monitored using sensors. A graph of pressure against temperature can be plotted as it happens. After the experiment, the scale of the axis can be changed to estimate Absolute Zero.

**Apparatus**

- Water bath, flask with bung, delivery tube, interface, temperature and pressure sensors.

**Setting up**

- If desired, flush the flask with dry air, then seal it.
- Connect the pressure sensor to socket 1 and the temperature sensor to socket 2.
- If the sensors are adjustable, set a 10kPa range on the pressure sensor and a 0-100°C range on the temperature sensor.
- Some systems recognise the sensors you attach automatically, in others you do this yourself.
- Your software may allow you to plot the pressure against temperature as the experiment proceeds rather than afterwards.

**Recording the data**

Record for 10 minutes. Start heating the flask, after 5 minutes allow it to cool.

**Using the results**

- What does the graph tell you about the change in pressure?
- What does the graph tell you about the change in temperature?
- Use the software to plot the pressure against the temperature.
- What seems to be the pattern between pressure and temperature?
- Set the temperature axis to include absolute zero and extrapolate the graph down to absolute zero.
A temperature sensor can be used to study the conduction of heat through different materials. Two temperature sensors allow a comparison to be made. In this experiment strips of metal are heated in a Bunsen flame and the temperature change recorded. The material which shows the faster temperature rise is a better heat conductor.

**Apparatus**

Different metal rods of identical size, clamps, stands, Bunsen burner, tape, interface and temperature sensors. Take care not to heat the sensors beyond their maximum rated temperature.

**Setting up**

Connect temperature sensors to sockets 1 and 2 on the interface. Tape the temperature probes at the ends of the metal rods. Use the clamps to hold the sensors and rods. Some systems recognise the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 5 minutes. Move the rods into the Bunsen flame and ensure that each is heated equally.

**Using the results**

How does the graph tell you that the metals are getting hotter?

Does the graph tell you if heat is travelling through the metal? Could the temperature probes be getting warmer without the heat travelling through the metal?

How can you tell which of the rods gets hot fastest?

What do the graphs tell you about the two metals?
A temperature sensor can be used to study the insulating properties of different materials. Two temperature sensors allow a simultaneous comparison to be made. In this experiment two beakers of hot water are insulated with different materials and allowed to cool. As they do so a cooling curve is plotted. The experiment could be repeated to see the effect of wrapping things in aluminium foil.

**Apparatus**

Beakers, clamps to hold the probes, stands, hot water, insulating materials, fabric and aluminium foil, interface and temperature sensors.

**Setting up**

Connect temperature sensors to sockets 1 and 2 on the interface. Wrap one beaker with fabric.

Some systems recognise the sensors you attach automatically, in others you do this yourself. If the sensors are adjustable, set them on a 0-100°C range.

**Recording the data**

Record for 15 minutes. Pour equal amounts of hot water into each beaker. Repeat the experiment using loose aluminium foil instead of insulator.

**Using the results**

How does the graph tell you that the water is getting cooler?

How can you tell which of the beakers is getting cool fastest?

When will the insulated beaker reach the same temperature as the uninsulated one?

What does the graph tell you about the effect of insulation?
Two temperature sensors can collect some interesting information about cooling during a change of state. In this experiment the temperature of a water bath increases as a substance cools. But the unusual setup here will also show that, during the change of state, heat is lost from the substance even though its temperature remains constant.

**Apparatus**

Beaker, test tube, water bath, insulation material for the beaker, stearic acid (or wax; benzophenone), test tube rack, interface, Temperature sensors (not First Sense types - they might be damaged).

**Setting up**

Connect two temperature sensors to sockets 1 and 2 on the interface.
Place one temperature probe in a test tube half-filled with Stearic Acid. Warm the tube and probe in a water bath to melt the stearic acid.
Some systems recognize the sensors you attach automatically, in others you do this yourself. If the sensors are adjustable, set them on a 0-100 range.

**Recording the data**

Remove the tube from the water bath. Place it in a small insulated beaker, partly filled with water.
Record for 10 minutes. Stir the stearic acid continuously.

**Using the results**

How does the graph show you that the stearic acid is getting cooler?
What is happening to the water temperature as this occurs? Why is this?
What is happening to the stearic acid when the graph is flatter?
What is happening to the water temperature as this occurs? Where does the water gain its heat from?
A position sensor is attached to a weight and spring assembly as shown. This can be used to graph the extension of the spring with increasing mass.

**Apparatus**
Clamps & stand, ruler, spring and masses, interface and position sensor.

**Setting up**
Connect the sensor to socket 1 on the interface. Set up the position sensor, spring and masses as shown. You may need to do a trial run to arrange the position sensor so that, with no mass, the arm rests near the top of its range.
Some systems recognise the sensors you attach automatically, in others you do this yourself. You may be able to calibrate the movement of the sensor in absolute distance units.
The software also needs to know that you will be entering masses, of say, between 0 and 50 g via the keyboard.

