Teaching Practical Science with Information Technology: The Potential of Data-logging Examined Through Case Study.

Thesis submitted for the degree of Doctor of Philosophy at the University of Leicester

by

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Teaching Practical Science with Information Technology: The Potential of Data-logging Examined Through Case Study.
Leonard Richard Newton BSc MA

Abstract

Laboratory based practical work typically involves pupils in observation, measurement, recording, display and analysis of experimental data. In recent years, computer tools have been applied to these processes through ‘data-logging’ methods. The benefits of these methods and their potential to serve the purposes of investigative practical science have been identified in the literature.

This study presents an examination of the use of data-logging methods in order to identify factors that influence their use and to explore the extent to which the benefits claimed are achievable in everyday classroom settings.

The study is organised around four major research issues concerning the features of data-logging activities designed by teachers; the ways in which activities are presented, organised and managed; the roles adopted by teachers and pupils in data-logging lessons; and evidence of productive interaction between the participants in data-logging lessons.

The methodological approach adopted to examine these issues is that of instrumental collective case study. A rationale is presented for this strategy derived from literature and based on the needs of the research.

The findings indicate that influences shaping the use of data-logging methods are wide-ranging. In addition to technically well-serviced ICT facilities and teachers experienced in the use of data-logging methods, the role of teachers emerges as highly influential in relation to:

- designing data-logging activities with sufficient scope and clarity of objectives, matched to pupils’ needs;
- recognising the complexity of managing data-logging activities in classrooms and balancing this with the potential benefits of the technique;
- fostering an exploratory classroom ethos, encouraging pupils’ talk about data-logging activity and exploiting intervention opportunities.

Finally, in the light of these findings, suggestions for further empirical research are made.
INTRODUCTION

The Purpose and Scope of the Study

Much laboratory work in school science involves observation and measurement, and an important development, in recent years, has been the application of computers to this activity. This study is concerned with the application of computer methods to practical work, in particular those methods that are known as ‘data-logging’. Data-logging techniques have been available to science teachers for some time (outside the 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, is now a realistic alternative to traditional approaches to practical work.

The purpose of this study is to explore and to understand the influences on the practice of data-logging in some everyday science classrooms. It is concerned with influences that shape teachers’ decisions about how they teach and with what is currently achievable using data-logging methods. By reflecting on case studies of current practice of data-logging, identifying their benefits and the factors that may influence their use, the thesis seeks to reveal ways in which this aspect of
ICT\(^1\) can be more effectively used to support pupils’ experience of learning science and to reveal avenues for future exploration.

My interest in this subject has its origins in my experience of secondary science teaching in a number of different school and college settings. An important principle for me, as a science teacher, has been that pupils’ experience of science lessons needs to be about much more than mere acquisition of a body of scientific knowledge. I believe that, in its broader sense, education should be concerned with enabling learners to take control of and responsibility for their learning. Science is well placed to provide a wide range of opportunities in which pupils can exercise this type of responsibility.

However, the prescription of any curriculum and the role of teachers as its ‘gatekeepers’, necessarily influences the freedom of pupils to exercise control and responsibility over their learning. Nevertheless, it would seem that effective teaching concerns striking an appropriate balance in the management of pupils’ activity so that there can be freedom for genuine learning whilst ensuring that the reasonable expectations of other interested groups (parents, governments, society etc.) are adequately met.

The teaching of science provides ample opportunity to employ a range of approaches to challenge and engage pupils’ interest. For me, science can be awe inspiring, up-to-date, intellectually demanding, and exciting. There are ‘mental’ and practical challenges which can engage the learner. In recent years an added interest has come from the introduction of computers into the classroom.

\(^1\) The term ‘information and communications technology’ abbreviated to ‘ICT’ is used throughout this thesis to refer to use of computers in teaching and learning
Computers provide an up-to-date way of working which, experience suggests, many pupils find engaging. Moreover, computers also provide science teachers with completely new ways of approaching their teaching. As this thesis will show, these novel ways of working in science present teachers and pupils with exciting new opportunities. However, there are also new challenges which arise that can present both teachers and their pupils with impediments to full exploitation of the attributes of computer-based activities.

Overview of the thesis

The study presented here sets out to describe some exploratory case studies of data-logging methods in use in routine science classrooms. Its purpose is to identify aspects of practice that can help teachers and pupils make their experience of it more fruitful. In order to identify these features, the early chapters of this thesis set out a background of evidence from literature against which the application of computers in data-logging activities can be considered.

Chapter One deals with general aspects of information and communications technology (ICT) use in schools. Set in the context of ideas about learning in science and the role of group work, the chapter presents a body of literature that identifies some of the potential benefits of computer approaches in classrooms. The motivational aspects of ICT use are discussed and the value of collaborative activity described. From this generic description, those benefits which have potential for science learners are identified.

