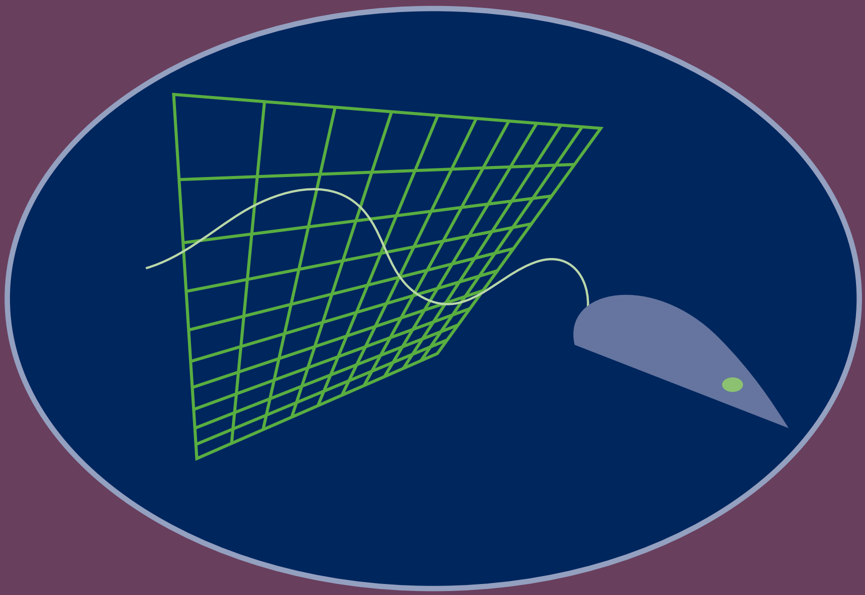

Datalogging inservice booklet

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Roger Frost

Ideas for ITE and CPD activities

Why use ICT

Much is said about the value of ICT to science teaching. While parents, students, teachers and politicians agree that we should use it, how do they perceive its benefits? If you find a different rationale comes from the head and the school ICT co-ordinator it could be a sign that we need to be clear about what counts.
Below is a list of good things about ICT. See if we can agree on which are the most important.

Sort the 'good things about ICT' into those that are properties of ICT and those that are benefits.

About ICT – data logging	**Is this a feature?**	**Or a benefit?**	**Your top ideas**
'Real time' graphs offer opportunities for discussion		✓	
Data logging allows us to experience variables such as pH and oxygen.			
Data logging graphs show how variables change			
ICT allows students to see changes as graphs in 'real-time'			
ICT better handles variables			
ICT brings school science into the current age			
ICT can be a strong motivator			
ICT can lead to a better understanding of science			
ICT encourages students to ask questions.			
ICT helps us measure with improved precision			
ICT improves students' view of the status of science			
ICT is used in the world of work			
ICT measures very fast or very slow changes.			
ICT offers a way to develop analysis skills			
ICT offers an automatic way of collecting data			
ICT presents more opportunities to investigate science			

About this booklet

"Data logging in-service" is a collection of activities used for numerous in-service days and courses. Some will find a place in teacher education or CPD courses. No-one ever used all of these activities, but some of them will surely provoke discussion or give you a head-start in designing your own.

Among the activities are pages of advice and maxims which like technology, people, and me, are prone to aging. So it goes.

Roger Frost

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When or when not to use ICT

"ICT for ICTs sake can make the science fake". Examine the reasons we use sensors in experiments.

Mark the data logging activities that could be enhanced by using technology.

Burn a candle in a bell jar and measure the temperature and the oxygen, humidity and light levels.	Make acid-base titration curves by dripping acid from a burette and measure the pH.
Measure the oxygen and light levels in an aquarium for a whole week.	Titrate acid into base by dripping acid from a burette and measuring the heat of neutralisation.
Compare different insulating materials using temperature probes.	Record a cooling curve in a tube in a cool water bath.
Find the most heat producing ingredients for a sports injury pack.	Measure temperatures deep and shallow in the soil, and see how they change during a day.
See the effect of concentration on osmotic pressure by using a pressure sensor.	Study distance-time graphs of students walking towards a distance sensor
Measure reaction time using two light switches or light gates	Measure force and acceleration using light gates or dynamics pulley.
Measure the cooling of test tubes to show the benefit of penguins huddling	Study simple harmonic motion by monitoring a pendulum with a position sensor
Monitor the noise from the class with a sound sensor.	Take sensor readings of light level and temperature at different locations in field work
Measure the rate of the ‘acid plus thiosulfate reaction’ using a light sensor	Use a light sensor to see how two tube lamps interfere and produce beats.

When or when not to use ICT

Match these reasons for using sensors in an experiment with those on the previous page

A fairly easy activity requiring little equipment for getting up to speed with data logging		Allows us to measure a change that normally takes too long or runs overnight	
Allows you to quantify a change or difference you don't normally quantify		Introduces the idea of graphs and measurement using the computer	
Provides a real time graph that offers an opportunity for a useful discussion about what is happening		Leads students onto an investigation of their own	
Data is plotted on a graph in real time to show its rate of change		Involves the simultaneous measurement of several variables that could otherwise be difficult	
This is an opportunity to show how ICT can help science - or scientists		Easier to understand for less able students	
Provides an opportunity to investigate science using better tools		Graphic display of 'abstract' variables such as pH or oxygen level	
Provides an opportunity for work where students can use a range of investigative skills		Offers an opportunity to extend able students	
Introductory activity to get students used to the software in the lower school		Provides an opportunity to develop skills in data analysis	
Provides an opportunity to develop ICT capability		Provides a modern way to do this experiment	
Doing the experiment like this saves time		Provides a more accurate or precise method of doing this	
A novel approach to an experiment		Students will enjoy doing this	
A very small, subtle change is made significant using sensors		Having two data sets appear at the same helps students to look at them critically	

Using software to handle data

More than record data from sensors, software lets us handle their data in special ways. There are ways to display the data, to read graphs, do maths and model. Here we look at the ways that data logging software can handle your data.

