# Teachers' strategies for making effective use of datalogging

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Four case studies from a wider research project illustrate experienced practitioners' strategies for using datalogging technology to support teaching and learning in secondary whole-class settings

Recording and handling experimental data through use of sensing equipment is part of the National Curriculum for England and use of datalogging systems is widespread in secondary school science departments. In a review of the impact of government initiatives relating to information and communication technology (ICT) in schools, Ofsted (2004) asserted that its use in science teaching and learning enables *'a higher level of analysis to take place than would otherwise be the case'*. The contribution of datalogging systems is highlighted as allowing pupils *'to focus more quickly on the graphical results of their science experiments'* (p. 41). However, while the potential benefits of the technology in supporting pupil investigations are widely recognised (Newton, 2000), teacher demonstration seems the most common mode of use (Rogers and Finlayson, 2003). The role of the teacher is pivotal in determining how effectively ICT is used to enrich science teaching and learning (Osborne and Hennessy, 2003). Identifying and understanding the strategies that underlie successful practice is central to the contemporary quest for well-informed approaches to effective applications in the curriculum (Becta, 2003). In this article we present four case studies to illustrate how experienced practitioners are supporting learning using datalogging systems within their classroom settings.

**ABSTRACT**
This article reports on findings from the ESRC-funded SET-IT project, which investigated how experienced secondary science teachers in England are integrating ICT into their classroom practice. Data are drawn from ten focus-group interviews and four detailed case studies in three schools. Examples illustrate how teachers blended use of datalogging with other activities and harnessed its features to encourage pupil participation and collaborative knowledge-building in whole-class settings. Successful strategies included use of prediction and joint interpretation of outcomes to address pupils' conceptions and build the 'scientific story'. Practical approaches to managing the use of the technology are also suggested.

## The SET-IT project (2002–04)

This project investigated successful pedagogical approaches incorporating ICT in secondary science teaching. First, drawing on multiple recommendations, we identified ten science departments considered to be successful in terms of the quality both of the education that they provided, and of their integration of ICT into classroom practice. All of the schools were state-funded with specialist status and three were technology colleges. Group interviews were conducted with teachers in each department to find out what they regarded as particularly successful classroom uses of ICT, and to identify practitioners who articulated a well-developed pedagogy for using these technologies. Datalogging systems were one of the three applications most commonly mentioned. (The others were multimedia simulations and interactive whiteboards; findings relating to these are reported elsewhere.)

We invited four teachers to help us gain insight into their practice with the technology and observed two lessons in each case (on the same or similar topics with different classes). After each session we interviewed the teachers about their pedagogical strategies supporting the use of ICT. We also asked a group of six pupils to comment on which aspects of the lesson they had, or had not, found helpful to their learning. Details of lesson topics and pupil groups

**Table 1** Case study details. (Year 9 = 13/14 year-olds; year 10 = 14/15 year-olds.)

| *Teacher/ school* | *Science topic* | *Obs 1 pupil group/set* | *ICT resources* | *Obs 2 pupil group/set* | *ICT resources* |
|---|---|---|---|---|---|
| D/G | Earth materials: igneous rock formation | year 10 middle | Temp. probes linked to laptop computer; projected onto ordinary whiteboard | year 10 higher | Projected cartoon animation; temp. probes linked to laptop computer; projected onto ordinary whiteboard |
| E/G | Heat transfer via radiation | year 10 higher | Temp. probes linked to laptop computer | year 10 middle | Temp. probes linked to laptop computer, display projected onto classroom wall |
| J/K | Heat transfer via radiation | year 10 middle | Temp. probes linked to laptop computer | | |
| J/K | Speed/time graphs and acceleration | | | year 10 lower | Motion sensor linked to laptop computer, projected onto ordinary whiteboard |
| K/D | Interpreting distance/time graphs | year 9 upper | Motion sensor linked to graphical calculator displayed via OHP. Projected terminal velocity simulation | year 9 higher | Motion sensor linked to graphical calculator displayed via OHP. Projected terminal velocity simulation |

are shown in Table 1. Data were analysed within and across cases, drawing on lesson plans, schemes of work, lesson observations and transcribed interviews.