Chapter Two sets out to describe the place of practical work in science education. It considers some of the ways in which practical work has been viewed over the
past twenty years and reflects the debate over the purposes of practical work. An important aim of Chapter Two is to consider the nature of practical work in national curriculum science. In particular, the roles of practical work in helping pupils to acquire skills in scientific investigation, and as a means of presenting scientific content knowledge, are considered.

The development and application of computer methods to practical work is considered in Chapter Three. Later in the Chapter, the claims made for application of computers to science practical work and the development of data-logging methods are discussed. Initiatives which have promoted the use of these methods are described and some factors which apparently constrained this development are discussed. Some of the research findings that indicate benefits for the data-logging approach to practical work are then considered. These findings serve to frame a set of orientating research questions which the study set out to explore in order to understand better the apparent mismatch between potential and practice in the use of data-logging methods.

Chapter Four seeks to develop a framework, derived from literature, against which the use of data-logging methods in practice can be considered. The purpose of the framework is to facilitate a critical examination of laboratory use of data-logging methods describe in the case studies, in order to identify aspects practice which appear to be particularly beneficial to their use.

Data collection methodology and the approaches to analysis employed are the subjects of Chapter Five. The research stance adopted is presented, and the methodological consequences of this are considered. Here, I argue for a qualitative case study approach to exploration of the research questions posed in
Chapters Three and Four. A rationale is presented, derived from relevant literature, for an instrumental case study: its benefits and costs are considered. The choice of study sites is discussed and the opportunities and limitations of these considered. Data collection methods are then discussed, and the development of these as the study progressed is presented.

The detail of the case studies is presented in Chapter Six. The cases described include three cases in which data-logging methods were being used as a part of regular teaching activity. The fourth case considers the use of a self-contained teaching package for acquisition and use of skills in data-logging techniques. The approach adopted in this chapter is to present descriptive accounts of the cases, illustrated with vignettes from the case data. Where possible, the meanings attributed to these accounts are corroborated from interview data which is considered in Chapter Seven. However, the findings reflect only the cases studied and the data collected. The implications of these factors for the reliability and validity of the study are considered.

MAIN FINDINGS

The conclusions and implications of the case study data are discussed in Chapter Eight. For the cases studied, it is argued that the use of data-logging methods in science have yet to fulfil the aspirations expressed in curriculum policy or the expectations indicated by research findings.

It is suggested that data-logging is often used for tasks concerning gathering data rather than tasks of a more interpretative kind. Further, the thesis argues that the attributes of data-logging technology are not fully appreciated, even by computer
enthusiasts. Teachers may hold different visions of what ICT can offer and this influences the effectiveness of its use in classrooms.

It is also argued that there may be a mismatch between the claims made for ICT by software designers and academics, and what can be practically achieved by teachers in schools. Although benefits are claimed for the use of data-logging methods in science teaching, how these can be secured in classrooms is not sufficiently well understood.

However, in the cases studied, constraining factors prevented wider or more advanced use of data-logging. Constraining factors including technical and organisational matters, as well as curricular and pedagogical issues emerge as requiring further development and study.

From these findings it will be argued that, in the cases studied, teachers made the most of their situations. Nonetheless, there is a need to develop teaching activities to make the most of data-logging activities. In order to move data-logging forward, it will be posited that greater attention needs to be directed towards planning and preparation of teaching materials and approaches for use with pupils.

Included in this chapter are suggestions for further work.
Chapter 1

Information and Communications Technology (ICT) in Schools.

1.1 Educational Computer Use

Computer usage is now an established feature of contemporary life. Over the past twenty years there has been increasing use of microcomputers in and outside the workplace and, more recently, in people's homes. These machines have become ever cheaper and offer ever increasing computing power as the technology on which they are based has developed. The use of microcomputers in schools has perhaps trailed their appearance in other settings. Nonetheless, microcomputers are now an established feature of schooling and can be found supporting both the administration of schools and pupils' learning in classrooms.

It is useful to reflect on personal experience of science teaching in the 1980s, when microcomputers first appeared in schools. Technology and its application in educational settings has developed enormously since then, but it is telling that many of the issues which faced us then are still pertinent today, particularly in regard to application of computers in the classroom.

I recall, the acquisition of a single Sinclair zx80 by the science department in which I was teaching during the 1980s. This machine was followed by the purchase of more powerful and useful computers such as a Commodore Pet, and BBC Microcomputers. These machines were a focus of interest for teachers and pupils alike. As we became familiar with them, and as the availability and range of software increased, the computers gradually became more frequently used in
classrooms to support science teaching. They were always popular with the pupils, even if some teachers were more enthusiastic than others to use them.

Initially most interest in the use of computers in the classroom was found in the science and mathematics department. Computer programs were written and shared by enthusiasts who had mastered this skill. Later, collections of programs began to be published many of which needed to be laboriously keyed into the machine, until storage media such as tape and floppy discs provided a more convenient means of transferring software.