Display tools

Display tools allow you to discuss a graph. Bar gauges, time graphs and other graphic displays provide feedback during an experiment. For example, a bar gauge rises as you make a sound. This is useful feedback, but the discussion and interaction that goes with it are the keys to making data logging into something to learn from. After an experiment the software may let you 'play back' the experiment as if it were happening again. A digital meter display is especially handy for demonstrations - for example, a whole class can see the pH numbers change as you add acid to alkali. You can split the screen, having half with a digital display and half with a bar gauge and all should still be able to see. A feature that lets you change the scale to zoom in on interesting parts of a graph is crucial. Finally, being able to see the correspondence between a graph and a table of results is helpful too.

Graph measuring tools

Graph measuring tools let you do special things very quickly. The essential graph-measuring tool is a cursor or cross hair that reads the points on the graph. Some programs let you use the cross hairs like callipers to compare say, the period of one pendulum swing with another. You also can find the highest and lowest values when you have measured something cooling, or calculate the difference between two points to show how much the pH changed or how long the change took to happen. Statistical features let you work out the average temperature in an insulation experiment to see which graph line had the highest temperature overall. You could also see the standard deviation of a data set - though I am scratching for a reason why. A versatile tool calculates the area under a graph to tell you which container stayed hottest the longest. And if it seems that there is some overlap in what is on offer, appreciate that you choose from this range of tools to suit different experiments and different age groups. In other words, you will not need to use them all in a single situation and in fact doing so risks confusion.

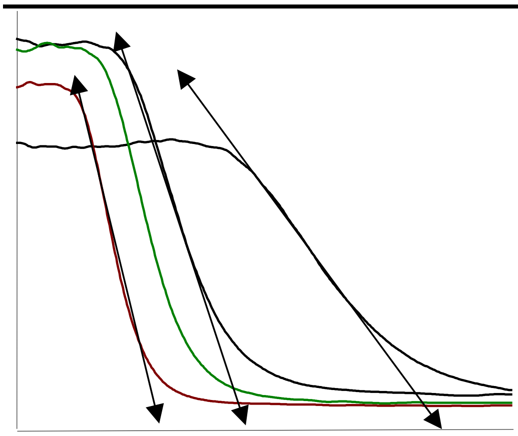
The most familiar graph-measuring tool will calculate a gradient at any point along a line. The software uses a few consecutive points to calculate a slope such that if three points in a row go up, you can read off a positive gradient. If you see a steady line you will want to measure its gradient. If you see the sine wave of a pendulum you can see how its gradient (or velocity) changes. However attractive we find the gradient concept, it’s a fact that the data we collect nearly always 'wobbles'. This confuses the calculation so that gradient is erratic. In most cases we need to use other approaches.

A first alternative, suitable for advanced groups, is to calculate the differential of the line and plot this against time. This will show the part of the graph that is changing fastest. A second idea is to find the 'best' part of the graph, and fit a function to it. The gradient of this line should be the same as before. (Remember: the software gives you a value for 'm' in a straight-line based on $y=mx+c$).

A third easier alternative is calculating the 'rate of change'. This takes two points and works out the average gradient between them. This works well nearly all of the time but we need another graph measuring method for younger groups.

We could, for example, measure the difference between two points on the graph. We could measure which graph changed the most in 10 minutes. Or we could see where the graph lines intercept the time axis as here:

Using software to handle data



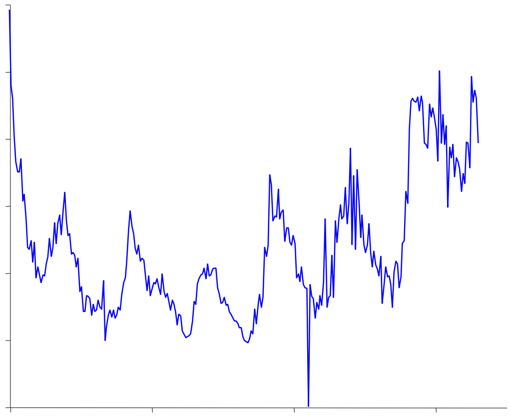
In short, if you do try to measure the gradient, do so on a 'wobble-free' line.
To see this in practice, see the experiment sheets later on rates of reactions and pendulums.

Formatting features

You may want to add a title, labels, a grid or comments to a graph. You can change what plots against what, switch to a log scale, change the size of lettering, graph scales, tick marks or graph points. There is more to formatting than cosmetic gloss because these features help to highlight your findings.
It may be too much to expect these features and still have a an uncluttered software package, but if you need this much control, you could send the data to your spreadsheet. Incidentally, if you copy and paste the graph to a word processor such as Word, a double click sometimes opens a drawing toolbox to give further control over how the graph looks.

Calculating and graph editing tools

If you have a noisy graph, you can 'smooth' it. Smoothing makes the trace look better but loses its fine grain detail. A noisy record of an oxygen sensor improves greatly with smoothing, but do the same with a distance sensor and you can lose detail you need. One rule of thumb is that if you need to do some maths on the data, do this before smoothing.

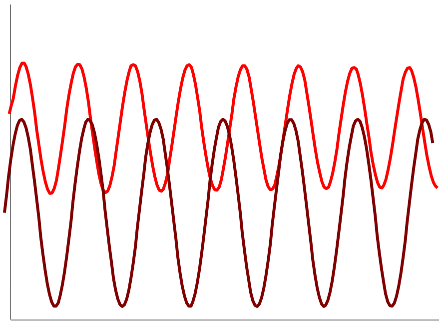


Sensors may contain circuits that smooth the data before you ever get to see it. If not, data logging software has various ways to remove noise. Borrowing from the world of electronics, it may offer different smoothing algorithms: the median smoothing algorithm simply averages readings that are close together while Fourier smoothing looks for high frequency changes. For example, you could remove a sudden spike in a graph with Fourier smoothing, when averaging would leave the graph with a bump.
When you need to look at data in a new way, calculate a fresh graph line. For example, you can subtract room temperature from a graph or remove your control reading from your test reading. The software may provide you with equations to manipulate the data and ‘define’ a new line. Look in the software for an 'x-y' equation and choose which line is x and which is y.
When you want to see how fast things are changing, you can calculate the differential of the line. For example, you can find the equivalence point in a pH titration by calculating the differential of the pH. You can find the velocity of a pendulum by calculating the differential of its angle. When you do a differential, the machine plots the gradient of the graph against time. Use this when you are teaching an advanced group.

