Gathering Data: does it make sense?

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ABSTRACT Much laboratory work in school science involves observation and measurement; an important development, in recent years, has been the application of computers to this activity. Data-logging techniques have been available to science teachers for some time (outside the United Kingdom [UK], this technology is sometimes known as microcomputer-based laboratories or MBL). It is only relatively recently, however, that data-logging technology has become sufficiently user-friendly and affordable for it to be more widely adopted. The use of sensors, interfaces and data-loggers to capture and record data, and its subsequent display and analysis using computer software, now constitute a realistic alternative to traditional approaches. With the National Curriculum for initial teacher training including information and communications technology now in place in the UK, the time seems opportune to take stock of current use of data-logging methods and to consider how they might be further developed. This article describes how data-logging currently appears to be used in science lessons. It considers how the demands of the National Curriculum have shaped current practice, and argues for a shift of emphasis in the pupils’ role in data-logging activities. Some suggestions are then offered for encouraging pupils to engage in more interpretative activity, which recent software readily supports.

Data-logging Because We Have To

In the past, the movement to incorporate data-logging methods into science teaching has, to a large extent, been driven by enthusiasts; but the 1995 revision of the science National Curriculum Orders in England and Wales, made the use of information technology (IT) statutory.

As a core National Curriculum subject, occupying a significant proportion of curriculum time, science is uniquely placed to contribute to the development of pupils' capabilities in information and communications technology (ICT). Science can provide real-life contexts in which to develop these capabilities, and which reflect the growing use of data-logging technology in research and industry.
At the time of going to press, there is debate about the distinction between the terms IT and ICT. However, in National Curriculum science, IT is envisaged as supporting pupils in their systematic enquiry of the subject. As pupils progress through their secondary education, there is a move towards the expected use of IT to support pupils’ study. For pupils aged from 11 to 14 years (known in the United Kingdom [UK] as ‘Key Stage 3’), emphasis is placed on pupils’ use of IT “... to collect, store, retrieve and present scientific information” (Department for Education [DFE]/Welsh Office, 1995a, p. 14). However, for 14 to 16 year-old pupils (in Key Stage 4), there is an apparent shift in emphasis because pupils should be given opportunities to “collect, handle and investigate scientific information” (DFE/Welsh Office, 1995a, p. 24, author’s emphasis).

Advice on science and IT at Key Stage 3 from the School Curriculum and Assessment Authority (SCAA), indicates that manipulation and interpretation of data can be supported by IT (SCAA/Curriculum and Assessment Authority for Wales, 1995). Various case studies are offered in this advice, which illustrate how IT can be used to support pupils’ learning in science and develop their IT capability. The case studies reflect the range of potential opportunities for the use of ICT which the science curriculum affords. They also imply a broader view of the kinds of IT activities which pupils may experience in science than is apparently required by the science National Curriculum Orders for Key Stage 3.

However, in relation to the use of IT generally, there appears to be a gap between potential and practice in many schools. The Chief Inspector’s most recent Annual Report on standards and quality in education (Office for Standards in Education [OFSTED], 1998) states that:

Half of schools fail to comply with statutory requirements. In these schools, progress is often unsatisfactory in important aspects of the subject, such as modelling and higher-order aspects of data handling and control. Progress is better in Key Stage 3 than Key Stage 4, where many pupils do not follow the programme of study ... (p. 34)

This statement reveals an expectation that pupils’ skills in the use of IT for “higher-order” data handling are being developed at Key Stage 3 and Key Stage 4. As a core subject, science is well placed to make a significant contribution to developing these IT skill areas. Yet the need to use IT is not so strongly stressed in the science National Curriculum Orders; the role of IT is perhaps concealed in the detailed content of the Orders. This lack of emphasis may be reflected in the above quotation from the Chief Inspector’s report. However, when one examines the National Curriculum Orders for IT at Key Stages 3 and 4, one is offered a clearer insight into the kinds of processes where science activities could both contribute to and benefit from pupils developing IT capability.