## Perceived benefits of automated data collection, graph production and display

The advantages of using datalogging systems put forward by the teachers in our focus groups corroborated those reported in previous studies (e.g. Rogers and Finlayson, 2003). Use of the technology was perceived as enabling:

- pupils' attention to be focused on the 'underlying science' through alleviating laborious data collection and graph production (especially beneficial for lower-attaining groups);
- pupils to conceptualise more easily by watching dynamic plotting of results in real time;
- procedures to be monitored, adjusted and re-run;
- accurate data to be provided for further analysis;
- time to be released for additional activities;
- 'dry' areas of syllabus to be enlivened.

Additionally, teachers felt that using the technology encouraged pupils to remain on task: *'Having something on screen acts as a magnet and helps them focus on their work'*. Class sets of equipment were available in two of the three departments represented in our case studies, but the majority of datalogging routines nominated as particularly successful were teacher-led. Observed lessons involved pupils in two such types of activity: (a) interpreting cooling curves during studies of energy or earth materials, and (b) interpreting and emulating distance–time graphs in lessons on motion. There were, however, some distinctive ways in which teachers incorporated the technology; these are characterised in the four cases summarised below.

## Case 1 (Teacher D)

Both of D's observed lessons on earth materials were designed to *'revise and reinforce'* an earlier topic, and help pupils to *'realise how cooling of lava affects the crystal size in igneous rocks'*. Activities included a teacher demonstration using temperature sensors to log the cooling of melted Salol (a) in ice and (b) at room temperature. A parallel pupil practical (without use of technology) involved cooling the substance under similar conditions and comparing sizes of resultant crystals. In one lesson pupils also inspected rock samples of granite and basalt; in the other, a projected cartoon clip was used to introduce the topic. In both lessons D led a plenary discussion of results, and pupils wrote up their findings.

D chose to use the technology so pupils could *'see the scientific point much more quickly'* and because it added *'another dimension'* that lent interest to the topic:

> *Otherwise you'd have to … take the temperature every minute, and that's quite a long laborious process. Whereas you can actually get on with this; it's a smaller practical that they can see and get instant results from, while this practical is going on in the background, and actually bringing them together at the very end.*

Overseeing class practical work alongside the demonstration created some conflicting demands on D's attention but producing model results was a priority:

> *As long as at the end of the day they know 'Oh this is what happens in this situation,' … then you've succeeded.*

Projecting the output onto a whiteboard aided visibility and enabled D to annotate and extrapolate the cooling curves during the plenary discussion:

> *It's important when you bring it together they can all see the board, and the brilliant bit about using the projector is you can actually write on the board as well and annotate your graph as you go along.*

Although D expected pupils to be able to identify features of the graph (graphing skills were taught in the department from year 7), ensuring that pupils noticed the relative melting points was critical to their appreciation of the results:

> *The point at which it gets the melting point, that has to be explicit ... drawing their attention to that was actually quite important.*

Pupils confirmed that watching the cooling curves being plotted in real time had helped them to grasp the relationship between cooling conditions and the different crystal sizes they had observed:

> *A moving graph was good. It wasn't just a graph and as he pointed at it you could see it happening … so you saw it actually going down and it cleared that point.*

Illustrative practical work was blended with teacher use of datalogging so as to lead pupils inductively towards an understanding of the physical process.