Using software to handle data

Curve fitting

Curve fitting lets you guess at a mathematical model of your results and the model allows you to make predictions. In curve fitting you choose from a list of functions that draw straight lines or curves and see which best fits the data. You can punch numbers into an equation until it fits the original data or in some software, you nudge the graph until it fits:

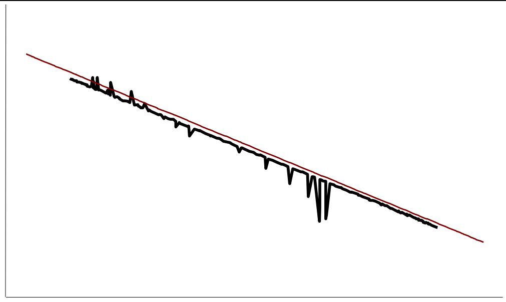


Either way, you end up with a model of your original data – and without the wobbles that calculating a curve from your data tends to produce. From this you can make a prediction, for example, if you fit a straight line to a pressure versus temperature graph you can predict absolute zero. Just read off the temperature intercept and hope that it goes through zero K.

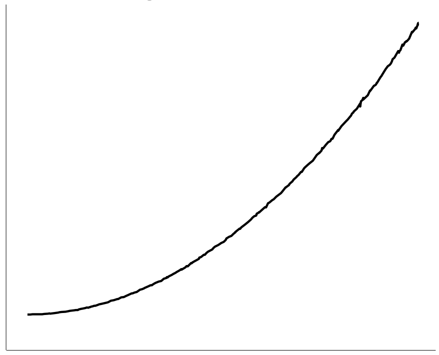
There will be many occasions when only part of a graph is interesting. For example, in a rate of reaction experiment you could fit a logistic function to the whole S-shaped graph but really, fitting a line to the middle part feels OK. To do this, you just select or zoom in on the part you want and then fit the line to that.

There are many types of function to fit and of course knowing what the relationship is in the first place tends to get the right answer! If you can't find the exact function that you need, try building one up in parts. If you want $ax^{1/b} + c$ but you can only find $ax^b + c$ in the software, first calculate 1/b then put the result in $ax^{1/b} + c$. Here are some of the fit functions you might find:

- Try y = c + m x for when you expect a straight line such as the relationship of temperature to pressure. The slope (m) is constant and the graph intercepts the x axis at c



- Try the quadratic or parabolic $y = c + mx + a x^2$ for square law functions. If you had measured the distance as an object falls, you could use the function to find the acceleration due to gravity. The slope of the curve changes continuously. Show this with the gradient tool, then straighten the line by calculating its differential.



- Try y = A log (Bx) for a logarithmic relationship
- Try the exponential $y = A e^{Bx}$ for examples where the rate is not constant such as cooling, radioactive decay, or yeast growth curves.
- Try a logistics function on S shaped graphs from pH titrations and rates of change.
- Try a sine function y= c + a sin (bx) for waves and pendulum swings. Note that a is the amplitude, c the vertical shift and b the period.

Use a spreadsheet?

You can open your data in a spreadsheet program and do all you wish with it. The spreadsheet is a general-purpose analysis tool, so any skills you have are put to good use. Furthermore, spreadsheets have a familiar look that helps everyone get up to speed with them. Use your data logging program to save your data as a CSV or TSV or SID file. A spreadsheet will then be able to use it. I'm not particularly inclined to use a spreadsheet as I find that a data logging package is more made for reading values from a graph and for delivering the features just mentioned.

How do you discuss a graph?

"Looking at a graph on a computer screen shows only part of the picture".

Graphs are helpful pictures of change. Just as an art teacher directs attention to a painting and helps attach meaning to it, data logging activities need to do this with graphs. And just as the artist needs the language to describe paintings, so too the science learner ought develop the language to describe graphs. But more than describe a graph, ICT tools allow students to work out areas, measure rates of change, calculate new graphs or model them with an equation.
If the discussion around a graph is crucial to achieving the benefits of ICT, this set of question prompts aims to feed such a discussion:

Q. Predict the graph you expect to see.
Q. At what temperature do you expect the graph to start? Will it go up or down?
Q. There are two traces. Which line is which?
Q. Which line is changing faster?
Q. Should the two traces start at the same point?
Q. How does the graph show you that x is better?
Q. Compare the graph with your prediction
Q. Label the graph to say what happened
Q. How would the graph be different if you had done it another way? Test your idea.
Q. How much have the readings changed:
Q. Which trace shows the highest reading?
Q. How long did the change take?
Q. Where did the graph change fastest? How fast does the graph change?
Q. Fit a curve or line to the graph. What does this tell us?

Q. Sketch a graph to show what you think will happen
Q. Why are the peaks different?
Q. What made the bump on the graph?
Q. Why did the trace go up rather than down?
Q. When does the temperature change fastest?
Q. How do you know when it has finished changing?
Q. Is there a pattern in the way the two traces change? Describe the pattern.
Q. Which trace had the highest reading overall?
Q. How much did it change? Which changed the most? Is there much difference?
Q. How much do the graphs change in a minute? What does this tell us?
Q. What is the gradient of the graph? What is the gradient of a best-fit line?
Q. What happens if you subtract the control reading from the trace? (e.g. subtract room temperature)
Q. Calculate the integral of the line. What does this tell us?

Strategies

A teacher's work scheme is the result of choosing ways to deliver a curriculum. In that work scheme, sometimes students do things, sometimes we show them things and sometimes we just tell them. This exercise is about applying the same choices to data logging activities.

Put the experiments below into the table on the next page.