**Recording the data**
Start recording - you should be prompted to enter a mass value at the keyboard. With no mass on the spring, type 0 for the mass.
Add a mass to the carrier. Type in 10 for the new mass. Continue adding masses and entering the total mass each time.

**Using the results**
How is an increasing load on the spring shown on your graph?
How does the extension of the spring change with mass?
Save your data on disk. Print the graph.
A position sensor is attached to a weight and spring assembly as shown. This can be used to study simple harmonic motion and the effects of changing the mass or damping.

**Apparatus**
Clamps & stand, spring and masses, interface and position sensor.

**Setting up**
Set up the position sensor, spring and masses as shown. Connect the sensor to socket 1 on the interface. Test the motion of the oscillating weight and check the time taken for it to stop moving - with one or many weights. You will need to adjust the position sensor arm to ensure that when it is still, the screen trace is say, halfway up the screen.

Some systems recognise the sensors you attach automatically, in others you do this yourself.

**Recording the data**
Record for 30s and displace the weight. If you record for much longer you will lose some of the detail in the graph.

Store the graph and make another recording - displacing the weight a bit more this time.

**Using the results**
How does the graph describe the movement of the weight?

Save your data on disk. Print the graph.
Absorption of thermal radiation

A shiny surface and a black surface absorb heat differently. Using temperature sensors or thermocouple probes it is possible to compare the temperatures on two these different surfaces. Either the temperatures will be plotted against time on the computer or in the case of the thermocouple, the graph will rise as the difference between its two probes increases.

**Apparatus**

Radiant heater, two metal containers - one shiny, one black, interface, temperature sensors or thermocouple probe/sensor.

**Setting up**

Connect the sensor to the interface. The software needs to know that you have connected this sensor and some systems will do this for you. If the thermocouple sensor is adjustable, adjust it to expect a suitable difference (say 10 to 20°C) between the two probes.

**Recording the data**

Record for 5 minutes. When the temperature difference falls to zero, switch on the radiant heater.

**Using the results**

If the sensor shows the difference in temperatures, what does the graph tell you when it moves up the screen? What does the graph tell you when it moves down the screen? Does the graph tell you which container is hottest? What does your graph tell you about the temperatures of the two containers? Does you graph stop changing at any point? What does this tell you? Save your data on disc and print the graph.
As acid reacts with alkali, heat is evolved. This is the heat of neutralisation. This can be easily monitored using a temperature sensor. In this experiment the temperature is monitored continuously as acid is added to alkali.

**Apparatus**
- pH Indicator solution, 50 cm³ 1 M sodium hydroxide NaOH, 10 cm³ 5M hydrochloric acid HCl, 200 cm³ beaker, interface, temperature sensor.

**Setting up**
Connect the temperature sensor to socket 1 on the interface.
Place the temperature probe in a beaker containing 25 cm³ alkali and pH indicator.
Some systems recognise the sensors you attach automatically, in others you do this yourself. If the sensor is adjustable, set a range of around 40 degrees.

**Recording the data**
Record for 3 minutes. Add 5 cm³ acid and stir.

**Using the results**
- How does the graph show you the mixture is getting hotter?
- When during the reaction is the mixture getting hotter fastest?
- When does the mixture start to cool? Why is this?
- How would other acids and alkalis behave?
- Save your data on disc and print the graph.
Exothermic reactions

A temperature sensor can collect information about the heat generated when lime is mixed with water. This reaction ‘might’ be used in a ski boot heating pack. The proportions of the mixture are important. If icing sugar is added to the lime mixture the rate of heat generation changes. You can investigate the results of adding different amounts of sugar (or water) to the lime and so determine the mixture which gives out most heat for the longest time.

**Apparatus**

Beakers, insulation for the beaker, test tube, balance to weigh solids, icing sugar, quicklime, plastic gloves, interface and temperature sensor.

**Setting up**

Connect a temperature sensor to socket 1 on the interface.

Place the solid ingredients in a beaker. Put the temperature probe in a test-tube with a measured volume of water.

Some systems recognise the sensors you attach automatically, in others you do this yourself.

**Recording the data**

Record for 15 minutes. Add water to the solids and stir.

Repeat the experiment using different mixtures of lime and icing sugar.

**Using the results**

How does the graph tell you the mixture is getting hotter?

When during the reaction is the mixture getting hotter fastest?

How long does the heating effect last for?

What might the area under each graph be a measure of?

How can you decide which mixture is the best?
Sodium thiosulphate and acid react to form a precipitate. The light sensor can be used, like a colorimeter, to monitor the rate of the reaction. In this experiment we study the effect of different amounts of acid on the reaction rate. It will also be possible to study the effect of temperature.

**Apparatus**

0.1M hydrochloric acid HCl, 0.1 M Sodium thiosulphate Na₂S₂O₄, distilled water, a sheet of black paper, interface and light sensor. Bright light source.