In the case of data-logging in science for example, there are opportunities for pupils to use IT for measuring and recording physical
variables, to display information graphically, and to interpret and analyse data. Each of these processes features in the Key Stage 3 programme of study for IT (DFE/Welsh Office, 1995b). Moreover, these processes can support pupils’ capabilities in some of the more demanding aspects of Experimental and Investigative Science required at Key Stage 3 and Key Stage 4. For example, those aspects of the IT Orders concerned with checking the accuracy of information and questioning its plausibility match well with science skills of evaluating evidence.

Despite the demands of the National Curriculum, there is clearly a gap between policy and practice relating to IT in science teaching in some schools. Whilst OFSTED has identified the gap, their reports offer neither comments on factors which may contribute to the present situation, nor advice on how these might be positively addressed.

Data-logging Because We Want To

There are cogent arguments for making greater use of IT in teaching, many of which are supported by a growing body of research evidence. In the UK, for example, Brown & Howlett (1994) have described some of the educational benefits which can be attributed to IT generally. Other contributions to the debate have sought to encourage use of ICT from a single discipline perspective (Newton, 1997a). Research into the impact of computer-based learning in science education, particularly from a North American perspective, has been reviewed by Nakhleh (1994) and more recently by Weller (1996). Some of the research Weller cites indicates that data-logging methods (or microcomputer-based laboratories [MBL]) can offer genuinely scientific experiences to pupils. Furthermore, data-logging can contribute to pupils’ skills in scientific inquiry and add to their understanding and interpretation of graphically presented information.

There has also been some consideration of the particular case of data-logging methods and the reasons for the relatively slow development of its use in British schools (Barton, 1993). In addition, Barton (1997a) has described some of the teaching and learning opportunities which become available when data-logging is used in practical science; for example, the opportunity to extend data collection because of the speed at which it can be gathered and the potential for pupils to engage in discussion about their data. Other research suggests that there are potential gains in the type and quality of data that pupils can access using data-logging technologies (Rogers & Wild, 1996). Developments in data-logging software enable pupils to explore data in new ways that can support science investigations (Rogers, 1997). There is research evidence of the contribution computer-generated graphs of data can make to pupils’ appreciation of the meaning in the data and of the advantages of computer-drawn graphs over manual ‘pencil and paper’ methods (Barton, 1997a).
Outside the UK, recently reported findings from the Technology-Enhanced Secondary Science Instruction project (TESSI), which included an MBL activity, have indicated that pupils show enhanced metacognition in IT-rich settings (Pedretti et al., 1998). In the TESSI project, where a wide range of technology was fully integrated with carefully thought-out teaching approaches, it was found that the pupils began to work in more independent ways. The pupils attached a high value to these new ways of working, but interestingly, the authors note that in determining the impact of the technology on the pupils’ experience: “…the pedagogical and social milieu of a technologically-rich classroom is every bit as influential as the technology itself” (p. 586).

What seems to emerge from this evidence is that there are significant benefits to be gained from greater use of data-logging in science teaching. When one adds to these factors the enthusiasm pupils frequently display for using IT, the case for wider use of data-logging methods seems compelling. However, it appears that many pupil activities in science have yet to fully exploit these opportunities. The rest of this article considers some of these benefits further, in order to identify teaching approaches which can help pupils profit from them more fully.

Data-logging in Practice

Clearly, the availability of IT resources will influence the scope of data-logging activities in science lessons. However, resolving problems of equipment levels will not necessarily lead to better use of IT. The ImpacT Report of 1993 identified teacher experience as an important factor in realising the potential benefits of IT to learning (Watson, 1993) and experience suggests that this factor remains significant.

My research has focused on ‘routine’ use of data-logging in secondary science teaching. This research involved a small-scale observational study in four English secondary schools with pupils across the 11-18 age range, which took place between May 1997 and March 1998. At the time of the study, two of the schools had special status as ‘technology schools’ and as such were relatively well equipped with IT resources. For these schools, IT was a prominent institutional feature and figured routinely in their pupils’ experience. The other schools did not have specialist status but their science departments had accumulated data-logging equipment and established its use over time. Thus, across the four schools there were varied levels of IT resources but the use of data-logging methods was a customary feature of the science teaching.