1. Monitor class noise	2. Study simple harmonic motion of a pendulum	3. Measure the effect of emulsifiers on the activity of lipase
4. Compare insulators	5. Find the optimal ingredients for a sports injury pack	6. Oxygen and light levels in an aquarium
7. Study force and acceleration	8. Cooling curves and latent heat	9. Look at huddling emperor penguins
10. Study distance-time graphs with a distance sensor	11. Measure rates of reaction of acid and sodium thiosulfate.	12. Monitor how the soil temperature changes during a day
13. Monitor AC ripple on a strip lamp and seeing how two lamps interfere	14. Acid-base titration	15. Measure the effect of concentration on osmotic pressure

Strategies

Choose the most fitting strategy for the experiments on the previous page

Strategy	Experiment	Justify your choice
These experiments I would demonstrate and discuss		e.g. it's more valuable; affordable; reliable; manageable; efficient
In these experiments, I would give students my results to analyse		
These are experiments that the whole class should do		
Some students can do these experiments while the rest of the class do the experiment the usual way		
These ideas are good for student projects		
These experiments are best done as we always did them		
These ideas are best for science club		

Getting round to using ICT

"Most of us need some support to move ourselves on; only some of us generate our own energy."

Science departments offer tips and advice on introducing ICT in school.

"Start with activities and demos that are reliable and easy. I felt that a room with ten computers, ten data loggers and countless boiling beakers of ice was not a situation to thrust at a first time user – I would not try it myself anyway. Instead we started with activities and demos that were reliable and easy."	"Choose the right group to work with. I'd be very anxious about doing this with some of my classes. With a large group it doesn't seem to be really viable. With a wild group forget it – I tried it with them as a special treat but it ended in tears. But my year 10's were great…"
"Write it into the work scheme. The school set out an action plan where one teacher would introduce an experiment this year and others would come on stream next. They used a highlighter pen to mark the work scheme with ICT opportunities. They graded them with stars – one star meant it was a suggestion, two stars meant it was a 'must-do'. The head of science forced the issue: he removed ordinary experiments from the work scheme and replaced them with ICT experiments."	"Start with success. The chemistry teacher really wanted to do an acid-base titration but how do you tell them it is best to start with something reliable and manageable. It is best to get up to speed with an easy idea than have do the value-added activity that is too clever or tricky. For example, it is easier to use temperature sensors, or use a spreadsheet to draw a graph or use science software to revise for an exam. Data logging is the hardest place to start using ICT."
"Get students to help with demonstrations. I demonstrate a few experiments using the sensors. But the students are very astute and notice the tiniest hint of hesitation with the mouse. That's why I get a student to do the mouse stuff as I talk them through. You have to be very patient with them - even if they aren't with you!"	"Not every one is keen on ICT or will ever be. This is a mixed ability profession – humans staff it and not every one is keen. We respect how they feel and trust that when the rest of us are up to speed they will fall in line. There is just no point in upsetting good teachers. If after our best support their heart isn't in it, there's no point in banging on at them."
"Don't snatch the mouse out of someone's hand. When you're stuck, someone will take your mouse, whiz around over the screen with it and do it all for you. We've rule here that no one may do this. Instead they have to talk the person through the snag. You'd think that people teaching ICT would know better – I mean, if I snatched that pen from you and did the writing for you, you'd pretty soon feel deflated."	"Get a successful ICT lesson in your armoury - a sort of party piece. Repeat your party piece with every class to learn the pitfalls faster. What staff needed was a successful ICT lesson in their armoury. They needed to see a good lesson with ICT and they need to get good at something, to have a sort of party piece. I used this party piece with every class that month. OK, it took some contriving to do that, but I learned to handle the pitfalls much faster."
"Document ICT lessons. We need curriculum materials and exemplars as a priority."	"Use old computers. People get a bit anxious about brand new computers and environments that change frequently. They'll only use things when the equipment has stood still long enough and looks as old as the rest of the place."
"Use portable computers. We went for portables that the staff borrow in the evenings. It is hard to get them back I know, but you do notice that these teachers are very confident with them – using discs and printers and so on. Convenient and comfortable access to computers has moved them on. We started using the laptops for doing graphs with spreadsheets and writing experiment reports."	"Build a bit of a computer culture about the place with displays and students using machines in science club. We started to build a bit of an ICT culture about the department. Students browse through the CD-ROMs at lunchtime and use them for science club. The club mounted a really good ICT display in the science corridor and they're going to move it to the foyer for next week's open day."

Getting round to using ICT

"Pray for serious support from school. The management was serious about ICT, and the deputy head formed a group of 1-2 science staff who could take ICT forward. He chose people who had time to draw breath and explicitly not the head of science! They worked with the ICT co-ordinator, trying out things in class and often with support. The group became a sort-of working party and argued for timetabled support for the rest of the department."	"Staff need to use a computer for their work. They need to get good with computer for their own work before they feel able to teach others. Here everyone does their work on the word processor, and quite a few use spreadsheets. We are more comfortable handling a class with these applications than with data logging. Don't try to do too much Start with something easier than data logging Use clipart to make worksheets"
"Get the vision right. Over the years, we have bought bits of gear but we still do not have what we need to make ICT work with a whole class. The result is inaction and despondency because frankly we are being too ambitious. It makes more sense to look at what you can do. You could say we've refocused our vision to match our resources."	"Use reliable equipment: I used to make our own sensors here – it was miles cheaper but these days you can get them ready made. With the homemade sensors, wires were always coming off – but now the commercial ones don't cost much more and they even calibrate themselves. It gives others a lot more confidence."
"A good printer motivates teachers. We saw having a printer that worked brilliantly and printed in colour not as any sort of luxury, but as a key motivator. When staff see their work looking that good it really is worth using a computer. Compared to the cost of staff development, ink cartridges come at bargain prices."	"Time to go on courses and attend trade shows. Staff who need ICT training are allowed to go on a course although we have bought someone in for a training day. We encourage staff to get to education trade shows and events to expose them to the culture of ICT in education. Examples include the BETT show in London and science association events."
"Team-teach first lessons using ICT New users appreciate a helper nearby. We are no strangers to visiting each other's lessons so this would work. Here, your first lesson using ICT is nearly always team-taught with another – what 's more, it didn't always matter if the helper wasn't an expert either. They would learn too."	"Use palmtops on field work. The biology teacher was never keen on computers, but I joined her on a field trip and took laptop and palmtop computers. The students quickly learned how to record data and draw graphs on the palmtops. The teacher was impressed."
"Choose ICT that enhances the science. ICT ought to be about improving things. Some topics are just too dry so we're keen for ideas where ICT makes the science easier to teach. These things convince the sceptical teacher. Still, I'd admit that not everything we do with computers is aimed at 'extending science' as you say. You have to lead people into this so there is no point in going for a big whammy - like an experiment where you use sensors, do an investigation AND try to assess it at the same time. That is nuts. Some things we do just because they help get people familiar with the gear."	"Get familiar with the software. There is no rational reason why we should balk at using this equipment. Becoming familiar with the software was key. We put a graph on the screen and set about teaching ourselves the ins and outs of the software. We made a list of things like 'how to measure a rate of change', 'what to do if no trace appears' and so on. Some software is much better for getting started and it's getting started that we are about. The choice of software is very important. I take classes into the ICT room just to use the software to analyse a pendulum graph."
"Analyse data in the computer suite. Having a whole class do much the same thing is easier than some other ways of handling ICT. Do a demonstration and take a data file to the network room for analysis. Choose between trying this first with senior groups where a data rich file on rate of reactions, pendulums or dynamics offers much to do or doing a basic exercise with junior groups. Ask another teacher to co-teach the lesson."	"Use a department meeting to showcase ICT activities. Our department meeting often has a slot where I show an experiment I have done. The technician has been great at debugging ideas; she gets things ready for the meeting and joins in. Sometimes we just go over skills like copying a graph into a word processor. When we've seen something working and we can then discuss its place in our work scheme."