**Setting up**

Set up the light sensor and a beaker containing 30cm³ of thiosulphate Na₂S₂O₄. (Better alternative: use a smaller volume in a plastic cuvette made from a pH indicator paper box).

Use black paper to shield the beaker from changes in the light level. Try not to completely cover the chemicals - it helps if you can see the chemical change occurring.

Connect the light sensor to socket 1 on the interface. Some systems recognise the sensors you attach automatically, in others you do this yourself.

Start the computer recording and see if the trace is on screen. If the Light sensor is adjustable, change its range to get the trace on screen.

**Recording the data**

Add 5cm³ acid to the beaker. Record for 90 seconds. Avoid leaning over the beaker!

Replace the beaker and 30cm³ thiosulphate solution. Repeat the experiment using 10 cm³ acid.

**Using the results**

How does the appearance of the solution change during the reaction?

What does the graph tell you about the progress of the reaction?

When was the reaction working at its fastest?

What condition did you change? How has this affected the graph? How has this affected the reaction?

Calculate the average gradient of the graphs. Which part of the graph should you use?

Save your data on disk. Print the graph.
**Hydrochloric acid and marble (CaCO\textsubscript{3}) react to form carbon dioxide gas. The gas can be captured and measured using a gas syringe. A position sensor can be attached to the syringe to record the rate of the reaction. This experiment shows the effect of surface area on the reaction. The effect of acid concentration could also be explored.**

**Apparatus**
- Clamps, bosses, & stands, marble pieces (large, medium and small sizes), 1M hydrochloric acid H\textsubscript{2}Cl\textsubscript{2}, flask, bung, delivery tube, a good gas syringe.
- Interface, position sensor.

**Setting up**
- Set up the position sensor, flask, 1g of large marble pieces and the gas syringe as shown.
- Connect the sensor to socket 1 on the interface. Some systems recognise the sensors you attach automatically, in others you do this yourself.
- You may be able to do a two-point calibration of the sensor so that the computer displays the volume of the syringe directly.

**Recording the data**
- Place 1g of marble in the flask. Add 5cm\textsuperscript{3} acid when you are ready.
- Record for 90 seconds.
- Repeat using different sized marble pieces.

**Using the results**
- How does the graph show the progress of the reaction?
- When was the reaction at its fastest? How can you tell?
- Which part of each graph best shows how fast the reaction was working?
- Calculate the average gradient of each of your graphs to compare them.
- Save your data on disk. Print the graphs.
As acid drains into alkali the pH changes. This can be monitored using a pH sensor and instantly produce a graph of pH against volume. The volume of acid added is entered using the keyboard. The experiment can be repeated using different combinations of strong and weak acid.

**Apparatus**

Burette, stand, magnetic stirrer, indicator soln., pH electrode, pH buffer solution, 200cm³ 0.1 M sodium hydroxide NaOH, 50cm³ 0.5M hydrochloric acid HCl, 200cm³ 0.1M ethanoic acid CH₃COOH, 200cm³ beakers, interface, pH sensor/electrode.

**Setting up**

Set up a beaker with 20 cm³ alkali & indicator, place on the stirrer. Fill the burette with acid. Connect the pH electrode to the pH sensor. Connect the pH sensor to socket 1 on the interface. Place the pH electrode in the beaker of alkali.

**Sensor identification**

The software needs to know that you have connected a pH sensor. Some systems do this automatically. You may be able to calibrate the pH sensor to read correctly in known pH buffer solution.

The software also needs to know that you will be entering volumes of between 0 and 10 cm³ via the keyboard.

**Recording the data**

Start recording - you should be prompted to enter a volume at the keyboard. With no acid added, type 0. Add 1 cm³ acid from the burette. Type in 1 for the new volume. Continue adding 1 cm³ acid and entering the total volume each time.

**Using the results**

When does the pH change most slowly? Is this at the beginning, the middle or the end of the titration? When does the pH change most rapidly? What does the graph tell you about the change in pH during a titration?

Save your data on disk. Print the graph.
Acid-base titration

An example using icon driven software

As acid drains into alkali the pH changes and this can be monitored using a pH sensor. Your data logging software will need to have a feature where the volume of acid added can be typed in as you do so. When you want to do something a little bit out of the ordinary, icon driven software such SoftLab, Robolab, PASCO’s Data Studio are particularly flexible and allow you to do this in an intuitive way.

Apparatus

Burette, stand, stirrer, pH Indicator solution, pH electrode, pH buffer solution, 200 cm$^3$ 0.1 M sodium hydroxide, 50 cm$^3$ 0.5M hydrochloric acid, 200 cm$^3$ beakers, interface, pH sensor.

Using the program

Drop a Sensor on the Benchtop
Choose Keyboard Entry. Click OK.
Drop a Sensor on the Benchtop
Choose pH sensor. Click OK.
Drop a Graph on the Benchtop
Wire the boxes together as shown.
Double click the Graph to open a window. Re-position the window.
Choose Run, Check & Start.

