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Datalogging

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What is datalogging?

The lines drawn year after year on a wall by parents marking the height of their children as they grow is an example of datalogging. We often use datalogging to enable us to study things that are obscured by the passage of time.

A car smashing into a wall as part of its crash-testing routine is an example of an event that happens too quickly for us to study without using datalogging of some kind. Using a high speed video camera to record the event is an example of videologging.

When cashiers scan your groceries with a barcode reader, they are using datalogging to ensure your goods are accurately identified, priced, and removed from the store's stock list.

However, in this paper we will be referring to ***datalogging*** as the capture and storage of variables as they change over time, and ***experiment*** as the context in which the datalogging takes place.

Students can use datalogging to:

- monitor their heart rate during different activities
- see how temperature varies during cooling, melting and boiling
- compare materials that reflect light or make sounds
- compare sounds made under different conditions
- study the relationship between light, temperature and plant growth
- study factors affecting speed and acceleration using light gates
- study factors affecting rates of chemical reactions
- study the relationship between voltage and current
- study characteristics of their environment over long periods of time.

At regular intervals, datalogging equipment records measurements from a sensor that detects environmental conditions, such as light, heat, sound, pH or motion. The time interval between measurements can be any period – from daily readings to compile weather forecasts to the 100,000 times per second sampling used to analyse sound.

Datalogging equipment can also be used to take a single measurement from the sensor and display it. This is referred to as 'sensing'; the term 'monitoring' is used to refer to both sensing and datalogging.

Having the data collected accurately and automatically allows pupils to focus on interpreting the data. They can spend more time talking about what is happening and speculating on what is likely to happen and why. However, the way the data is represented after it has been collected contributes most to the learning outcomes. For example, if the data is immediately represented as a graph this can contribute significantly to pupils' understanding of the experiment. Research shows[1] that the pupils' understanding of line graphs is also significantly improved, particularly with low-achieving pupils[2].

Sense, convert, store, interpret

Datalogging can be considered as a four-stage process.

Sensors are transducers that translate into an analogue signal the changes taking place in the parameter being measured, for example, temperature, light or sound. (Each sensor measures one parameter within a specified range, for example, temperature from 10° to 60°C.)

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[1] McFarlane, A. *et al.* 1995 *Developing an understanding of the meaning of line graphs in primary science investigations using portable computers*. Journal of Computers in Mathematics and Science Teaching. 14 (4), pp.461-480.

[2] Marcum-Dietrich, N., & Ford, D. *The Place for the Computer is in the Laboratory: An Investigation of the Effect of Computer Probeware on Student Learning*, Journal of Computers in Mathematics and Science Teaching 21(4), 361-379, 2002. [http://www.aace.org/dl/index.cfm/fuseaction/ViewPaper/id/10624]

The analogue signal is converted into data by an analogue-to-digital (A-D) *converter*, then calibrated to provide a numeric value in the appropriate units, such as 20°C. (The resolution of the A-D converter, measured in bits, indicates the accuracy of this conversion.) With more complex sensors there may be further interpretation of what has been sensed, as in the case of a barcode reader or motion sensor.

A processor logs the data – at regular intervals the processor takes the numeric values provided by the converter and *stores* them in memory. (The rate at which these values can be stored in memory, the sampling rate, and the amount of memory available are a measure of the logging capability of the device.)

The set of readings for a particular experiment (called a data set), can be *interpreted* by a range of software such as spreadsheets, graphing packages, and other specialised data-handling software.

Where is datalogging used?

We benefit from the information provided by many datalogging systems – from the logging of cars entering and leaving a car park, displayed as ‘spaces available’ or ‘car park full’, to the electrocardiogram (ECG) which is used to diagnose many heart abnormalities.

Disabled drivers benefit from datalogging systems, such as Spacehog [http://www.spacehog.org.uk/]. By using sensors, such systems are able to monitor the use and availability of disabled parking bays. The sensors detect cars as they enter/leave the bays and transmit the arrival and departure times (using a wireless transmitter) to datalogging equipment housed in a specially designed sign. The sign issues a message that informs the driver that the bay is reserved for disabled customers. The collected data is analysed to provide details about occupancy rates (information which will be required to comply with forthcoming legislation).