Policy points

Here are a selection of tips about using computers.

Something is always broken: from time to time, something will go wrong and it is sad to have to tell one group to watch another group. As one teacher puts it "I have nine sets of equipment but I plan for only eight to be fully working. When I do a demonstration, I have a spare of everything to hand. Another ICT tip is that insoluble problems are often due to two things being wrong at once! Ideally, I would like two of everything, as swapping bits of equipment is the clearest way to solve problems.

It takes ages to organise Setting up, packing away and checking in a data logging system takes a lot of time. One idea is to have a leader for each student group. Another is to leave the equipment permanently connected and ready to go. Another is to keep each set in a plastic tray or toolbox. The items and cables can be labelled to say what they are and where they connect, and you may find that colour or numbering is helpful. By using such a coding system, you soon notice that 'cable 2 in kit 2 is faulty' – whereas without a label the problem will recur randomly.

Students forget how to use it: if students use it once a year, they will surely forget. Do data logging in time blocks: choose a science topic such as forces or energy where there are many opportunities to use data logging. You can demonstrate how to use it in the first lesson and use it in many subsequent lessons - that way the students are more likely to remember how to use the equipment. Teachers learn by repetition too, a teacher was so impressed with a linear air-track and his light gates he used it in every lesson that week.

Students are not impressed: Using a computer can give a head start when you introduce something, though how long it lasts depends on how well you deliver. Most students have seen the awesome things that computers can do so maybe don't expect too much response. A force feedback joystick (which jolts them as they play arcade games) is tough competition for a data logger. Do not expect dropped jaws or even kudos for being adept at a computer. Under-promise and over deliver excitement is the policy.

Students are better than me at computers: If teachers are adept at showing respect for the science knowledge that students bring to the classroom, we can show the same respect for student's computer skills too. The science teacher brings the skills for handling data to the classroom. This is where the kudos comes from. If you feel in competition with students, shift your battle to this familiar ground (but don't fall off the computer).

Printing: Imagine at the end of a lesson, in full sight of the class, you take everyone's work and throw it in the bin. That is just what we do when we use ICT and inhibit students from printing their work.

"A lesson deserves a payoff so we have good printers that respect a student's effort, and fast printers that help to remove queues and bottlenecks. Colour printers seem to be essential when two coloured graph traces overlap. However, students can instead write over the graph lines with a felt pen.

Policy points

There is not enough equipment: If there is not enough kit to go round, you have a choice: you can do projects, you can just demonstrate or you do nothing. Demonstrations and discussion help get one up to speed - although a large screen is essential. Prioritise experiments with fast changes for demonstrations as watching a cooling curve appear is like watching paint dry. Set up longer experiments during the lesson introduction so that you get a chance to look at the results. When there is not enough equipment, the class might analyse the data in a computer room using one of the many activities in this book.

It is too hard: Take a simple experiment to compare insulators, add a data logging system and you have a lot of equipment and not a good place to start your first foray into data logging. If your system has a digital meter display, start by using these without the computers. In short, get support.

Need a worksheet: In one science department, the lead staff member for ICT trialled an ICT activity and wrote a worksheet for it. It told how to set up the experiment and had extra work to deal with idle moments where results were slow coming. It offered practical tips as well as questions to ask as the graph appeared on screen. It was not perfect but there were activities involving reading, sketch graphs and thinking questions. Whatever, this worksheet was the lesson organiser, the teacher's 'ring of confidence' and security!

Data handling is too hard for the class: Data handling is hard if students are thrown into it, and hopefully that is not being suggested. A colleague reassures that data handling is not just about numbers "We encourage students to annotate their graphs – we get them to add words on screen or in pencil. Their notes say what happened and capture the discussions they have had. We get them to write about 'how long it took' or 'how much it changed' and more importantly, what it means. If there is no time in class, we make homework out of this. It is too important to ignore." In time, handling data will become part of the culture and some of what seems hard now will filter down the school.

The computer does the experiment so quickly that students do not learn from it: We would need to research this point but we can agree that the technology raises questions about what and how we teach. When you measure the acceleration due to gravity in under a minute, you start to wonder. Students quickly get the idea of a distance-time graph by using a distance sensor. Using ICT certainly trivialises some experiments and there are three coping strategies: As you now have a way of doing something that previously wasted a lot of time, you can move on to the next thing you teach. Secondly, you can use the time to extend the work and see if the mass or height of the object affects the acceleration. Thirdly, you can of course do it the old way.