Enter the volume of acid added:
i.e. type 0
Add 2cm$^3$ acid, let the pH stabilise then,
Enter the volume of acid added:
i.e. type 2
Continue like this till the titration is complete.

Results

From the graph window choose Analysis, Coords and move the pointer over the graph to take readings.
If you would like the results in a table, drop a Table on the SoftLab Benchtop, wire it to the graph and repeat the titration.
As acid reacts with alkali the pH changes and heat is evolved. This heat of neutralisation can be easily monitored using sensors - to produce a graph of temperature and pH against time. If it is assumed that the burette drains at a constant rate, then the time will be proportional to the volume of acid. Heat production decreases after all the alkali has been neutralised.

**Apparatus**

Burette, stand, magnetic stirrer, pH indicator solution, pH electrode, pH buffer solution, 200 cm\(^3\) 1 M sodium hydroxide NaOH, 50 cm\(^3\) 5M hydrochloric acid HCl, 200 cm\(^3\) beakers, interface, temperature sensor, pH sensor.

**Setting up**

Set up a beaker with 20 cm\(^3\) alkali & indicator, place on the stirrer. Fill the burette with acid.

Connect the pH electrode to the pH sensor and the sensor to socket 1 on the interface.

Connect the temperature sensor to socket 2. Place the temperature probe and the pH electrode in the beaker of alkali.

If the temperature sensor is adjustable, set a suitable range of say, up to 40 degrees). You may be able to calibrate the pH sensor to read correctly in known pH buffer solution.

**Recording the data**

Record for 2 minutes. Turn on the stirrer. Turn on the burette and let the acid drip in gradually. Ideally try to top up, and maintain the same head of liquid in the burette.

**Using the results**

When does the pH change most slowly? Is this at the beginning, the middle or the end of the titration?

When does the pH change most rapidly? What does the graph tell you about the change in pH during a titration?

How does the graph show you the mixture is getting hotter?

When during the reaction is the mixture getting hotter fastest?

At what pH does the mixture start to cool? Why?

Save your data on disk. Print the graph.
As a candle burns oxygen is used and heat and water are produced. A few sensors can be used to monitor this process - including a light sensor to indicate when the candle is extinguished.

**Apparatus**
Candle, bell jar, matches, interface and sensors: temperature, light, oxygen and humidity sensors.

**Setting up**
Set up the candle and sensors inside the bell jar and arrange them so that the probes will be well away from the candle flame.

Connect the sensors to the interface. Allow an oxygen sensor time to stabilise. Some systems recognise the sensors you attach automatically, in others you do this yourself.

**Recording the data**
Record for 3 minutes. Light the candle, cover it with the bell jar. When the candle has extinguished, readmit air into the bell jar.

**Using the results**
How does the graph show you the candle produces heat?
How does the graph show you the candle produces water?
How does the graph show you the candle produces light?
How does the graph show you the candle uses oxygen?
When is the oxygen level at its lowest?
Why does the oxygen level increase at the end?
Save your data and print the graph.
Weather station

An example using a datalogger

With a data logger several sensors can be used together to monitor the weather over periods lasting weeks. Suitable sensors include temperature, pressure, humidity, light or even a rotation sensor to check the wind speed. For serious work, involving months of weather recording, a dedicated weather station should be considered.

**Apparatus**

A data logger and sensors such as temperature, humidity and light sensors.

**Setting up**

1. Connect the sensors to the sockets on the data logger.
2. Position and fix the sensors in suitable places, for example, hang them out of the window. If the equipment is placed outside, keep parts of it in a polythene bag.
3. Start the data logger recording.
4. After the recording, connect the data logger to the computer and get the software to transfer the data from the data logger.

**Using the results**

See the companion guide, *The IT in Secondary Science Book* for a worksheet where students are asked to look for patterns in their weather data.
This section looks at some of the sensors and equipment you can obtain or indeed may have. It aims to give an idea of the scope of the technology. Here you will find what is available, what you can use each sensor for and some practical tips. Later we look at software. Although no one manufacturer has all of these sensors, there are all sorts of creative ways to achieve your needs so you will not need everything.

Breathing movements
Conductivity
Colorimeter
Distance / Motion
Force / Acceleration
Humidity
Infra-Red radiation
Light levels
Time using light gates, light switches, magnetic switches, pressure pads and other switches.
Magnetic field
Oxygen level (air / dissolved oxygen)
pH values
Pressure / Low pressure / Barometric pressure
Position or Angle
Touch using a pressure mat
Pulserate / Pulse wave
Radioactivity
Redox
Rotation speed
Sound level
Speed of sound
Temperature (various ranges from -10 to 110°C)
Extreme temperatures (Thermocouple -50 to 1100°C)
Heat flow
Ultra-violet radiation
Potential difference and current
Mass through an electronic balance

See also:
Sensing glossary Page 10
Ideas for data logging and control Pages 11-32
Sensors

Air pressure sensor

The sensor can be used as part of a weather station or to measure air pressure changes with altitude. To avoid tying up the computer for long periods use it with a remote data logger.