Some systems use complex data processing to deliver useful services such as traffic news. The ‘blue pole’ roadside traffic cameras [http://www.trafficmaster.co.uk/page.cfm?key=trunk-road] identify a vehicle by sensing the centre four digits of its number plate. As the vehicle passes subsequent cameras the elapsed time is calculated, and this data is used to assess the speed of the traffic. In systems such as Trafficnet [http://www.vauxhall.co.uk/trafficnet/] this type of information is displayed on a map of the motorways. The map is coloured to show the speed of all traffic travelling below 25mph. Systems like these have been developed into intelligent traffic management systems, as in Southampton [http://www.romanse.org.uk/] where variable message signs indicate traffic conditions, the number of car parking spaces available, and provide real-time information re bus services (displayed at bus stops).

Videologging and sophisticated video analysis is also used in sports training where an athlete’s performance can be recorded and analysed using software such as Dartfish [http://www.devon.gov.uk/dcs/dartfish/] (used at the 2002 Winter Olympic Games), and Quintic [http://www.quintic.com/the_quintic_system.htm] (used in the 2002 Commonwealth Games).

In schools

The following table outlines where datalogging can be used to deliver the National Curriculum [http://www.nc.uk.net/] for both ICT and science during Key Stages 1 to 4.

Examples of pupils’ work involving datalogging can be found on the National Curriculum in Action website [http://www.ncaction.org.uk/index.htm] and case studies of schools using datalogging in science can be found in the Virtual Teacher Centre [http://curriculum.becta.org.uk/docserver.php?docid=1082].

Age /KS	In ICT pupils will need to:	In science pupils will need to:	Datalogging in practice
5–7		Know that there are many kinds of sound and	Use sensors to detect and

KS1		sources of sound (Sc4/3c).	compare sounds.
7–11 KS2	Create, test, improve and refine sequences of instructions to make things happen and to monitor events and respond to them (ICT/2b).	Make systematic observations and measurements, including the use of ICT for datalogging (Sc1/2f). Show that some materials are better thermal insulators than others (Sc3/1b). Know how to change the pitch and loudness of sounds produced by some vibrating objects [for example, a drum skin, a plucked string] (Sc4/3f).	Use sensors to record temperature changes, compare sounds made under different conditions, and compare the amount of light reflected by a range of materials.
11–14 KS3	Use ICT to measure, record, respond to and control events by planning, testing and modifying sequences of instructions (ICT/2b).	Make observations and measurements, including the use of ICT for datalogging [for example, variables changing over time] to an appropriate degree of precision (Sc1/2g). Use diagrams, tables, charts and graphs, including lines of best fit, to identify and describe patterns or relationships in data (Sc1/2j). Know that plants need carbon dioxide, water and light for photosynthesis, and produce biomass and oxygen (Sc2/3a). Show that when physical changes [for example, changes of state, formation of solutions] take place, mass is conserved (Sc3/2a).	Use automatic weather stations; use datalogging in fieldwork and experiments, such as using sensors to record factors that affect photosynthesis; and use data loggers to collect, analyse and evaluate changes of state, temperature and mass. Use light gates to determine the average speed of a vehicle along a slope and study the effect of changing the slope and vehicle mass.
14–16 KS4	Apply, as appropriate, the concepts and techniques of using ICT to measure, record, respond to, control and automate events (ICT/2c).	Make observations and measurements, including the use of ICT for datalogging [for example, to monitor several variables at the same time] to a degree of precision appropriate to the context (Sc1/2g). Understand the great variation in the rates at which different reactions take place and how the rates of reactions can be altered by varying temperature or concentration, or by changing the surface area of a solid reactant, or by adding a catalyst (Sc3/3h,3i). The quantitative relationship between resistance, voltage and current, and how current varies with voltage in a range of devices [for example, resistors, filament bulbs, diodes, light dependent resistors (LDRs) and thermistors] (Sc4/1c,1d). How distance, time and speed can be determined and represented graphically (Sc4 double/2a).	Use data loggers to analyse and evaluate reaction data, such as pH during a neutralisation reaction, and relationships between resistance, current and voltage. Use sensors to measure the current in a circuit with a lamp as the voltage changes continuously. Use data loggers to plot a live displacement versus time graph as a pupil moves towards a motion sensor.

What types of datalogging are there?
We can classify datalogging activities in various ways, including by the type of sensor used, by the location of the sensor or by the way they relate to time.