With the development of word-processing software and, later, spreadsheets, the machines also began to appear additional curriculum areas. Indeed, it became apparent that technology for handling information had potential applications across the whole curriculum. Writing in the mid 1980s, Wellington (1985, page vii) identified three aspects of educational computing as shown in Figure 1.1 below.

![Figure 1.1 Facets of Educational Computing](image)

The facets of educational computing identified by Wellington provide a useful starting point for consideration of the types of interactions which occur in
computer use in education. Whilst computers, the curriculum and issues centred on pupils can all be considered separately, it is the interplay between these sets of influences through which any benefits of educational computing arise. My concern in this thesis is to explore an aspect of computer use in action; consequently there is a genuine sense in which one cannot meaningfully study any of these individual facets without regard to the others.

One challenge which faced schools in the introduction of computers was the question of what type of use should be made of the machines and how pupils might be afforded access to them. One point of access was through the use of computers to support subject learning, a second was through computer literacy programmes which sought to raise pupils’ awareness of the new technology. A third access point was through the development of computer studies courses and examination syllabuses. The development of computer studies as a subject in its own right posed problems for schools in that the computers tended to be sequestered into a room and used predominantly for teaching the new subject. This meant that the limited hardware resources were not available in other classrooms for support of subject teaching. Additionally, access to machines for supporting subject teaching could become organisationally difficult. In some schools teachers would need to book computer facilities, move classes of pupils etc. Inevitably this would restrict the frequency and types of activity which pupils could experience with ICT.

The significance of this for the present study is that schools are often still managing their ICT resources in dedicated computer suites. Moreover it seems likely that individual science departments may still face difficulties in organising access to
computers. Whether the deployment of ICT resources in dedicated computer suites may restrict or facilitate their use by teachers may be an open question. There may be benefits in teachers using ICT suites for whole class teaching activities, with technical support readily available. Equally, there may be benefits in using computers in the normal classroom, although this approach may bring other problems. Which approach is most satisfactory may well depend on the teaching purpose, but the ways in which ICT resources are deployed in schools has been identified by the Office for Standards in Education (OFSTED 1998) as an influential factor in raising pupils' general ICT capabilities. Thus:

"A significant problem for the application of it across the curriculum is access to appropriate IT facilities in the subject rooms as well as in specialist areas such as a computer room or library. A minority of secondary schools are very well resourced for IT. There are many more schools at the other end of the scale, where unsatisfactory equipment provision or accommodation hinder pupils from developing their skills in IT. Availability of sufficient equipment on its own, however, is no guarantee that the progress of pupils in it will be good. ..."

(OFSTED, 1998 page 29)

It is significant that OFSTED allude to factors other than resource allocation as being influential in developing pupils' ICT capability; this theme will recur in this thesis. Nevertheless, the impact of organisational factors on teachers' planned use of ICT in science teaching, and their pupils' experience of it, are likely to be influential matters in this study.
1.2 The Place of ICT in the Curriculum

Information Technology has featured in the National Curriculum in England and Wales since its inception in 1989. Although, familiarisation of pupils with ICT was an intended outcome of its use, enhancing computer awareness was not seen as its sole purpose. In addition, due recognition was given to the importance of ICT for “enhancing learning at all levels throughout the school curriculum and in providing opportunities for both independent and collaborative work.” (DES 1989, page 73). Early thoughts on the use of ICT in schools also included the hope that IT use would “reflect the use of IT in the ‘real world’...” (Underwood 1994, page 8). This view suggests the use of ICT as a tool to support other activity, rather than its use being an end in itself. However, there is a distinction to be drawn between a utilitarian view of ICT capability for finding, storing and presenting information for example, and its use as tool to support learning. This distinction is still pertinent today because pupils’ ICT capability remains a ‘Key Skill’ in the curriculum.

1.3 General Qualities of ICT.

What are computers ‘good’ at?

Computers are generally considered to be ‘good’ at certain types of task. They are effective at storing and retrieving large amounts of information rapidly and consistently. They are useful at managing repetitive and complex processes with greater reliability than can be achieved by people. Furthermore, the output of these processes can be displayed in a variety of ways.
The impact of these generic properties of ICT on teaching and learning situations has been a subject of interest for educationalists. However, as Scaife and Wellington (1993) have pointed out, it is questionable whether in an educational setting, it is desirable for computers to be used uncritically, since the learning purpose might be for pupils to acquire the very skills that the machine replaces.

In considering the benefits to pupils of the labour saving effects of computers, Kemmis et al. (1977), distinguish between what they describe as pupils' authentic labour and their inauthentic labour. Authentic labour is seen as valued learning. On the other hand, inauthentic labour is seen as: “activities which may be instrumental to valued learning, but are not valued for their own sake.” (Kemmis et al., 1977 page 28). Scaife and Wellington’s interpretation of this view of pupils’ labour stresses its importance in considering the educational uses to which ICT is put. Thus they state that:

“The distinction between what counts as authentic (i.e. desirable and purposeful) and inauthentic (i.e. unnecessary and irrelevant) labour in the learning process is a central one in considering the use of IT in education.”