## Case 2 (Teacher E)

E's two observed lessons on radiation were part of a module on energy, and followed lessons on conduction and convection. Subsequent lessons were to cover different types of renewable energies – including a focus on solar energy. E used temperature sensors to log cooling curves from the surfaces of a Leslie's cube; her aims were for *'pupils to recognise that different colours radiate different amounts of heat, predict the shape of a cooling curve, use scientific knowledge to explain how they reached their conclusions and use ICT to ease the process of gathering data in an accurate way.'*

Her strategies for supporting learning with technology included: building on previous work, *'going in at a level they can comprehend'*, relating the topic to everyday examples and presenting the activity in stages. Prior to the lessons, E collected readings from two sides of the cube; printouts were provided and pupils invited to predict curves for the remaining two sides:

> *… at first it was her experiment that she did earlier and then we got to talk about it, and then we got to do the other experiment and then we got to write about it, rather than doing it all in just one big chunk and then writing about it.* (P)

She harnessed the visual affordances (perceived benefits) of the technology to support individuals' cognitive engagement with the activity and to aid their conceptual understanding:

> *They can see it visually. The top set can grasp concepts that you're talking about verbally and can actually imagine it, whereas there are some people in the group today who need to see an image to be able to talk about it.*

Pupils reported that *'seeing it happening'* was particularly helpful – *'much better than Ms E telling us about it'*. E's strategies further exploited real-time graph plotting by requiring pupils to *'think about their predictions of what's going to happen and drawing their conclusion from what they can see'*. She highlighted inconsistency between pupils' predictions and the data by building on related informal conceptions (using cooking foil as an example) and reconciling these with the scientific view. Again, pupils confirmed that prediction (and subsequent reflection upon the outcome) had helped to focus their thinking successfully:

> *It's good that we actually had to draw down the prediction because otherwise you kind of, you don't really think about it when she asks you ... You have to think about it.*

E facilitated learning through a 'dialogic' style of interaction which recognised and built upon pupils' existing understandings to formulate joint understanding (Mortimer and Scott, 2003), using the output display as an object of joint reference.

Although E regretted that pupils were unable to conduct the practical work themselves, she judged that the work would have taken much longer and *'they wouldn't have been able to do the conclusion, the evaluation, the questions and the preparation task for next week'*. Time saved enabled E to assess pupils' progress informally *'just by going round and talking to them'* and to help pupils to consolidate and apply their developing knowledge by discussing the possible rationale for using black radiators.

## Case 3 (Teacher J)

This case study comprised two lesson observations on different topics: 'Energy in the home' and 'Moving around'.

### Lesson 1

The main lesson objective was for pupils to understand heat transfer due to radiation. J used question and answer to recap on conduction and convection before introducing radiation. The lesson then concentrated on *'what radiation was, and what things emitted it, and what factors affected how much was emitted'*. Demonstrations included: investigating the effect of heat on ball bearings using the Griffin (Kinetic Theory Model) machine; use of temperature sensors to measure heat loss from black/silver-coated flasks; comparison of heat radiation from black and silver irons; and examination of whether dull black or shiny silver discs absorbed more radiation. Activities were interspersed with whole-class discussion on thermal-radiation waves and the effect of surface colour on their absorption. Pupils recorded conclusions by copying key facts/diagrams from the board, and then (with peer assistance) completed 'fill-the-gap' worksheets on radiation, while J circulated before going through the answers with the class. J drew on many everyday examples during the lesson and at the close he linked ideas together by presenting the thermos flask as an example of the three types of heat transfer:

> *It gives them something tangible that they can see and analyse, and see the actual science behind it … to get them to think about practical applications of it, rather than just the concept itself in isolation.*

Use of datalogging allowed graphs to be generated while the lesson continued. Simultaneous readings at regular intervals accentuated the differential between the curves over the same time frame. J reported that this use of technology enabled him to focus pupil attention on conceptual, rather than executive, aspects of the activity:

> *I wasn't trying to test their ability to draw graphs, I was trying to test their ability to understand the concept involved with the transfer of the heat, and the reduction in the rate at which the heat was lost … so they could see that one cooled down at a different rate compared to the other.*

He was careful to explain how data were being generated and demonstrated the temperature probe by holding it in the palm of his hand whilst pupils watched the trace appear on screen – providing *'concrete evidence that it is acting on the heat of the hand'*.