- real-time systems which monitor and display the data, such as an ECG, thus opening up the possibility of interacting with them.
- time-shift systems, which allow us to study very slow and very fast events, like a car crash test.
- Remote logging, where a portable datalogger or remote logging system is used, such as the internet-based robotic telescope at the National Schools' Observatory [http://www.schoolsobservatory.org.uk/staff/sres/ltdloggr.htm].
- Remote sensing, where the sensor can measure at a distance, like the Total Ozone Mapping Spectrometer (TOMS) [http://jwocky.gsfc.nasa.gov/] which measures the ozone layer from a satellite.

What equipment do I need for datalogging?
The type and amount of equipment required depends on the overall vision of how datalogging will be used to enhance learning. Unlike control technology, the focus is on observation and measurement rather than on understanding the process involved in datalogging. Thus a good datalogging device is one which assists in making observations and measurements without distracting the user from the activity.

Understanding requirements

Datalogging takes place in a number of contexts and is best catered for by a range of equipment.

One way of analysing requirements is to identify a series of activities where datalogging would enhance learning, and then ask the following questions about each activity:

- What parameters will be measured – heat, light, sound, pH?
- What range and accuracy is required?
- Do the results need to be displayed in real time?
- Will it be a class activity, a teacher demonstration, or part of a circus of experiments?
- Will there be sufficient desktop computers and mains power sockets available, or will a stand alone, battery-operated solution be required?
- If battery-operated equipment is to be used, will the activity last longer than the battery?
- What data analysis and graphing functions are required?
- Is there a need for training, support and curriculum materials before staff are confident performing this datalogging activity?

From this analysis you may decide on a basic set of equipment for class activities (that will use cheaper and simpler equipment), and a selection of more sophisticated sensors and dataloggers for use in teacher demonstrations or as part of a circus of experiments.

The following online documents, published by Becta, may provide additional background information:

- Sensors: what types are there and what do they do? [http://curriculum.becta.org.uk/docserver.php?docid=1250]

- Datalogging interfaces [http://curriculum.becta.org.uk/docserver.php?docid=1232]

- Datalogging software [http://curriculum.becta.org.uk/docserver.php?docid=1251] and [http://curriculum.becta.org.uk/docserver.php?docid=1265]

Types of hardware

Traditionally, sensors are wired to a datalogging interface that is connected to a computer. Software on the computer is then used to read data from the sensors at regular intervals and to store and interpret the results. Once the various components are set up, this arrangement can be as simple to use as any other system for datalogging. However, there are now a number of more integrated, but possibly less flexible, solutions called dataloggers.

Dataloggers, which integrate sensors with the electronics required for collecting and storing data, come in all shapes and sizes. Some can display data as it is collected (either numerically, graphically or both), record a number of data sets, accept a wide range of sensors, and work with desktop, portable and handheld computers. Others are dedicated to a particular task, such as the iButton temperature datalogger that the Science Enhancement Programme (SEP) suggests using for some Key Stage 3 and 4 activities [http://www.sep.org.uk/kitpot3.htm].

The iButton is a completely self-contained electronic device about the size of a £1 coin. It has a sealed-in lithium battery that lasts for approximately ten years. The iButton can record temperature readings from -10°C to +85°C at intervals of 1 to 255 minutes. At £10 for the iButton and £30 for the serial adapter and software, iButtons make a cost-effective solution for certain applications (for details of educational support material for the iButton, see *Other sources of information* at the end of this document).

What issues should be considered before buying?

General purchasing issues

In a primary school, a combined datalogging interface and control box that is able to fulfil both datalogging and control curriculum requirements may offer significant benefits. Training is simplified, and confidence in using the system transfers between the different activities. Some devices use one software application to run both the control and datalogging functions while others use separate software applications for each function. Integrated software may simplify use, but consideration needs to be given to whether the functionality of either component has been compromised. Can the combined solution meet all of the school's datalogging and control needs?

Other general issues:

- What are the implications for staff training and curriculum integration?
- Is training and support for the chosen equipment available locally?
- Does the local Science, Engineering and Technology Point (SETPOINT) support particular products? (see Other sources of information at the end of this document)
- Are there support networks for the product, such as staff at other local schools or internet-baseduser groups?
- Are teaching resources for use with the product available from the LEA, Regional Broadband Consortium (RBC), or from the supplier via the internet?
- What equipment and software is already in use?
- How will the equipment be stored and maintained?
- Will similar equipment continue to be available so that resources can be extended or replaced in the future?
- What constraints are imposed by the activity to be covered – length of time, sample rate, sensor requirements, accuracy and range?