Seven teachers with experience of using IT in science teaching were involved in the study. Each teacher had expressed an interest in the research and a willingness for their lessons to be observed. Selection of the lessons for observation was at the teacher’s invitation. The lessons observed were
not especially arranged for the research but were part of each teacher’s planned teaching programme. As such, these data-logging episodes could be viewed as a part of the ‘real-world’ science learning classroom.

Approximately 56 hours of lesson time was observed, comprising of 35 separate lessons. In these lessons, pupils were given opportunities to gather data in a variety of experimental settings. Often, the main purpose of the lesson appeared to be the gathering of data. To the external observer, the emphasis on data gathering seems entirely appropriate – in some lessons. For novice users, for instance, there are operational skills to be learned in order to be able to collect data successfully using new technologies (Figure 1). These skills are additional to those required for the conventional management of laboratory apparatus and one should not underestimate the extra demands associated with them. For example, there is a need to develop pupils’ confidence in resolving technical difficulties which may occasionally arise with computer hardware or software.

![80mm](https://example.com/80mm)

Figure 1. Operational skills required in typical data-logging activities.

Initially, some operational choices may be made by teachers on their pupils’ behalf. However, as users become more expert in these operational aspects, one might expect to see development of other “higher-order” skills which data-logging software can support.

It seems legitimate to ask what value is added to pupils’ experience by the use of IT to collect experimental data. Of course, pupils’ IT capability is developed if they have experience of data-logging in science. The use of
sensors and software enables data to be collected rapidly and displayed graphically. It also allows collection of several sets of data if required.

But what role do the pupils have in these experiments? If the technology does the measuring, recording and display work which, in equivalent non-"T" experiments, would be done by the pupils, what do they do now?

In my lesson observations, this issue was not lost on teachers. Where pupils have used real-time data-logging, teachers have often encouraged pupils to use the ‘wait time’ for writing up their work. Now, there may be good reasons for this from the classroom management perspective - the devil makes work for idle hands, etc. ...! However, where teachers have felt comfortable not to structure pupil activity during the wait time, some pupils also seem to have mixed feelings about apparently ‘doing nothing’ (Newton, 1997b).

These findings suggest that teachers and pupils have yet to fully appreciate the new opportunities which IT-based experiments present. Furthermore, pupils and perhaps teachers need to develop a better understanding of how their roles in these new contexts differ from those in traditional practical work. If the benefits of data-logging methods are to be more fully realised, new ways need to be found of managing data-logging activities. Where obtaining the computer-presented graph seems to be the primary lesson objective; where pupils are distracted from experimental events by the need to ‘write up’; where time is not available for pupils to consider and explore their data, teachers seem to be operating in familiar and conventional ways. Although it may meet some of the National Curriculum requirements for IT, solely gathering data seems inadequate. New ways of working need to be found which enable teachers and pupils to exploit new technologies more fully. How this ambition might be achieved is considered further below.

**Why Gathering Data is Not Enough**

It is suggested above that data-logging activities in science need to do more than just extend pupils’ IT capability to collecting information. This assertion needs justification. On the face of it, emphasis on data collection appears to meet the requirements of the science Orders at Key Stage 3. However, in some important respects, using data-logging methods without careful consideration of what the pupils might do with the data, offers a poorer experience of practical science than traditional approaches where pupils are more involved in the data-gathering process.

In any learning activity, pupils need to engage in ‘minds-on’ work. One of the benefits of data-logging methods is that they can allow pupils to work more independently. However, the value of teacher interventions remains high in IT-based lessons. Barton (1997a; 1997b) has described how teacher
interventions can prompt pupils’ interpretations of computer-presented graphical data. This finding is of particular importance in the context of the training of future science teachers who will be required to utilise ICT in their subject teaching. Teachers employing data-logging techniques should be aware of the need to engage pupils in discussion about their data. Skilful questioning of the pupils by the teacher can, as Barton has shown, assist the pupils in their interpretations of data. However, even without the direct influence of the teacher, there appears to be a benefit in pupils attending to emerging graphs in real-time data-logging as has been argued elsewhere (Newton, 1997b).

So it seems that the richness of pupils’ experience is much enhanced by IT. Software presents the opportunity to explore data in ways that are impossible with ‘pencil and paper’ methods. The studies described above indicate that ways of using data-logging activities need to be developed which exploit those special qualities which can contribute to pupils’ understanding of experimental data.