J promoted knowledge building by challenging pupils with questions that raised uncertainty such as *'whether the surface, the colour of something, could affect how much radiation it gives off'*. He then capitalised on the slow pace of real-time results to reiterate salient points and engage pupils in *'thinking about what was happening'*:

> *I was trying to emphasise the fact that they were looking for one to drop more quickly than another, and it … took 10 minutes for that to happen. So, it made the point quite relevant really, because we kept coming back to it ...*

Use of technology was integrated with other lesson activities to provide insight into the phenomena in question. (The strategy of provoking and addressing conflict between pupils' prior conceptions and observed phenomena used by both E and J is in keeping with Doise and Mugny's (1984) work which suggests that group-generated conflict stimulates the joint construction of a more advanced concept, which is then individually internalised.)

### Lesson 2

Previous lessons with this group had covered distance–time graphs and the objective for this session was for pupils to understand the difference between speed and acceleration (as change in speed/time). J began the lesson with a review of distance–time graphs, using a motion sensor with pupils emulating graphs drawn on the board. Pupils then worked in groups using ticker-tape timers to produce samples of constant speed and acceleration. Distance travelled was calculated using segments of tape stuck onto graph axes. Finally, J led a whole-class activity working out distance travelled by calculating the area under the graph.

He considered that use of the datalogger made it *'much easier to see trends and patterns'* and enabled him to *'move on much more quickly and cement the ideas'*. J encouraged participation by inviting a pupil to draw a distance–time graph on the board and to choose a peer to emulate it while his/her movement was monitored by a motion sensor:

> *If I draw it I'm asking them to do something. But if somebody else draws it … because quite often you don't get volunteers to come up and do it – so getting one of the pupils and saying, 'Right, you pick somebody to try and get that graph on the datalogger'*. (J)

J viewed this type of engagement as making the activity more memorable for pupils and they appreciated being involved in this way:

> *He made us join in so you could understand it a bit more*. (P)

> *When you're looking at somebody else doing it then you are wondering what's going to happen*. (P)

J helped pupils to relate to the technology by providing information about the output scale and units (i.e. '0.1' referred to 0.1 metre/10 centimetres) and by explaining how ultrasound is used in applications such as vehicle-reverse warning systems and the measuring devices used by estate agents. Later on he prompted pupils to make connections between their work with the ticker tape and the motion sensor:

J: *So a flat line on a speed-time graph – what do you think it'll mean?*
All: *Constant speed…*
J: *What did the flat line on a distance–time graph tell us?*
P: *You weren't moving*.

Through the juxtaposition of the two activities J felt that pupils had been able to *'see for themselves'* and *'build up ideas'* which were then consolidated and applied during the plenary discussion.

## Case 4 (Teacher K)

The objectives of K's lessons were to consolidate work with distance–time graphs and then to build pupils' understanding of how forces affect motion. By involving pupils in physical emulation of given graphs (as in Case 3), he aimed for them to visualise *'what a distance–time graph actually means in the real world'*. Like J, K explained the operation of the motion sensor *'to give the kids a quick insight into what it is that's physically happening… to talk to them a little bit about the ultrasound and the echoes so they had some perception of what was going on there'*.

Strategic questioning and a brisk pace were considered to be critical factors in pupils' engagement:

> *I get concepts flying around quicker ... sometimes it's good to plan something that's, you know, fun and rapid and interactive*.

He also believed that physical and verbal involvement (aided by immediate feedback) helped pupils to conceptualise; the process began with them hypothesising about the motion their classmate needed to generate in order to match the graph (Figure 1):

P: *She's got to go back ... then stop for a few seconds then go forward.*
K: *And what can you tell me about the speeds…?*
P: *She's got to be steady.*
P: *She's going forwards slower than she would go backwards.*

K described how learning took place as pupils became further involved in the activity:

> *Initially there's ... a lack of confidence to put ideas forward. And then, given a couple of students and a couple of goes at it, then literally everyone is shouting out, you know, 'Stand there, go forwards, go faster!' and whatever ... it's there that you really see the learning happening*.