Things to consider when purchasing sensors

- What sensors are available and can you build your own? If the range of sensors is limited to those provided by the manufacturer, ensure that all of the sensors required for the planned activities are available for the chosen datalogging interface.
- Do the sensors have suitable range and accuracy? Sensors designed for use in the primary curriculum may not have the range and precision required for use at Key Stage 3 and 4 – check range and accuracy carefully.
- Which sensors are the most robust? (This factor may influence the decision about what to use for class work.)
- Can the sensor withstand, for example, boiling water and chemical attack? Ensure that the sensor can meet the specific requirements of the intended activities.

Things to consider when purchasing datalogging hardware

The first consideration should be about how the interface or datalogger connects to the computer. Traditionally, datalogging interfaces connected to the serial port, but there are now devices that connect to the USB (universal serial bus), parallel and SCSI (small computer system interface) ports. These more advanced communication ports facilitate increased data-transfer speeds and sampling rates. For example, the Pico Oscilloscope and Spectrum Analysers [http://www.picotech.com/oscilloscope.html] connect via the parallel port.

Most modern equipment is provided with at least one USB port, and this port has enabled some elegant solutions to be designed. For example, Pasport, from Pasco [www.pasco.com/pasport] allows sensors to be connected to the computer's USB port and automatically runs the datalogging software when the sensor is connected.

However, when considering the purchase of dataloggers or interfaces that connect via the USB, an audit needs to take place to ensure that the school has sufficient USB-enabled computers. It is also important to audit the operating system of the computers as some versions of Microsoft Windows are not fully USB compliant – Windows NT has no USB drivers supplied as standard, and Windows 95 has reduced USB functionality. The information gained from the audit may place a constraint on the choice of datalogger.

Some dataloggers may be able to use a USB-to-serial converter. There may be some constraints imposed by using an adapter, which may appear as an unusual port name such as COM9, which the datalogging software may not allow. Some dataloggers will only work with specific adapters - check with the manufacturer of the interface before purchasing one.

Other factors:

- Can data be logged without the datalogger being connected to a computer?
- Can the sampling rate be changed at the datalogger as well as from the computer?
- How many samples per second can be recorded?
- What is the resolution of analogue to digital converters?
- What is the total recording time (influenced by memory and number of readings being taken per second)?
- How is data exported, and in what formats?
- Is battery backup provided to preserve the data recorded, or is everything lost when there is no longer enough power to record data?
- What is the battery life? (Some activities may take longer than the batteries can last. Also, the age and condition of rechargeable batteries can reduce life expectancy by 50 per cent or more.)
- What is the display quality and what does it show?
- Is the size and weight appropriate to the activities being planned?

- What is the maximum recording speed (number of samples per second)? (This may depend on which computer operating system is being used.)
- How many data sets can be held in the device's memory (This limits the number of experiments you will be able to record.)
- Are there any built-in sensors?
- Does the datalogger recognise the type of sensor attached and display the correct units?
- How many sensors can be logged at the same time?

For a detailed consideration of purchasing strategy see [http://curriculum.becta.org.uk/docserver.php?docid=1242]

Things to consider about data-handling software

A table giving some of the features associated with different types of software is available online [http://curriculum.becta.org.uk/docserver.php?docid=1265].

Some considerations include:

- What are the data-handling capabilities of the supplied software? Both mathematical and statistical functions may be required for different activities.
- Are the default scales used for graphs appropriate and can they be varied?
- Can you export data to a spreadsheet?
- What can you print from the software?
- Can data be saved and loaded? This facility increases flexibility - for example, exemplar data can be created, or several data sets illustrating different conditions can be investigated.

What are the implementation issues?

The main implementation issues relate to the factors involved in using and organising datalogging systems in the classroom and these are considered in a separate online document [http://curriculum.becta.org.uk/docserver.php?docid=1239].

With certain activities, when the focus is on data handling, it would be possible to demonstrate the datalogging and export the data to a common area on a network so that all pupils could use the software to analyse the data. In this case, it would be necessary to ensure that all computers running the program were covered by the appropriate software licence. In addition, it is useful to have some sample datasets available in case the experiment fails.