(Scaife and Wellington, 1993, page 23).

According to Kemmis et al., much curriculum reform seeks to enhance the authenticity of pupils’ work by heightening its relevance, making work more engaging and seeking to make difficult ideas more accessible to the pupils. In my view, these ambitions are equally pertinent in the contemporary context. Moreover, the widespread use of ICT and pupils’ increasing familiarity and confidence with
ICT makes computer supported learning well placed to increase the authenticity of pupils' school experiences. Thus one can envisage computer use reducing pupils' inauthentic labour and enhancing their authentic labour.

*Effects with technology.*

The ways in which new technologies may contribute to more effective learning have been classified into two sets of effects: effects *with* technology and effects *of* technology (Salomon *et al.*, 1991). The first set of effects are due to users working *with* the technology, i.e. an enhanced performance on a task carried out with the aid of technology; what Underwood (1994) has described as using the computer as a 'tyre lever'.

These effects are considered as an outcome of an intellectual partnership between user and machine which allow the user to shortcut part of the cognitive effort involved in a process and thereby achieve an improved outcome on the task. It is suggested that the computer, by carrying out some of the lower level operations, might liberate the user to achieve at higher levels which would otherwise be beyond their 'cognitive system' (Salomon *et al.*, 1991 page 4). These effects are ascribed to the reduction in demands on users to process large amounts of information: an activity which needs to be 'automatized' in order for the user to move on to higher order activity. The opportunity for the user to then organise and interrelate ideas ascribes to the user skills akin to the expert rather than the novice. In this way, the performance of the user plus technology can be greater than the performance of the human alone: the workhorse effect.
However, the point is strongly made that the extent to which a user can benefit in this way is not an automatic outcome of using technologies but demands some intellectual effort in interacting with the technology. This effort is under the user’s voluntary control and is non-automatic. The need to interact with the technology in a thinking way (what Salomon et al. (1991) call ‘mindfulness’) enables learners to mobilise more of their cognitive power and commit more of the information to memory.

These authors usefully go on to describe features of technologies which increase users’ mindfulness. These features include the degree of pupils’ control of the activity; immediate presentation of results; inter-activity; conflict; graded goals and moderate uncertainty. These attributes face the user with choice points which require mindful consideration and ‘trigger mental experimentation’ (Salomon et al. 1991 page 4).

However, caution needs to be expressed in so far as not all pupils even in apparently structured situations would expend the intellectual effort required to benefit from engaging with the technology in a mindful way. The willingness of a user to operate in this way is key to developing the benefits ascribed. This caution serves to emphasise the extent to which the benefits of ICT approaches to classroom activity need to be seen as potential benefits. The extent to which potential benefits are actualised is likely to be shaped by many other factors which contribute to the context in which technology is used.
Effects of technology on learners.

Salomon et al., (1991) posit a second set of effects of ICT use: those effects of technology on the user. It is suggested that these are effects which might bring about a transferable 'cognitive residue' related to the development of skills and abilities. Whether such skills as are developed are bound by the context in which they are developed or whether they are transferable to new contexts is a further point discussed by these authors. The suggestion is made that cognitive effects can be made to occur in certain situations but that the effect may be less marked in natural, day-to-day conditions. This raises the question of whether cognitive effects of technologies can be enhanced by 'engineering' contexts in which transferable thinking skills are fostered. This has clear implications for classroom settings employing new technologies, and for developing pupils' skills in making choices about when and how to use ICT in their own activity.

1.4 ICT Supporting Pupils' Learning

Uncertainty over the value of educational use of ICT clearly emerges as a factor in its implementation in the teaching and learning context; it is this uncertainty that, at least to some extent, drives research. There is also a distinct need to invest in research in order to test ideas about the potential benefits of ICT to education. Notwithstanding more than twenty years of ICT use in education and after significant research into its effects, the Stevenson report (1997) revealed a continuing measure of uncertainty over the benefits of using computers:

"The perhaps more legitimate question is how and to what extent ICT presently helps learning. Evidence is now emerging on how ICT
can improve learning. This evidence points to the conclusion that ICT brings considerable benefits to bear on the learning process, albeit benefits with different weight in different situations. It will be a very long time, however, before there is conclusive evidence to justify the substantial investment by the community at large that we believe to be necessary; and by the time this justification is achieved, almost certainly a generation or two will have lost out, not to mention that the investment then required will be different! In our view there is no substitute for government taking what we describe as a common sense act of faith view of the need to ensure a co-ordinated approach to the application of ICT in schools. It would, after all, be remarkable if school education turned out to be the one area in society where effectiveness and productivity were not dramatically increased by the application of ICT! …"

And:

"It seems to us a matter of common sense that the educational process in our country will gain massively as a result of using ICT wisely. If this proposition cannot be entirely proved, it has to be an act of faith. It is important that government makes this act of faith and that we use technology rather than study it over the next decade."