**Doing IT Better**

As teachers’ confidence with IT has grown, so imaginative uses for data-logging methods have emerged. Computer methods have been applied to existing practical activities and new activities have been devised which were not possible using traditional approaches. The time has now come to shift greater attention towards developing effective pedagogies for IT.

When developing new methods for data-logging techniques, consideration also needs to be given to what the pupils’ role will be in the activity and what learning outcomes can be expected. Perhaps the most important question to be considered is why choose data-logging activities in the first place. The need to use data-logging when developing pupils’ operational IT skills is self-evident. Rogers & Wild (1996) have suggested some other potential benefits which may accrue from the data-logging approach. These authors proposed that the benefits arise from the intrinsic properties of IT. Furthermore, they suggested that the extent to which the benefits were delivered was heavily dependent on the context in which the technology was being used. Rogers & Wild imply that more consideration needs to be given to the context of application of the data-logging activity than to the procedural details.

The shift of emphasis in data-logging lessons argued for above does not necessarily call for the acquisition of new teaching skills. Rather, it calls for those skills which underpin good teaching (and which many science teachers possess in abundance) to be applied critically to the new ways of learning practical science. Thus, the argument is for pupils to do better data-logging, not necessarily more data-logging.

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The notion of critical selection of teaching approaches with IT features prominently in the UK Initial Teacher Training National Curriculum for the use of ICT in Subject Teaching (Department for Education and Employment, 1998). One of the implications of these requirements for data-logging will involve teachers having a greater understanding of intended learning outcomes for pupils. The point here is that science teachers should be as critical about choosing a data-logging activity as any other activity. Moreover, teachers should be confident to reject the IT option as inappropriate when necessary. How these choices can be informed is considered in the following section.

**What Constitutes a ‘Good’ Data-logging Activity?**

**Gathering or Analysing Data?**

When one considers the need to develop pupils’ skills in describing and interpreting experimental data, the use of software tools provides opportunities to explore the properties of data in novel ways (Rogers, 1997). If the lesson aim is to develop pupils’ analytical skills, then one quickly needs to get to this part of the activity. It is questionable whether the pupils need to collect their own data for analysis at all, although doing so may be desirable since pupils’ sense of ownership of the task may be heightened by the data-gathering process.

The gathered data is often the starting point for the exploratory and interpretative activity. Some examples of such software-supported activities and their demands on pupils are shown in Figure 2.

![Figure 2](image-url)
Recent developments in data-logging software enable pupils to readily engage in these activities because the software performs the necessary calculations for the pupils (for example, Insight 2 software). The advantage of such software is that the ease and rapidity with which these operations are performed affords pupils the opportunity to quickly test ideas and so develop their appreciation of the meaning in the data. In this sense, the pupils’ exploration of data is software-supported. It is noteworthy that these abilities and skills relate well to aspects of experimental and investigative science in the National Curriculum at both Key Stage 3 and Key Stage 4. Here is a good example of a practical way in which the use of data-logging can help pupils develop higher-order data-handling skills.

What other ingredients offer a fruitful mix in data-logging lessons? It seems likely that elements of general good practice will be as influential in promoting good data-logging as in any other activity. There seem however, to be some features of effective teaching which are particularly well supported in IT settings. Here, there is the prospect of IT contributing to positive learning environments because of the way it is used with pupils.

**Encouraging Interaction**

The way that teachers tend to organise pupils at the computer can encourage interaction between them. Limited availability of equipment frequently means that pupils work at the machine in small groups. Crook (1996) has discussed some interactions in relation to computers and their possible contribution to learning. Since the common focus for the pupils is the computer, this arrangement seems likely to encourage group interaction. The potential value of talk in the social construction of meanings has been explored by Mercer (1995). At the very least, this research suggests that teachers using data-logging should be actively encouraging their pupils to talk about what they are doing and finding. It is likely that the quality of the interaction will benefit from encouraging the pupils to talk about what they expect to do and to find before they begin their practical work.