Breathing sensor

- Semi-quantitative breathing measurements.

Conductivity sensor

- Acid-base titrations
- Precipitation and other titrations.
- Measuring salinity of rock pools.
- Environmental (water) monitoring.
- Conductimetric titrations.

Sensor notes:
The probe for this sensor is a conductivity cell. Keep the conductivity cell as far as possible from the computer to minimise electrical noise picked up by the cell. When transferring the cell from one solution to another, rinse the cell in distilled water and shake it to remove drops. Never wipe it. After use wash in distilled water. Store wet or dry. For absolute conductivity measurements, the reading on the computer must be multiplied by the cell constant. This value should be marked on a tag on the conductivity cell. The cell constant can also be determined by making a measurement of 1.0M KCl which has a conductivity of 11.175Sm at 18°C.

Colorimeter sensor

- Lots of chemistry - bleaching, iodine-propanone reaction, thiosulphate-acid.
- Lots of biology - starch-iodine-amylase, action of pepsin on milk, of trypsin on milk or of the proteases in biological washing powders.

Distance sensor

- Direct measurement of distance.
- Preparing distance-time graphs and calculating kinetic energy, acceleration and speed: when walking, cycling, moving trolleys, bouncing a ball.
- Oscillator motion (with a spring held weight).
- Studies of an air track puck; friction studies. Conservation of momentum.
- Investigations into the design of a ski jump.
- Stopping distances of model cars.
- Acceleration due to gravity.

Force / Acceleration sensors

- Forces involved in lifting, pushing a trolley
- Force on a mass going up/down in a lift

Humidity sensor

- Rate of transpiration and humidity.
- Moisture in exhaled air.
- Hygrometry.
- Weather station.
- Moisture from burning fuels.
- Moisture uptake through fabrics.

Sensor notes:
Measurements are usually within the range 10-90% humidity. In a moving current of air the sensor responds more quickly. Acetone and organic solvent vapours are harmful to the sensor. When the probe is wet, the reading is unreliable.
**Sensors**

**Infra-Red sensor**
- Comparing body heat (cold or warm hands). Striking a match.
- Measuring radiant heat, IR from a filament lamp, sunlight.
- Heat from a 'Leslie Cube' or a radiator and the effect of distance on radiation.
- Heating effect of current through a nichromewire.
- Using a prism to split up light and then detecting infra red at the end of the spectrum.

**Light sensor**
- Monitoring of light levels day/night.
- Light levels in photosynthesis.
- Environmental studies.
- Response of a flash gun using a fast data logger.
- As a timing light gate - e.g. to time the swing of a pendulum.
- Variation of light intensity with distance: the inverse square law.
- Colorimetry in the starch-iodine reaction. Rate of reaction between iodine and propanone.
- Turbidimetry of acid-thiosulphate reaction, action of pepsin on milk, of trypsin on milk or of the proteases in biological washing powders.
- Investigating diffraction and interference patterns.
- Measuring leaf transparency.

**Light gates and switches**
- These sensors are digital sensors so they respond to 'light' rather than measure it. That response can be used in timing events. Typically you need two digital sensors - one to respond when an event starts and one for when it stops. They can also be used in control systems - such as a sensor for a burglar alarm.
- How fast objects move down ramps.
- Reaction timing
- Air track measurements
- Counting pendulum swings or how often a bird table is visited.
- See Forces for more.

**Light sensor notes:**
- Light sensors have logarithmic or linear ranges. The LOG setting will sense the full range of light intensity. This would be useful in monitoring sunshine. The logarithmic type is a bit less suitable for quantitative work. It is however, much simpler to use.
- Diode types can respond much faster than light dependant resistor types. The slower type will respond less to interference such as fluorescent strip lighting. The fast type can even pick up AC ripple.

**Magnetic field sensor**
- Electromagnetic induction.
- Hysteresis curve.
- Magnetic field along a coil.

**Manometer / bio pressure sensor**
- Small volume and pressure changes.
- Monitoring fermentation.
- Respiratory rates - gas exchange/breathing movements of a locust.
- Use of gas by rusting nails.
- Osmosis/diffusion experiments.
**Oxygen sensor**

- The effect of changes of temperature upon oxygen demand by yeast, maggots, locusts and germinating peas.
- Biological oxygen demand.
- Use of oxygen in fermentation and in the manufacture of yoghurt.
- Use of oxygen by a burning fuels.
- Solubility of oxygen in water as it cools.
- Investigating photosynthesis.
- Oxygen content of ponds and aquaria: and the effect of depth.
- Oxygen content of exhaled air.

**Sensor notes:**

At least twenty minutes before use, fill the membrane cap with electrolyte gel. Avoid introducing air bubbles. Connect the electrode to the sensor and leave it hanging in air, switched on to stabilise. To calibrate the sensor simply use air! If desired, also use boiled water as 0% oxygen. If an aquarium pump aerates a cylinder of water for an hour this can be used as a 100% saturated standard solution.