(Stevenson, 1997)
Within the United Kingdom, two major studies have set out to investigate the effects of ICT on pupils’ learning. These were the ImpacT study (Watson, 1993) and the PLAiT report (Gardner et al, 1994). The ImpacT study was a major long term study involving over two thousand children of primary and secondary school age in England and Wales. The authors reported on the contribution to pupils’ learning made by ICT, but attention was also drawn to difficulties associated with ICT in use and the implications of this for teaching effectively with technology.

One important finding of these studies was that computers raised pupils’ motivation, interest and enjoyment of the subject and raised the status of the subject in their eyes. The pupils’ learning was focused by ICT and their attention and activity sustained over long periods resulting in raised quality in their work. Pupils showed pride in work produced using ICT. Computer-based activities tended to be open-ended allowing for greater involvement of the pupils. Knowledge of their experience was retained by the pupils over time and conceptual misunderstandings were made more apparent in computing environments. From the perspective of teachers, many were able to use ICT to support their existing practice. It was accepted by teachers that computers fostered collaborative work between pupils and this was viewed as an important aspect of classroom practice. Importantly, it was reported that teachers’ personal confidence in the value of ICT applications and their enjoyment in their use, were reflected in pupils’ use of the technology.

Problems of ICT in use were reported in the ImpacT study. These included technical difficulties with software and management of the ICT facilities but they
also included other key aspects of pedagogy. Teachers tended to be constrained by
the demands of the national curriculum so that limitations were imposed on what
was done with pupils. Teachers became more concerned with outcomes than with
process and had difficulty in incorporating ICT based work into normal
coursework assessment. They had difficulty in promoting collaborative work with
pupils and tended to use ICT to complement existing strategies. Nonetheless, there
were many positive benefits for pupils using ICT: the issues raised by the ImpacT
study have implications for the way ICT is managed in use by teachers to maximise
these benefits for pupils. Thus in considering the contribution of ICT to pedagogy
and practice:

"the results from the case studies, mini-studies, and aspects of IT
use indicate quite clearly that any contribution was dependent upon
a range of factors, the most important being that of the role of the
teacher."

(Watson, 1993 page 3.)

The PLAIT (Pupil's Learning and Access to Information Technology) project was
funded by the Department for Education for Northern Ireland and carried out by
researchers from the school of education, Queen's University of Belfast.

The project placed 235 portables in nine schools for one year. Complete class sets
of machines were provided in one primary, one special and seven secondary
classes. Most classes were 12 to 14 year olds but there was one 10 to 11 and one
14 to 15 age group.
In each of the three target subjects of English, science and mathematics, there were indications of raised pupil motivation, greater pupil autonomy, enhanced quality of work and acquisition of transferable skills through the uses of ICT.

The PLAiT project raised other issues with importance for the day-to-day teaching of classes with portable computers. These issues included the following:

**Technical issues for teachers**

- The need to develop teacher competence and confidence in the use of it tools;
- Implications for teaching schedules in terms of lesson length and planning;
- Technical support problems and strategies for minimising the negative impact of these on lessons;
- Advantages of portable over networked machines.

**Teaching issues:**

- New models of teacher-pupil interaction (less teaching from the front);
- Additional teaching effort due to use of computers; need for contingency strategies;
- Problems of pupils without machines or forgotten disks;
- Management of absentees and the need to catch up missed work;
- Printing problems due to a lack of facilities.

**Equipment issues:**

- Screen quality on portables;
• Location of equipment in teaching room;

• Software problems (ease of use, guides, virus protection);

• Hardware issues (robustness, durability, portability, power management, support from suppliers, memory, user interface).

It is noteworthy that the majority of the issues listed above concern operational matters: issues to do with the organisation and management of computers in the classroom.

An important objective of the PLAIT project was to investigate the contribution of portable computers to the delivery of the curriculum. Within the context of science teaching, a range of ICT applications were studied and some of the benefits of the ICT approach were described. However, in the case of science:

"Teachers reported that the use of portables by pupils had not dramatically altered their own approach to classroom management, nor had it changed their teaching style. ... teachers reported, and the research team's observations confirmed, that they had become more mobile in the classroom and that they interacted more with individual pupils. These extra interactions, however, were mostly about queries or problems with machines."

(Gardner et al., 1994 page 25)

This statement suggests that at the time of the PLAIT project, there was less apparent concern with aspects of pedagogical content knowledge in relation to
ICT i.e. the knowledge of how to teach particular ‘content’ to particular groups of pupils using an ICT approach.

In considering their conclusions to the *PLAIT* project, the authors comment that:

"The general conclusions are that portable computers in the project resulted (although not universally) in high levels of pupil motivation, harmonious and purposeful learning environments and greatly accelerated information technology literacy among pupils and teachers alike"  
(Gardner et al., 1994 page 53)

Moreover, they suggest that teachers needed to be properly equipped with portable computers in order for them to fully integrate ICT into their teaching repertoires. Despite various initiatives, this remains an unfulfilled ambition in many schools as indicated by OFSTED (1998).