They need to learn how to draw graphs: Using ICT trivialises the drawing of graphs. Students need to learn how to draw graphs but there are two things here: one is learning to plot graphs; the other is learning to understand the data. The students drawing graphs merely focus upon getting the dots in the right places rather than appreciating the patterns in their data. Data logging turns the idea around to produce something especially useful for younger and low ability kids - it helps them to understand graph patterns. That in turn helps them understand how to draw them.

Events and open days

Spreading awareness of how ICT has helped is important. That awareness encourages students and staff to exploit what ICT offers. Do this well and you not only help others, you are more likely to gain funding for future ideas.

If that sounds a bit frank, spreading awareness is a way to break out of a “resources Catch 22”: If you do not have kit, you cannot use it, and if you do not use what you have, it is hard to persuade people to give you funds to buy more.

Put up posters into corridors, make open day displays, run science fairs, have ICT activities to entertain parents queuing at report evenings; do a story for a school newsletter, do an Internet page, put up displays at science teacher meetings.

The message should be 'how we benefited from using ICT'. This works much better than saying 'look we use computers'.

Aim to show how the pupils achieved a higher level in science. This works better than saying that they have developed a list of crass computer skill.

Display ideas

- The display title should say in just a few words what you were trying to do. Look for a title that will appeal to the greater part of the audience.
- Photographs can show students planning experiments as a team; show the experiment as a story board; add captions and mix close ups and people shots. You can print very good photographs using digital equipment and glossy papers.
- Graphs should be printed and annotated to say what is happening and why. Edit them in a drawing program (MS Word has one built in) and thicken traces or increase text sizes. Print them in colour.
- Activity write-ups should be kept as short as possible - on a display one sentence is enough.

Science fair or open day ideas

- Measure your reaction time using light gates. Put the result in a database beside your year of birth. Is there a pattern between reaction time and your age?
- Does after-shave make your skin cold? Use temperature sensors and rub alcohol on a round flask of water. Decorate the flask as a face.
- Stress tester - measure the skin temperature or pulse as people do a puzzle.
- Which falls faster, a piece of wood or a piece of metal? Compare how fast heavy and light things fall using light gates.
- Hand temperature – who can ‘put’ the most energy into a temperature probe. Use a toy with a probe inside.
- Can you walk a graph? Put a graph on screen and try to copy it as you walk towards a sonar distance sensor. Have a paper puzzle where you have to match graphs to events.
- How many times do you breathe in a minute? How many times does your heart beat in a minute? How does this change after some step-ups? Use breathing and pulse sensors.
- Survey software – survey attitudes or attributes of the attendees. Provide detail on studying the results.
- Does sherbet make you cold or does it just feel cold? Does peppermint make your skin cold or does it just feel cold? Use temperature sensors to investigate.
  **(Sherbet is citric acid + baking powder + sugar).*
- Control technology – garden greenhouse temperature controller; premature baby life support system; robots.
- Control technology – if you are planning an open day, do not create the prank exhibit which I was a victim of at South London Science Centre. A lot of foliage was labelled as holding a rare ‘lesser-spotted spitting frog’. A light sensor, a spot light and 12 volt water pump were wired up. When the victim leans over and breaks the light beam the pump squirts a jet of water.

Department policy

Some school situations are ripe for progress. We tell you about what they are doing. Highlight the aspects that could work for you. Discuss ways that you can make progress

This science department has assigned a multimedia desktop computer to each lab. The computers are on trolleys and as the entire department is on a single level, they can be wheeled into any science lesson. They have a basic sensor kit for each one, a few more esoteric sensors and quite a few CD-ROMs. One of these computers connects to a wall mounted television in one of the labs. The department also has two machines in the science office both connected to a laser printer. These are used by most of the department for word processing. All the staff use computers for doing their reports because the head insists on it. Two members of the seven in this department make use of the trolley machines.

A few years ago this science department had a windfall and bought ten data logging kits with temperature probes. They bought further individual sensors until the money ran out. Recently the head has been pushing for more ICT in school – investing in a new Internet suite, though this is physically far from the science department who have four machines of their own. Recently someone went through the cupboards to see what they have and set about planning what to do next.

The science department has one computer in the science office that is used for admin. They have two data logging kits. There is one computer on a trolley shared between six labs – a seemingly unhappy situation but there is a very good networked computer suite just a few doors down the corridor. The key to this room is kept close-by in the prep room although few people know this. The idea was that the science department would book this room of computers and take along their data logging kits to do less messy experiments. However, the room is heavily timetabled for ICT lessons leaving very few slots. Few members of the department seem happy to make the trip to the room. In fact, when one keen member asked for some software to be put on the network he was told it could not be done. The person is working towards a UDI situation where 'science' has their own computer resources.

A department in a large school has a set of ten new laptop computers each with a small set of sensors. They made a joint bid with the geography department to get them, although geography only use them for field trips. They have highlighted three lessons per class per year in their work schemes when they will use them. A member of the department has the responsibility for implementing the use of ICT in science and with a prior windfall bought a data logging kit with one of each type of sensor. The laptops are kept on a trolley, and the technical staff keep the batteries charged. The computers are booked with an equipment requisition slip. A timetable on a noticeboard shows advance bookings. They have a portable colour printer though printing causes a bottleneck at the end of a lesson. The equipment is well used – at present mostly for drawing graphs and writing experiment reports in a 'Works' package.

This department has one desktop computer, three laptop computers and eight handheld palmtops computers. They have sensor kits with two temperature probes, for each of the palmtops. The equipment is stored in labelled sets with each in a separate tray. The set-up allows the whole class to use a computer - although when the palmtops have collected the data, it has to be transferred to the laptops for printing. They also use the palmtops for recording results from manual experiments and around the school surveys. Students quickly learned to use them to draw graphs with the built-in spreadsheet. They aim to get a full class set of palmtops when funds become available.

They have a modern data logging kit and recently discovered a cupboard full of sensors bought some ten years ago with some special funding. The boxes of old-style floppy discs in the cupboard are labelled with the names of some heavy weight programs – a sure sign that a technical life-form once used this cupboard. A keen member of staff has agreed to take stock of what they have and what they can do. Nearby is a carpeted suite of computers that the department has access to.