In the observational study of data-logging activities referred to earlier, it was found that with pupils of ages 11 to 13 years, explicitly telling the pupils to talk about what they see on the computer screen prompted discussion and description of data. Pupils struggling to articulate what they see seems to focus attention on the data and raises the prospect of them ‘talking some meaning’ into it (Newton, 1997b).

**Giving Pupils Responsibility**

Finding ways of ensuring that pupils have an active role in the data-logging task also seems likely to heighten their interest. The teacher needs to give careful consideration to aspects of task design and its presentation to the
pupils. The design of the task could include the teacher defining roles for different team members so that they are all involved in contributing to the group activity. Perhaps one pupil might be responsible for making observations, whilst another monitors measurements gathered by the data-logging system. One might then encourage the pupils to share their observations and relate experimental events to those displayed on the computer screen. Alternatively, where the tasks are open in design, the pupils can assume greater responsibility for decision making. For example, the pupils could decide what to investigate, identify key variables, discuss what should be measured and how often, etc. These skills are at the heart of experimental science and pupils need practice in applying them and in justifying their decisions.

**Pupils Knowing Their Role**

If pupils are inexperienced in assuming responsibility in regular science lessons for identifying variables, deciding on measurements, etc., they are unlikely to manage it successfully in IT-based activities. Data-logging tasks tend to have greater scope than their non-IT equivalents because the rapidity of experimental cycles affords the opportunity to investigate multiple variables. In the technical complexity of a data-logging lesson, it is perhaps not always fully appreciated that the pupils’ role needs to be explained. Pupils’ own understanding of their role in lessons is determined by their past experiences. Teachers need to help pupils to understand this role better if the pupils are to make the most of their experiences in practical work. It also needs to be appreciated that teaching and learning are different activities. Pupils need to be set clear and understandable goals for lessons, and the pupils’ progress towards these goals needs to be monitored.

**Learning to Notice**

Pupils’ understanding of practical data-logging needs to be extended in another important respect. It is suggested above that pupils can become too focused on operational matters during data-logging tasks and too little focused on the data outcomes. Pupils need help to appreciate the ‘big picture’ in which their work is set. One way of addressing this problem is for the teacher to share with the pupils an overview of where the experiment is going. The teacher, hopefully, has the benefit of having ‘been here before’, but the pupil is probably entering uncharted territory. Pupils can be helped to navigate their way through the unknown if they are given clearer ‘landmarks’ along the way.

In practical work, pupils need support in identifying significant events and help in distinguishing the important from the unimportant. This need is
particularly strong in data-logging activities, where events move quickly and where pupils face a wealth of experimental information. A useful strategy to support pupils in their understanding of the task being investigated is to ask them to make individual predictions before they start collecting data. Comparing group members’ ideas can raise interest. Matching the form of graphs presented by the computer with the pupils’ own sketch graph predictions can encourage discussion. Pupils describing what they see leads to qualitative descriptions of graphical data. Such descriptions can be encouraged by timely and skilfully posed questions from the teacher.

Observations of pupils working with data-logging software suggest that pupils can have difficulty in putting their ideas into words. One strategy used in mathematics classrooms to encourage pupils’ thinking and writing has been to offer them ‘sentence starters’ (Lee, 1997). A similar approach could be used in science to help pupils become better attuned to their experimental results and better prepared to do further mental work on their data. Some suggested sentence starters for helping pupils to consider their practical work are offered in Table I.

<table>
<thead>
<tr>
<th>What I think will happen is ...</th>
<th>The reliability of my results is ...</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think this because ...</td>
<td>One thing I didn’t expect was ...</td>
</tr>
<tr>
<td>I noticed that ...</td>
<td>I was surprised by ...</td>
</tr>
<tr>
<td>The pattern in the graph was ...</td>
<td>A problem I had was ...</td>
</tr>
<tr>
<td>The graph tells me that ...</td>
<td>What I need to do is ...</td>
</tr>
<tr>
<td>The results mean that ...</td>
<td>What it would be a good idea to ...</td>
</tr>
<tr>
<td>I know this because ...</td>
<td>I could improve my experiment by ...</td>
</tr>
<tr>
<td>The results agree with my prediction because ...</td>
<td>I could investigate my new ideas by ...</td>
</tr>
<tr>
<td>The results disagree with my prediction because ...</td>
<td></td>
</tr>
</tbody>
</table>

Table I. Some suggested sentence starters for science.