It is noteworthy that the *ImpacT* project did not include a data-logging activity in its science study whereas the use of sensors for measurement was a feature in the *PLAIT* project. Both of these projects focused on ICT use in the early 1990s when data-logging hardware and software was much less sophisticated and easy to use than that which is currently available. Significant importance was attached in these reports to technical issues, and their impact on classroom use of ICT. It is important to re-appraise the potential for use of data-logging methods in the light of recent technical developments which have greatly enhanced their ease of use.
Both the *ImpacT* study and the *PLAIT* report identified positive contributions to pupils' motivation and learning. They also raised questions about the developments needed in teachers' skills and vision so as to fully exploit these benefits in classroom settings. More recently, the findings of these two major studies have been cited in an attempt to appraise strategies for evaluating the effectiveness of ICT on learning. Hammond (1994) argues the need for evaluation of effects of ICT on learning to place emphasis on the contextual factors that pertain in its use. Accordingly, consideration needs to be given to:

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"teachers' and pupils' knowledge and understanding of the software, the characteristics of the software and what actually goes on in the classroom"
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(Hammond 1994, page 259).

This view implies that the positive effects of ICT on learning have as much to do with the nature of the classroom settings in which it is used as with the intrinsic characteristics of the technology itself. This assertion is consistent with Wellington's view of the facets of educational computing described earlier. It serves to emphasise the importance of the teacher's role as a manager of these interrelated facets of classroom experience when using ICT. The role of the teacher in exploiting these characteristics is, in this sense, asserted.

1.5 ICT and Motivation

A detailed discussion of literature on motivation is beyond the scope of this chapter. However, it is pertinent to consider aspects of research into pupils' motivation in computer settings, since this has emerged as an important factor in
both the *PLAIT* and *ImpacT* studies described above. Moreover, much everyday classroom experience suggests that pupils frequently enjoy computer based activities. For the purpose of the present study, two recent projects concerning motivational aspects of ICT use are particularly relevant.

Cox (1997) reported the results of a survey opinions of primary and secondary school pupils, and some university students, on the role of ICT in their education. The survey consisted of a series of Likert-type scales, supported by a small number of teacher and student interviews. A sample of 442 respondents was used.

A number of interesting indications arose from this study. Responses from first year university students, drawn from a number of different secondary schools, indicated that their own experience of ICT use in secondary school was significantly less frequent than had been suggested by other research; particularly that which explored headteachers' perceptions. In science, 50% of university students reported never having used ICT and less than 10% claimed to have used ICT in science for approximately an hour a week. There was evidence that students' own perceptions of their ability as ICT users motivated them to further ICT use. Moreover, frequency of ICT use appeared to lead to an increase in positive attitude and enhanced commitment to a learning activity. For some students, ICT use increased the importance of a school subject to them.

At secondary level the survey reported that 75% of students believed that using ICT made their subjects more interesting. More than half of the school students felt that using ICT helped them to greater achievement. The report indicates the link
between enhanced achievement and task engagement. Increases in students’ self esteem and ability to work independently were also reported.

The report acknowledges the limitations of the research and concludes that:

“... using IT in learning is perceived by many school students to enhance their learning potential, their achievement goals and their long term college and job prospects.”

(Cox, 1997 page 23)

Research carried out under the auspices of Keele University and the National Council for Educational Technology (Keele / NCET, 1997) during 1995/96 highlighted a number of issues of relevance to teachers. This research employed survey, pupil interviews and school-based action research methodologies in order to probe the nature of the motivation which ICT seems to enhance. The findings of the study indicate that pupils were well informed and enthusiastic about ICT. Important features of ICT-based activities included pupil autonomy, their heightened self-esteem and the non-judgmental nature of computers.

The research also indicated that some pupils were demotivated by poor quality ICT resources in schools, compared with that available in their homes. Whilst teachers noted that pupils were motivated by ICT use to support teaching, a significant percentage (40%) of pupils claimed only to use computers in ICT lessons, thus supporting Cox’s 1997 findings cited above. The Keele / NCET research identifies:

“...potential for much more effective and frequent use of IT to support teaching.”

and notes that:
"There is considerable scope for extending the use of IT as a catalyst for more effective teaching and learning. This can only be achieved if an improved understanding of the technology is used to develop new and effective strategies."

(Keele /NCET 1997, page ii).

Taken together, these two recent research reports confirm the motivating effects of ICT in the contemporary context, but they also indicate the need to exploit new technologies further through the development of new teaching approaches. There is also the cautionary note that use of outdated technology can be demotivating. Given the current pace of technological developments and the difficulties faced by schools in matching this pace, it seems that careful attention needs to be given to the ways in which the technology is used to support teaching. This will mean not only attending to the quality of the available resources, but also the range of ICT tasks which pupils are invited to experience. As the Keele / NCET report points out:

"Tasks are sometimes repetitive and unchallenging. There is often little time to embark on worthwhile activities. Teachers need clear guidance and support if ICT use is to lead to more effective teaching and learning."