Other sources of information

Curriculum related

Using ICT to meet teaching objectives in primary science (Word document) [http://www.canteach.gov.uk/publications/community/ict/exemplification/psci.doc]

Using ICT to meet teaching objectives in secondary science (Word document) [http://www.canteach.gov.uk/publications/community/ict/exemplification/secsci.doc]

ICT CD-ROM needs identification materials
[http://www.canteach.gov.uk/community/ict/nof/ict_cd.htm]

Datalogging is referred to in the Key Stage 3 National Strategy mathematics framework [http://www.standards.dfes.gov.uk/keystage3/strands/?strand=maths]. It is also included in the sample maths lesson plans being developed currently by the Association of Teachers of Mathematics (ATM) and the Mathematical Association (MA) for the Key Stage 3 strategy illustrating cross-curricular coverage of objectives from the ICT framework
[http://www.standards.dfes.gov.uk/keystage3/strands/?strand=ICT].

The Logging Lab
[http://www.shu.ac.uk/schools/sci/sol/invest/logging/loghead.htm]

Roger Frost's Dataloggerama
[http://www.rogerfrost.com/]

IT in Primary Science by Roger Frost (published by IT in Science, revised edition 2000, ISBN 0-9520257-3-6) available from the Association for Science Education (ASE) online bookstore.
[http://www.ase.org.uk/htm/book_store/]

Datalogging equipment and resources

Features and prices of interfaces and data loggers
[http://curriculum.becta.org.uk/docserver.php?docid=1215]

iButton
The Thermochron video [http://www.ibutton.com/videos/index.html], illustrates how the iButton is used in industry to track the temperature of food during transport.
The SEP support materials: an investigation of home heating using the iButton [http://www.sep.org.uk/downloads/iButton_home.pdf] include one activity where two iButtons are taken home by pupils for 2-3 days datalogging. They are asked to select a room and then tape one iButton to the outside of a window and one inside the room. When the iButtons are returned the data is transferred to the computer for analysis, using its serial adapter and data handling software. Data from different houses can be compared and reasons discussed with the results being graphed in a spreadsheet.

Data-capture and modelling in mathematics and science
[http://vtc.ngfl.gov.uk/uploads/application/datacapture-16796.pdf] using Graphic Calculators
[http://vtc.ngfl.gov.uk/docserver.php?docid=1760]

Videologgers
[http://www.auc.co.uk/videologging.htm]

Videologging in Science
[http://webphysics.tec.nh.us/vidshell/clips.html]

Online data collection projects
TrafficNet
[http://buypower.vauxhall.co.uk/trafficnet/index.jhtml]

The Remote Sensing Core Curriculum
[http://research.umbc.edu/~tbenja1]

National Schools' Observatory:

[http://www.schoolsobservatory.org.uk/]
The National Schools' Observatory is a major web-based resource that allows UK schools to use

world-class astronomical telescopes sited all around the world. The annual subscription is £45. A robotic telescope is a large data logger gathering a wide range of data. The LTDatalogger software is a computer-based learning resource for pupils to use and learn about datalogging and also its application in robotic telescope technology. Current data from the telescope weather stations, located on mountains around the world, and engineering data from the telescopes themselves will be available for analysis using this software.

Organisations/associations

CLEAPSS (Consortium of Local Education Authorities for the Provision of Science Services): CLEAPSS provides courses for technicians, and publishes the *Primary Science & Technology Newsletter,* which often contains equipment reviews (for example, issue 19, p2). [http://www.cleapss.org.uk/]

(SETPOINTS have been established by SETNET, the Science Engineering Technology Mathematics Network. SETNET is one of the outcomes of a government initiative: Action for Engineering. SETPOINTS operate as a focus for teachers, business and industry to obtain information about resources, schemes and initiatives concerned with science, engineering, technology and. Many SETPOINTS offer taught modules for 30 pupils, including transport to and from the school, for less than £5 per person. This is an interesting way to introduce datalogging; if you plan to take advantage of this scheme then the equipment used by the SETPOINT should be considered. To find your local SETPOINT, visit the SETNET website [www.setnet.org.uk/] or telephone SETNET on 020 7636 7705.)