**Developing Skills in Context**

Research into pupils’ interpretations of manually drawn graphs suggests that exploring the more subtle features of graphs, and relating these features to the relationships between variables, are skills exhibited by only a minority of younger secondary pupils (Swatton & Taylor, 1994). This research also indicated that variable handling skills could be taught in isolation. However, the authors argued that acquisition of these skills is better achieved within the context of whole investigations where adequate recognition can be given to the influence of affective aspects of pupils’ learning.
The more experience pupils can be offered of using data-logging software for analysis, the greater the hope of them acquiring well-rehearsed routines for exploring data. These strategies need to become an established part of pupils’ procedural understanding. Initially, coaching in the use of software tools will be required. As they become more expert in using these analytical strategies, however, pupils may begin to appreciate their value in understanding data. Only when the purpose is clear are pupils likely to transfer the skills between contexts.

Being Critical of Data

An important feature of data-logging is that it is possible to collect a great deal of data. Where anomalous results appear, these tend to have a ‘harder’ quality for pupils using IT than for those using non-IT methods. Perhaps pupils attribute this robustness to the data because it is collected and displayed by machine; the pupils’ usual explanation for anomalies of ‘operator error’ is inadequate. Pupils are quick to blame themselves for ‘errors’ in practical work and need support to cope with inconsistencies in data. The point needs to be made to pupils that such inconsistencies are not wrong, they just need more thought and analysis. In data-logging tasks, pupils are likely to encounter anomalies, especially where the sensitivity of equipment is such that small changes or variations are detected which ‘manual’ methods might miss. Pupils need to be encouraged to account for these variations. To do so, pupils will need to apply their experience, knowledge and understanding of investigative work. Drawing on these resources, pupils will need to ‘synthesise’ an explanation for anomalous data. These activities demand high-level cognitive skills and pupils succeeding in them will be achieving at higher attainment levels of Experimental and Investigative Science in the National Curriculum.

New Lesson Structures

The foregoing argument calls for a reappraisal of much of the current practice of data-logging in science lessons. Some practical teaching approaches that can offer better data-logging experiences for pupils have been suggested. If science teachers are persuaded by these arguments, what might the shape of future data-logging lessons be?

One possible framework for a data-logging lesson is suggested in Figure 3. Included are examples of some broad activity types which support particular teaching purposes. Not all of these will necessarily feature or be used in a single data-logging lesson. It is important that these choices are considered critically by teachers and that selected activities are matched to learning outcomes for particular pupils.
Where the pupils ‘enter’ the task will depend on a number of factors, not least their prior experience of data-logging. Nonetheless, the scope of the suggested activities serves to emphasise that gathering data is but a part of data-logging in science teaching. Moreover, pupils’ preparatory and follow-up activity should be a prominent feature of their experience, rather than the IT equipment used.

Readers may feel (with some justification) that the model proposed in Figure 3 is merely a restatement of a general approach applicable to any science practical activity. Nevertheless, it is timely to reassert it and to reinterpret it for lessons employing new technologies, lest operating the technology becomes the focus of activity rather than a medium for supporting pupils’ learning of science.

Conclusions
Data-logging techniques present science teachers and their pupils with exciting new opportunities and challenges in practical work. Software affords unique ways of helping pupils to hone their skills in data handling and interpretation; but the extent to which this can be achieved is largely shaped by the management decisions made by teachers and the teaching approaches employed. A shift of emphasis from data collection to data interpretation and increased awareness of pupils’ roles offer the prospect of more effectively exploiting data-logging activities to enrich pupils’ experience of science and of meeting the demands of an increasingly technological curriculum.

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References
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Brown, J. & Howlett, F. (1994) IT Works. Coventry: National Council for Educational Technology (now the British Educational Communications and Technology agency [BECTa]).


School Curriculum and Assessment Authority (SCAA)/ Curriculum and Assessment Authority for Wales (1995) Key Stage 3 Information Technology and the National Curriculum. London: SCAA.


Insight 2 software is available from Longman Logotron, 124 Cambridge Science Park, Milton Road, Cambridge CB4 4ZS, United Kingdom.