(Keele /NCET 1997, page ii).
1.6 Types of ICT Use

A useful way of classifying ICT implementation has been described by Kemmis, Atkin and Wright (1977). Their classification was used in the evaluation of the national development programme in computer assisted learning during the mid 1970s. The authors considered the use of computers from a curriculum perspective and proposed three paradigms of educational use which serve to illuminate the potential application of computers to particular teaching situations. In describing the paradigms, the authors provide profiles which typify each paradigm. These are summarised in Figure 2.

Kemmis et al suggest an additional fourth paradigm of ICT use, the 'emancipatory paradigm'. The authors are more circumspect in their description of the emancipatory paradigm because, as they state:

"Its curriculum emphasis and educational means are derived from the primary paradigm with which ICT is associated - for ICT never appears in isolation except as an impulse to curriculum reform."

(Kemmis et al 1977, page 29)

Nevertheless, the labour saving aspects of computer use and its value as a means of reducing the complexity of tasks facing pupils is a key feature of much computer use. Moreover, ICT plays an important part in reducing pupils' inauthentic labour, as described earlier in this chapter.
Figure 1.2 Paradigms of learning through ICT

<table>
<thead>
<tr>
<th>Feature</th>
<th>Instructional paradigm</th>
<th>Revelatory paradigm</th>
<th>Conjectural paradigm</th>
<th>Emancipatory paradigm</th>
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<tr>
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<td>Mastery of content</td>
<td>Discovery,</td>
<td>Hypothesis testing</td>
<td>Reduces inauthentic labour</td>
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<td></td>
<td></td>
<td>Intuition</td>
<td>Articulation and manipulation of ideas</td>
<td></td>
</tr>
<tr>
<td>Curriculum emphasis</td>
<td>Subject matter as object of learning</td>
<td>Student as subject of education</td>
<td>Understanding</td>
<td>Derived from associated primary paradigm</td>
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<td></td>
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<td>Active knowledge</td>
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<tr>
<td>Educational means</td>
<td>Drill and practice with feedback.</td>
<td>Provision of opportunities for discovery</td>
<td>Manipulation of student inputs</td>
<td>Derived from associated primary paradigm</td>
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<td>Finding metaphors,</td>
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<td>Model building</td>
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<td>Role of the computer</td>
<td>Presentation of content</td>
<td>Information handling</td>
<td>Tool for creating or articulating models, ideas or structures.</td>
<td>Calculation</td>
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<td></td>
<td>Task prescription</td>
<td>Simulation</td>
<td></td>
<td>Graph plotting</td>
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<td>Fast feedback</td>
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<td>Information retrieval</td>
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<td>Examples</td>
<td>ILS systems</td>
<td>Simulations,</td>
<td>Databases, spreadsheets, data-logging software</td>
<td>Data-logging software</td>
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<td>Databases</td>
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After Kemmis et al. (1977)
1.7 Learning and Collaborative Activity in the Classroom

Some perspectives from psychology

A number of learning theories have been influential in the development of teaching approaches and teaching materials in science, and which are of relevance to this study. These include behaviourism, constructivism and socio-cultural theories. A detailed consideration of these theories is not necessary for the purpose of this thesis; however, it is appropriate to outline some key features of these theories which are relevant to ICT in learning (a more detailed introduction can be found in Jones and Mercer, 1993).

The behaviourist school is concerned with the actions of individuals and the ways in which these can be shaped through reinforcement of desired behaviours. Skinner's work on operant conditioning in animals has been influential in developing behaviourist theory. The desired learning is encouraged through rewarding desired behaviour with a 'reinforcer' (e.g. food in animal experiments), inappropriate learning is ignored and in Skinner's terms becomes 'extinguished' over time. Thus by breaking down learning into a series of steps and carefully controlling the learning environment, it is believed that learning of particular behaviours can be developed.

Analysis of learning tasks by teachers into sets of sequenced learning objectives has behaviourist overtones. Use has been made of computers to provide ways of automating learning based on these behaviourist principles, as for example in the teaching machines of the 1960s and more recently in tutorial software of so-called Integrated learning Systems (ILS) (Woods, 1998). However, as Jones and Mercer
(1993.) argue, it is questionable whether all learning can be analysed in this way.

Furthermore, the learning of specific behaviours is not characteristic of much of
learning in humans, although it is represented in behaviour modification therapies.

Constructivist learning theory has been a significant influence on curriculum design
in the latter part of the twentieth century. The role of the learner in actively
building personal understanding is central to this constructivist view of learning.
The work of George Kelly (1955) in developing his ‘Personal Construct Theory’
has been particularly influential in this school of thought.