He facilitated onlookers' 'vicarious' involvement by encouraging them to monitor and direct the actions of their peers:

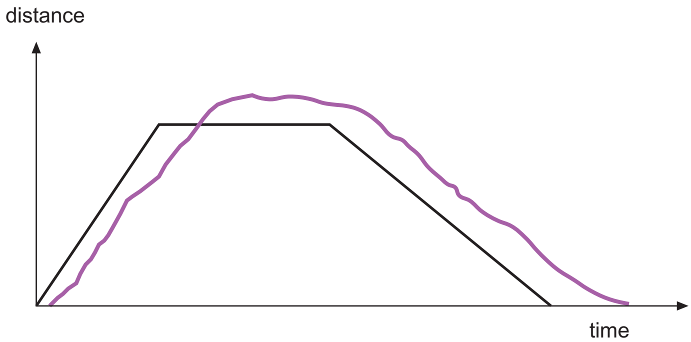


**Figure 1** Distance–time graph tracing a pupil's motion beside a pattern he/she tried to emulate

> *I needed to make sure that it wasn't the student who was moving backwards and forwards who was doing all the thinking. I needed to make it a bit of a discourse between the kids and the kid who's having a go to make sure they are all thinking … contributing and putting in their views.*

Feedback from pupils indicated that this approach was successful:

> *He got volunteers out to do stuff, to show us … instead of just getting it up on the board … he actually got people to do it so that you could like actually see it happening.*

> *If somebody you know's done it, then you're more likely to remember it happened … whereas if it was the teacher doing it ... I wouldn't watch as much as I did if I saw like one of my friends up there.*

The motion sensor activity was followed by a demonstration (using a simple animation) where K assessed pupils' understanding by inviting them to predict the line graph for a car moving at constant speed:

> *Although it seemed like a similar task, it's a bit of a cognitive switch round, and I was giving them the motion and asking for the graph rather than the graph and asking for the motion. So I wanted to do that just to see … if they had conceptualised the ideas and could apply them to a slightly different context.*

The lesson continued with a whole-class discussion of terminal velocity using a simulation and concluded with a plenary quiz. Pupils wrote down answers on individual whiteboards. K checked answers with the whole group after each question.

## Supporting learning with the technology

Teaching approaches and contexts differed across cases, but several common themes emerged from our analysis. All the teachers designed lessons to *exploit the dynamic visual representation* offered by the technology in order to make concepts more salient, accessible and memorable to pupils. Presenting information in a graphical form has been described as *'the cornerstone of our attempts to link data obtained during practical work with the abstract ideas and concepts of science'* (Barton, 2004: 32). Use of the technology for real-time datalogging enabled these links to be made more immediately and allowed teachers to *focus attention on underlying concepts and relationships*.

Although demonstration was the predominant mode of use, teachers created opportunities for learning through encouraging pupils' *collaborative involvement*. For example, they facilitated pupils' cognitive engagement through *dialogic interaction* and use of *prediction* to capture interest and focus on outcomes. The visual display was used as an object of joint reference to stimulate *whole-class discussion* of results. This enabled teachers to build on pupils' related informal conceptions and to reconcile these with the scientific view – talking into existence the 'scientific story' (Ogborn *et al*., 1996).

Datalogging was integrated with complementary practical and written activities so as to provide *additional perspectives* and support *sequential knowledge building*. At the same time, teachers were concerned that pupils should appreciate technology-mediated processes and products and their wider *application outside the classroom*.

The balance of lesson activities was configured and managed to suit particular groups. Whilst individual teachers did not vary their operational use of the technology for different groups studying the same topic, they tended towards broader treatment of topics and more discussion of abstract ideas with higher-achieving groups.