After use the electrode can be kept suspended in deionised water to prevent the electrolyte gel from drying out. The usual advice is that the electrode should only be kept like this only for a week and then it should be dismantled, washed with soapy water and rinsed in deionised water. Experience shows that the oxygen electrode can be left in a ready-to-use condition for many months. However, take great care of the membrane caps - physical damage to the polythene membrane appears to be a common cause of poor readings. Problems in use can be due to a poor connection between electrode and sensor, cleanliness of the electrode tip and condition of the electrolyte. The best advice is to allow sufficient time for the electrode to stabilise.

Electronic temperature compensation is vital in experiments where temperature changes occur.

**pH sensor**

- Rates of reactions where pH changes are involved: urea-urease reaction, souring of wine, making yoghurt, lipase activity on oil.
- Acid-base titration.
- Environmental monitoring (e.g. acid rain) or soil pH using a special pH probe.
- Carbon dioxide production during photosynthesis, growth of microorganisms or respiration.

The pH sensor requires a standard pH electrode. pH electrodes should not be wiped dry or allowed to dry out.

**Pressure sensor**

- Rates of reactions where gas is evolved.
- Gas laws: pressure/volume changes.
- Measurement of the arterial pulse.
- Use with a stethograph to monitor breathing.
- Measurement of osmotic pressure.

**Position / Angle sensors**

- Measuring plant growth.
- Responding to animal activity, for example when attached to a bird food supply.
- Rates of reactions with a gas syringe (e.g. marble-acid rain).
- Harmonic motion: oscillating springs and pendulums (displacement-time graphs).
- Breathing movements with a spirometer. Rise of bread dough.

**Sensor notes:**

When the sensor is mounted the 'opposite' way up, the output can be made to decrease or increase as it turns.
Pressure mat

These sensors are digital sensors so they respond to 'pressure' rather than measure it. This can be used in timing events. Typically you need two digital sensors - one to respond when an event starts and one for when it stops: one of the sensors could be a light gate. They can also be used in control systems - such as a sensor for a burglar alarm.

- Reaction timing.
- Counting people entering a room.
- Speed at which things fall.

Pulse sensor

Sensor notes:
The pulse sensor can have two kinds of output. One provides a measure of pulse rate as pulse beats per minute. The other gives an indication of the heart beat and heart action.

Radioactivity

- Half-lives, decay curves and the statistics of decay.
- Radioactivity with distance.
- Absorption of radiation by lead, aluminium and paper.

The sensor requires a Geiger-Muller tube to measure radioactivity. Any pulse output could be displayed on an oscilloscope or heard via an AC coupled audio-amplifier.

Rotation sensor

- Measuring speeds at which the gears in a gearbox turn.
- Wind speed
- Speed at which a record player, water wheel, wind mill or motor turn. Show the effect of current on say, the speed of the motor.

Sound sensor

- Sound travel through materials.
- Attack and decay characteristics of musical instruments and sounds.
- Comparing loudness of sounds. Using a data logger the sound sensor can be taken away from the computer to monitor traffic noise and the dawn chorus of birds.
- Sound insulating materials.
- Amplitude of sound with distance.
- Comparing waveforms of high and low sounds (e.g. tuning forks) using an oscilloscope or fast data logger.
- Comparing voice patterns; waveform analysis.

Sensor notes:
The sound sensor can measure over the range of 50-110 dB. The sensitivity may fast or slow. A slow response will hold the output from short bursts of loud noise for longer. Some allow the sensor to show the waveform of sounds of different pitch. To capture this detail a data logger is necessary.

Speed of sound sensor

- Speed of sound travel through materials.
- Change in speed of sound travel due to temperature.

Temperature sensor

- Energy release by germinating seeds.
- Monitoring respiratory activity.
- Thawing frozen food.
- Thermometric titration. Heat of solution.
- Cooling curve.
- Cooling by evaporation.
- Gas laws + pressure sensor.
- Variation of resistance of a thermistor with temperature.
- Absorption of thermal radiation.
- Insulation experiments. Studies of conduction; convection; radiation.
- Studying the effect of surface area on heat loss.
Thermocouple and high temperature sensors

- For monitoring the cooking of food.
- For checking temperatures in different parts of an oven, a Bunsen flame and comparing the combustion temperatures of different fuels.
- For studying melting points of metals.
- For making a cooling curve for oil.
- For comparing temperatures on black and white surfaces heated by the same source.
- For comparing double and single glazing. For comparing insulation e.g. vacuum flasks.
- For comparing skin temperatures on different parts of the body during exercise.
- For comparing temperatures when different liquids evaporate.

Thermocouple sensor

- See Differential temperature and High temperature for possible uses.

Heat flow sensor

- Transmission of heat through clothing or building materials such as plasterboard and glass.
- Comparing single and double glazing.