The head of science at a split site school was offered a set of old but serviceable computers for a large lab in the lower school. She accepted them with the proviso of some extra funding to buy a set of data loggers. She has highlighted several opportunities to use computers for measuring temperature and lots of trolley-ramp type experiments in their work scheme.

Hardware strategies

"In the ICT room no-one can hear you scream". The aim of this page is to arrive at a plan for the department. Rework these often-cheeky ideas to suit. Which can you work on now?

Idea	**Idea to compare it with**
Computers on trolleys or mobile furniture	Computers and monitors on mid-height shelves to clear working space
	Older 'handed down' computers to do just data logging
Personal computers for teacher admin and demonstrations	Laptop computers for teacher admin and demonstrations
A class set of ‘pocket’ computers for data logging	A class set of small portables or sub-notebooks
Cheapest possible machines built locally with service contracts	Reliable best brand machines and an in-house technician
	A class set of calculators (e.g. Texas Instruments) for data logging and analysis
A class set of less expensive (lower specification or older) computers	Current specification laptops with multimedia.
A class set of new, cheap, high spec machines	A set of low spec machines with service contracts and wireless network cards
A science room with stand-alone personal computers and printers	A science room with Internet access networked to ease printing and file sharing.

A computer connected to a mounted large TV for demonstrations	A computer connected to a projector for demonstrations
A PC projector with the highest affordable brightness	A less bright PC projector with a high brightness portable screen
PC’s with small flat panel displays	PC’s with large monitors

Colour laser printers	Colour laser printers with money put aside for consumables
Fast printers to avoid printing queues	
Printer shared through a switch box and printer lead.	Wire free printing from laptops
Networked but remote colour printers	Local colour printers

School owned and managed ICT	Department owned and managed ICT
Department owned and ICT department crisis managed	Department owned and managed. ICT department maintained
Computer suite ever available with a shared door key.	ICT lessons fill the ICT room timetable. Key is stored somewhere.
ICT department manages	ICT department facilitates

Labels for equipment

In schools people share computers and the glamorous name for this is 'hot-desking' though it's not as exciting as it sounds. Those who can happily adapt to different machines clearly have skill though the rest us need have things written down. Here then are some examples to make a simple point: when there is a lot to remember it needs to be written down.

Some schools have that we have a hard time recalling the idiosyncrasies of technology. One school had eight laptops and eight trays of data logging equipment - everything was labelled; instructions were copied from manuals and put on laminated card. Each item in the data logging trays was labelled to say what it was and which set it belonged to. There was a photograph on a laminated card showing the trays' contents.

The laptop

You should have a laptop, a cable with mains plug and a power transformer.
Plug in the power pack at the back. Connect to the mains and switch on.
Make sure the lights on the power transformer AND the computer are on. If not, give your connections a push.
Pull the two slide switches (on the side) towards you and lift the screen.
Push the power button at the back of the keyboard - once to turn it on.
The data logger plugs into the red socket. This is called COM2 in the software

Closing down

When you have finished, choose 'Start' and 'Shut down'. This computer turns off automatically.
If the computer completely 'locks up', press and hold the power button at the back of the keyboard to shut it down.

Using the 'mouse'

The laptop has a touchpad instead of a mouse.
To click, press the left button OR double tap the touchpad.
To find a program quickly, use the 'Windows' key and hit the cursor keys.
Use the cursor keys and 'Enter' to respond to screen prompts
To shut down, press ALT + F4 ; Press enter a few times.

Data logging software notes

Connect your sensors to the data logger and the computer before starting the software.
There are bar and meter displays to use in demonstrations
Press the 'readings' button to read values from the graph
Use the change button to see which graph has gone down the most.
Use the average button to compare two cooling slopes
Use the area button to see which graph stayed higher longest.
Don't use 'gradient'. Instead find out how much the graph rose overall in say, 10 minutes.
If you can afford a projector most likely you can afford a good screen. The screen can seriously maximise what the projector offers. Boxed portable screens are much nicer than the tripod ones which many people have yet to learn how to set up. Get advice because some screen surfaces are directional and will not suit a wide room.
Sometimes you can display the image on the projector and computer monitor simultaneously.
When you connect a projector to a desktop computer you use a splitter cable to send the image to both screens. When you connect a projector to a laptop computer you need to tell the laptop to output to its monitor socket.
In theory you can display the projector image and laptop LCD simultaneously but in practice it only works well with one or the other. If you're in a hurry to get the lesson started always output to the projector because it's rare to find a laptop LCD screen, graphics card and projector that are happy with the same resolution and refresh rate.

On a laptop you can change a 'BIOS' setting so that the image will display on a projector if one is connected. Mine is set permanently like this.
There are interesting ways to connect the projector remote control into the system to replace your mouse. If you want to do more that click through a PowerPoint, get a cordless radio mouse. Logitech do a combined radio mouse / presenter device which really is the business.

Data logging interfaces

There are two kinds of interface box that connect the sensors to the computer. The first and least expensive provides a simple route from the sensor to the computer and allows you to display results 'live'.

The second kind, a data logger, has additional recording and storage facilities. It can store readings from events taking days or weeks to unfold. Afterwards, the computer can read the data from it. These stand alone devices can often record data at high speed – for example they can record the flicker of a lamp and take 100's of readings in a second. The data logger has buttons to start and stop recording as well as an independent power supply. The buttons allow you to alter the recording speed or say when the recording should start. The data logger may have an LCD display to monitor what it is doing. When you leave a data logger to record it compresses the data. At each doubling of the recording time (e.g. 4s, 8s, 16s) it discards half the data. A computer is nearly always essential if you want to analyse the data. If specifications vary even the lowest spec is powerful enough for most uses.