## Managing use of the technology

All the teachers considered that familiarity with the equipment and knowing how to deal with technical hitches was essential, but it was also recognised that developing confidence in operating the technology and managing activities in a class situation took time and training:

> *A lot of teachers aren't trained how to use dataloggers. And it takes a lot of time, a lot of expertise, to be comfortable with them, to take it in front and present it to a group of 30 kids.* (K)

Practical expertise was not always transferable between available systems:

> *You cannot say 'Oh I've used dataloggers before'. You really have to play around with them and not just get it working. You've got to think and literally go through everything you're going to do with the kids before you do it in front of them because they can be temperamental.* (J)

Thorough preparation was emphasised as key to using the technology successfully:

> *Having the package up and running and waiting to be used – because when it goes wrong, your attention is focused on the computer and the class drift.* (D)

This included booking equipment and testing systems before the lesson (e.g. setting appropriate sampling rates and output scales) and having contingency plans (e.g. back-up data or, when working with class sets, being ready to reorganise groups if one of the dataloggers 'goes down'). Use of a data projector to ensure visibility was recommended, though not always available. Instilling in pupils (and staff) a careful approach to handling and storing equipment was important too (e.g. checking that control boxes were switched off after use to preserve batteries and packing sets individually). The assistance of support staff with operational knowledge of the technology was considered invaluable.

Rehearsing procedures helped both to pre-empt problems and to capitalise on learning points. For instance, in D's cooling curve demonstration:

> *I knew the cold one would go up because of the energy involved in the crystallisation, so knowing that would happen is also a benefit of actually running through it before … so nothing there is unexpected.*

Similarly, K knew that movement within too close a range of the motion sensor would produce anomalous readings, so he set a starting boundary. He also encouraged pupils to *'think more widely'* by explaining how *'the realities of moving'* were reflected in the output graph:

> *When we walk … we're not really moving at a constant speed, and even when we think we're standing still … it's rare that the line will be absolutely flat-lining. So I needed to explain that to them and try and get them to keep the target part of their body as stationary as possible.*

Teachers believed that pupils needed to be familiar with the technology and understand its limitations in order to *'see through the technical aspects … to the experiment'*. For this reason, in K's department, dedicated lesson time was invested in training pupils in the use of datalogging equipment early on. All the teachers recognised that pupils could accept computer-generated results too readily. Requiring them to predict outcomes was one way of encouraging more careful observation:

> *So if for instance we were doing the cooling curve, something's gone wrong and they get spurious data, they need to realise that isn't what they were expecting.* (K)

Dataloggers were deployed in different modes according to the perceived level of teacher support needed in interpreting the display:

> *Now if I had 15 motion sensors and they were doing it in pairs it would be a very difficult job for me to run round to each of them and interpret each of their graphs and talk them through it, so ... it's good to do it as a whole-class exercise. Other examples ... like the traditional cooling curve experiment, then it does give a more reliable smooth line and they should be able to interpret it themselves.* (K)

Nevertheless, across cases, the desired hands-on pupil use of dataloggers was often constrained by lack of available equipment or the amount of set-up time needed. Demonstration provided a way round these issues and, as both D and J pointed out, it also enabled procedures to be 'fiddled' if necessary to provide optimum results.

## Conclusion

In the contexts we observed, practitioners were integrating use of datalogging systems strategically with other resources and practical activities to support key facets of science teaching, such as dealing with abstract ideas and concepts, visualising dynamic interactions, and looking for the relationship between variables. Through skilful orchestration of activity and discourse (Scott and Jewitt, 2003) the technology was being harnessed in these whole-class settings not only as a data-gathering tool but also as a powerful, visual, explanatory resource or *'tool to bring something to life'* (E). Indeed, the teachers' role emerged as crucial in mediating this use of the technology and engaging pupils' thinking with the underlying science.

**Acknowledgements**

We are grateful to the participating teachers for sharing their expertise, to Theresa Daly for vital secretarial assistance and to Dr Laurence Rogers for his helpful comments in relation to this article. The *Eliciting Situated Expertise in ICT-integrated Mathematics and Science Teaching* project (2002/04) was funded by the Economic and Social Research Council (award ref: R000239823).

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**Further information**

The SET-IT project report and links to published articles arising from the research are available at: http://www.educ.cam.ac.uk/istl/pub.html

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