Ultra-Violet sensor

- Variation in UV light during the day
- UV level changes with angle to the sun
- Comparing sun creams and sunglasses
- Comparing glass, plastic and quartz for UV transmission.

Voltage / current sensors

- For current / potential difference measurements across resistors, a thermistor, a lamp or a diode.
- Discharge of a battery or a lead-acid accumulator.
- Surge current and the change in resistance when switching on a lamp.
- Output voltage of an electronic oscillator.
- Maximum power theory. Discharge of a capacitor.
- Measuring the heating effect of a current and specific heat capacity.
- Measuring the efficiency of a solar cell or an electric motor.
- Induced emf resulting from a magnet moving through a coil.

Balance

- For monitoring transpiration.
- For measuring reaction rates where a gas is evolved.
Choosing your software

Your choice of software for data logging is really important. There are so many issues arising from buying the hardware - like quality, quantity, cost and compatibility, that it is understandable that choosing relatively inexpensive software is often the last decision to be made.

Choose software no less carefully than a set of textbooks. Try to use it yourself, see it demonstrated by an expert and also see the competition. The software drives the whole system so if it is easy to use all the features you need, you will find even the most reluctant users more likely to pick it up and use it.

New versions of software appear year by year. Enhancements are made and problems fixed. New features, such as the automatic scaling of axes and automatic recognition of sensors, can make things easier for pupils. As a result, younger and younger pupils are gaining access to this technology. Consequently, it's worth review the software you are using - looking out for upgrades on the web, seeing if they solve problems you actually have, every couple of years.

Undoubtedly the best thing to happen to data logging software was to run in 'windows environments'. Modern programs share an easier and common way of working. So whether you are using a word processor, a spreadsheet or a data logging program, essential jobs such as printing and saving are accomplished in pretty much the same way.

Also, and no less importantly, you can share information between your data logging program and other programs. It is with this feature that pupils can reap yet more benefits from using the technology. They can write about graphs or tables of results they have copied to their word processor. Or they can put their results into a spreadsheet where they may find a set of features that enhance those of their data logging program.
There is data logging software that is brimming with features and there is software that is easy to use. But what we need is software that allows us to do what we want to do easily. That’s not quite the same thing.

If you teach at the extremes of the school age range then your students will obviously need the simplest or the most feature-rich programs. Otherwise, you will probably need different programs to cover the different levels of use in school.

At an introductory level, you will want a program which is easy to set up to display sensor readings and line graphs. The program should automatically recognize the sensors that are plugged in and it should automatically label and scale the axes.

A particularly useful feature is automatic recording over time: that means that the recording continues for as long as you leave it to and to compensate, the graph re-scales itself. You may want to switch this off occasionally. The program should be able to record from at least two sensors at the same time. It should also display readings as graphs, as numbers and be to record for as long as you want - perhaps for as long as 24 hours in an overnight investigation. Another feature which will prove to be essential is the ability to take discrete readings. So you may want, for example, to compare the light reflected from different surfaces and plot each light reading as a separate item on the screen.

At the medium to highest levels the software should do all the above as well be able to read values off graphs. It should measure the difference between two readings and measure the average gradient of a line.

Other features such as the ability to smooth out noisy graphs, to plot best fit lines and to export the data for use in other data handling programs are also essential.

One more feature will prove to be just as essential: you will want to plot one set of sensor readings against another. For example, you may want to plot pressure against temperature, volts against amps or even pH against a volume typed in the keyboard. No program should beep you with meaningless error messages. Yet they do.

There are a number of situations where the standard data logging program does not do all you want. You may have an electronic balance that requires special software to take readings from it or you may want to monitor and display changes, such as heart rate, electrocardiograms or tidal volumes in breathing. Although some progress is being made to address every measurement need in a do-it-all data logging program, you may still need to use dedicated software.

Where to get your software

Every manufacturer of data logging equipment has a suite of programs to use with their equipment. These are available for almost every make of computer you might find in school. This apparently basic point becomes of special interest if you use a mixture of computer makes. You just buy different cables and software for each machine and you can then use the same data logging hardware with each.

Manufacturer’s software often has the advantage of being able to exploit unique features of their hardware to the full.

Then there is the advantage that having bought your whole package from one source, you might rightly expect it to work as intended.

/continued...
Working the software ...

After your experiment you can...

... read values from the graph

... read the difference between two points

... smooth or average a 'noisy' graph

... find the slope or gradient of a graph

... put the graph in your word processed report
Before your experiment, you may need to check or change these settings...

1. Say which interface you are using

2. Say which sensors you are using

3. Say how long you want to measure for

4. Say whether you want a full scale graph or not

i. Get your experiment ready and start measuring
In recent years, software from ‘third parties’ has offered special features. This software has the unusual advantage that you can use it with different manufacturer’s sensors and interfaces. So you can have completely different sensor kits running on different computers and what you see on each screen is the same familiar program.