	Data logger A	Data logger B	Data logger C	Interface D
Special feature	LCD meter	-	LCD meter	Plug and play - USB
How much it stores	104,000 readings	32,000 readings	4500 readings	50,000
How fast it records	14,000 / sec	10 / sec	500 / sec	1000 / sec
Battery	Alkaline - 180 hour life. Data protected by silver cell.	NiCd rechargeable and unpredictable. Data lost with charge.	NiMH rechargeable and unpredictable. Safe memory NVRAM	Alkaline or Computer powered Safe memory
Resolution	10 bit	10 bit	10 bit	10 bit

How the parts work together

In nearly every system you can find, data logging sensors plug into a box. The sensor sends its 'readings' to the box and informs it which type of sensor it is. The sensor identifies itself using pins on the sensor plug – some systems place a resistor across the pins and use its value to identify it. Other sensors have a PIC chip which 'tells' the data logger all it needs to know. If you ever find a sensor identified incorrectly, it may be because the batteries are running low.

Some sensors have their own power supply but the best derive all their power via the interface. The latter is many times easier to manage. Some devices get all their power through a USB connection and these tend to be the most reliable.

The interface box has a circuit that converts an analogue sensor signal to a digital signal. It also has a way of communicating with the computer and most systems use 'serial' communication. Serial connections are compatible with almost every type of computer. While this is not fast communication, they transfer data fast enough for most purposes. If you want to show sound waves with these data loggers, you would record the sound at high speed and transfer the data to the computer afterwards.

You will find systems can record so fast that you can use the computer as an oscilloscope. These breathtaking tools replace the connection with fast USB connections. These are no longer expensive.

Data logging interfaces

"Every push button on a machine gives you an opportunity to press it when you shouldn't!".
Here is a list of data logging features with a commentary. As with all technology, you have to keep the features in perspective as they affect the ease of use.

Feature	**Comment**	**Score**
Interface has an LCD meter display	Display is very reassuring and good for taking 'single' readings in class and on field work	
Interface needs a computer to collect its data	Students can see graphs appear in 'real-time'	
Interface has an LCD meter and graph display	Graph display is very reassuring for long experiments and field work	
System has a meter, display and analysis features.	Does not need additional computers. An all-in solution – you're pretty much there.	
Data logger can collect readings independently of the computer.	Good for long experiments and field work. You may only need one of these.	
Data logger allows results collected in the lab to be downloaded in the ICT room	Queuing and printing bottlenecks likely. Would it be useful to see this data live and 'as it happens'?	
Data logger allows results collected in the lab to be downloaded to the lab computer	Queuing and printing bottlenecks likely. OK for occasional use	
Data logger has a rechargeable battery	An important cost consideration. Good feature for often used equipment	
Interface uses a Mains adapter	Clumsy in use, though this may be tolerable. Does the ICT room has spare power sockets?	
Data logger uses Alkaline batteries	Running costs may be tolerable. Tend to discharge in storage	
Data logger records very fast	A nice but niche use. You may want just one of these	
Data logger can be set to start recording during the night	It may be easier to start recording now!	
Data logger can be set to start recording at a certain sensor reading	For capturing fast events. Software on the computer can do this for you	
Data logger can store the results of many experiments	Value depends on how secure the data is. Still a niche feature	
Allows the number of readings and interval between readings to be customised.	Used mainly for fast recording. Less essential for long term recording	
Interface is USB powered	Very reliable, plug and play system	
Data logger time and date stamps collected data	Great aide-memoir for field work	

A list of most of the best datalogging ideas

Teaching about motion
Exploring pendulum swings
Current & voltage
Teaching about acids 83
Pendulum and oscillator
Exploring pendulum swings
Electricity – best battery for the job
Cooling coffee
Heat - day and night graph story
Cooling and size - Goldilocks story
Freezing and melting
Heat - keeping warm
Gas laws - pressure
Gas laws - pressure and volume
Radiation – sand / water and climate
Thermostats – monitor a refrigerator
Acids - heat of neutralisation
Evaporation data analysis
Latent heat - cooling curves
Latent heat - heating ice
Reactions - plaster of Paris
Rate of reaction - temperature
Fermentation of cut grass
Photosynthesis - aquarium
Transpiration
Radiation – best colour
Noise and sound waves
Motion - velocity in free fall
Motion - force, mass & acceleration
Pendulum - potential
Radiation - heat absorption
Stopping sound
Sound investigations - hearing
Electricity - lead acid accumulator
Endothermic reactions
Evaporation - make a drink cool
Exercise - blankets and athletes
Freezing - energetics
Fuels - combustion of alcohol
Order of reaction
Rate of reaction - iodate
Rate of reaction - concentration
Make hands the warmest
Temperature regulation
Hand response to hot and cold
Homeostasis - perspiration
Food - measuring energy

A list of most of the best datalogging ideas

Motion - measuring speed
Motion - distance - time graphs
Motion - reaction time
Motion - changing speed
Motion - momentum
Electricity - current and voltage
Electricity - current surge
Electricity - battery power
Electricity - AC ripple
Electricity - a capacitor.
Electricity - LDR and voltage:
Electricity - induction in a coil
Cooling and size - big and small
Do large animals stay warmer?
Do babies become cold easily?
Cooling and survival - a variation
Heat - more ideas
Cooling- hot things cool
Heat - insulation materials
More insulation experiments
Heat - using a heat loss sensor
Heat - central heating
Gas laws -
Gas laws – using a bicycle pump
Gas Laws / Radiation
Sound waves and phase - demo
Speed of Sound
Acids - multi-protic acids
Acids - alkali and acid
Acids - stomach acid
Corrosion - salt and steel
Endothermic reactions
Evaporation - teaching
Evaporation - ceiling fans
Freezing point- teaching
Freezing
Latent heat of the earth
Fuels - yellow and blue flames
Fuels - candle burning
Radioactive decay – half life
Rate of reaction - methods
Rate of reaction – a match
Rate of reaction - temperature
Enzymes - lipase and emulsifier
Enzymes - pepsin & peroxidase
Enzymes - amylase activity
Exercise - pulse and breathing

A list of most of the best datalogging ideas

Exercise - pulse
Using a spirometer
Exercise - skin temperature
Fermentation - methods
Fermentation - grass cuttings
Fermentation - bread dough
Photosynthesis – by measuring pH
The greenhouse effect
Respiration or Germination
Respiration - oxygen in air
Osmotic pressure
Transpiration – pressure

Find these ideas detailed in Roger Frost's other data logging booklets

A list of most of the best datalogging ideas