In keeping with the idea of this book not being tied to any particular make of equipment, these ‘third party’ or hardware-neutral programs qualify for a mention.

**SoftLab - historic note**

SoftLab (Homerton College) was a data logging program that worked with many brands of data logging hardware. It used a very different approach to other software.

Instead of pressing a button to start recording data you first have to assemble, on the screen, the elements you need to perform the experiment. So when you want to collect data from a sensor, you pick up a sensor icon and drop it onto the screen. And when you want a graph as a display tool, you pick up a graph icon and drop that onto the screen.

You can go on assembling tools. There is a bar gauge that rises and falls with the readings, there is a digital display and there is a meter display too. In fact, you will find a rich assortment of tools here which can be assembled in seemingly limitless ways to achieve the result you want to. In addition there are control and logic tools that allow you to build control systems without the use of a programming language. The program is flexible, quite comprehensive and well suited to advanced work.

This singular approach forsakes the instant results you can achieve in other programs and focuses attention on the design of the experiment. It may prove to provide a further enhancement of students’ learning in science. Learners aged from 16 years could use it well.

**Insight**

Insight (Leicester University/Logotron) is a data logging program which makes collecting data from sensors almost instantaneous and they work with many brands of data logging hardware available.

There is a control panel where buttons control many of the tasks you need to perform such as starting and stopping recordings and taking reading from graphs. Other features are accessed through menus. There are facilities to manipulate, re-plot and zoom in on the data. For work with timing light gates there is a separate program supplied as part of the package. This not only provides all the tools that timing experiments require, but also has a simple spreadsheet that allows you to plot x-y graphs. The program is as flexible and comprehensive enough to meet most teaching needs for students aged from 11 upwards.

The program is available for Microsoft Windows, RISC-OS and for the Macintosh.

**Junior Insight**

Junior Insight (Leicester University/Logotron) has a similar look to Insight described above. The screen layout and the menus are cleaner because the more complex analysis tools of Insight may not be required at junior level. Instead there are some extra features. For example, you can add pictures to the screen graph and there are icons to show which sensors are being used. Junior Insight could be used with learners aged up to 11 years.

**Investigate**

Investigate (Research Machines - discontinued) was similar in construction to the SoftLab software described on this page. Again this is a data logging program which works with most brands of data logging hardware available. Being aimed at younger students it is easier to use. For example, icons are replaced by buttons which do some of the setting up work for you and all the windows on the screen sit within one box. There are also features where pictures can easily be added to illustrate experiment designs on the screen.

The program could be used with learners age up to 15 years.
Addresses

The suppliers here will be able to equip you to handle the data logging ideas in this book.

Equipment and software

Australia: Southern Biological
www.southernbiological.com

Fisher Education www.fisheredu.com

Commotion, Unit 11, Tannery Road, Tonbridge, Kent, TN9 1RF Telephone: 01732 773399

Data Harvest www.data-harvest.co.uk
www.dataharvest.com

Deltronics www.deltronics.co.uk

DCP Microdevelopments www.dcpmicro.com

Economatics www.economatics.co.uk
Griffin & George www.fisher.co.uk

Matrix Multimedia www.matrixmultimedia.co.uk

PASCO UK Scientific www.pasco.com

Research Machines www.rm.com

Scientific & Chemical Supplies www.scichem.co.uk

Texas Instruments education www.ti.com

Tain www.tain.com.au

Vernier www.venier.com

Valiant www.valiant-technology.co.uk

Training days

• Roger Frost & IT in Science
Russet House, Foxton, Cambridge, CB2 6RT
Telephone: 01763 209 109. Email press(at)rogerfrost.com
Web: www.rogerfrost.com

Advice, training or support

• Association for Science Education, College Lane,
Hatfield. AL10 9AA. Tel: 0707 267411. Fax: 0707 266532. Internet: www.ase.org.uk
• Becta, Milburn Hill Road, Science Park, Coventry CV4 7JJ. Telephone: 01203 416994 Fax: 01203 411418. Internet: www.becta.org.uk

Books

• The IT in secondary science book by Roger Frost. ISBN 0 9520257 2 8 (from ASE). A rich compendium of ideas for using IT in school - including an acclaimed topic by topic guide where you will find appropriate applications of IT in your science curriculum. There are also worksheets and sections on using spreadsheets, graphics programs, word processors and database programs.
• IT in primary science by Roger Frost. ISBN 0 9520257 3 6 (from ASE). A compendium of ideas for using IT in the primary school - there are not only sections on using sensors (some shared with this book), but also on science software, spreadsheets, word processors and database programs.
• Data logging in Practice by Roger Frost
Looks at the practical aspects of using data loggers in schools and features graph and data handling exercises ISBN 0-9520257-4-4
• Software for science teaching by Roger Frost
(Out of print) Reviews and grades all the software and CD-ROMs useful in teaching science to all ages.
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Z...
The IT in Science book of

Data logging & control

Roger Frost

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