Piaget’s ideas have been very influential in education. His work is concerned with
children’s understanding of their experience. Whilst largely adopting a
developmentalist perspective, Piaget’s ideas have a constructivist dimension. Piaget
thought of knowledge as being structured by abstract mental schemata which
represent the essential characteristic of what is being presented to the learner. New
experiences are ‘understood’ by the learner in terms of their existing schemata.
According to Piaget, new knowledge could be incorporated or assimilated into
existing schemata. Where there was a mismatch between new experience and
existing schemata, Piaget suggested that the schemata would be modified to
accommodate the new knowledge. Thus a child’s intellectual development occurs
through a process of assimilating their personal experiences within their existing
mental frameworks or developing those frameworks in a more sophisticated form.

Piaget’s observations and experiments on children led him to propose that mental
development proceeded through a series of stages characterised by the form of
reasoning of which the child is capable. In very early years, children’s thinking was
described as sensori-motor, early school years are characterised by concrete reasoning leading to formal abstract reasoning in adolescence.

Much of the influence of Piaget's views on education has resulted from those aspects of his work concerned with staged cognitive development. This has been manifest particularly in curriculum development; where acknowledgement is made in curriculum content and design, of the stage of the target audience. It has been suggested that emphasis on this aspect of Piaget's work has led to his views on the active role of the learner in constructing personal representations of experience being less prominent. In this sense, Piaget's work has led to a developmentalist perspective on learning being seen as an alternative to a constructivist view. However, it has been pointed out that there are respects in which these two alternative perspectives can be reconciled (Gunstone, 1988).

Developmentalist views of learning have been less to the fore in recent years. However, there remain currently important and influential projects in science education and learning with ICT, based in the Piagetian tradition. Two examples of such work are the Cognitive Acceleration in Science Education project (Adey et al., 1989) and Papert's work using Logo (Papert, 1980 and 1993).

Constructivist perspectives of learning have been applied to science education over the recent past (Driver and Bell, 1986; Driver, 1988). The focus of the constructivist perspective was initially concerned with learners' individual perceptions of experience. However, this view has more recently been developed to acknowledge the influence of the social settings in which learning takes place (Driver et al., 1994).
Communication and learning

The communicative interactions between participants in classroom activity and their prior perceptions of the culture of the learning environment are seen as of equal importance to learning as the content to be learned. Thus meaning and understanding is shaped through the social interactions of discussion and negotiation (Edwards and Mercer, 1987).

The origins of a cultural perspective of learning are in the work of Vygotsky who proposed that language and thought work together to provide a "cognitive tool for development" (Edwards and Mercer 1987, p19). Vygotsky suggested that children's joint activity and conversations with other people played an important role in intellectual development. This view contrasts with the individualistic approach to development proposed by Piaget.

Language is important in development in two respects in this perspective. Firstly it is the medium through which teaching and learning occur. Second it is a tool used by the child to construct a way of thinking. The role of speech in intellectual development is exemplified in the work of Luria who, in a study of development in a pair of speech-retarded twins, reported "significant changes in the structure of their conscious activity built upon the basis of verbal speech" (Luria and Yudovich, 1956 p107).

Others have written about the role of language as a means of understanding and organising experience; and as means of creating that experience through interaction with the outside world (see for example, Barnes, 1969; Britton, 1970; Sutton, 1992).
Collaborative activity in the classroom

In drawing on a socio-cultural approach to learning, Mercer (1995, page 4) has described language as a "social mode of thinking". Mercer sees conversations as 'situated' and places great importance on the context in which they take place, in shaping the meanings attributed to the experience by the participants. Context is seen in very broad terms here, and includes much more than the physical conditions that pertain in the conversation. Context is viewed as encompassing all those factors internal and external to participants; present and past, which bear on the exchange. Such factors are particularly relevant in classroom settings. Here, exchanges are affected by the history, expectations and understandings of the implicit rules governing interactions between teachers and students.

The attraction of these perspectives to the present study lies in their social and communicative aspects. These seem more readily applicable to the classroom settings in which teachers and groups of learners operate than do those perspectives more focused on individuals' sole actions. They relate to the ways that students are organised in classrooms into group activity and as Mercer (1995) points out, they offer a way of acknowledging and investigating the partnership between teaching and learning.

Considerable attention has been paid in the literature to collaborative aspects of learning in classroom settings. This has particular relevance to computer-based activity since, for reasons of resource levels, students are often organised in groups when working with computers. Collaborative activity has been viewed, from a Piagetian perspective, as providing opportunities for individual learners' schemata
to be challenged through group interactions. Such scenarios involve socio-cognitive conflict. Thus, when two children working together hold slightly differing understandings there is a potential for the conflict of understandings to be resolved such that individual understanding is developed (Light, 1993; Light and Littleton, 1994). However, research on group work in primary school settings has suggested that collaborative activity is not an automatic consequence of grouping students together: children need to be taught how to collaborate (Galton and Williamson, 1992).

From a socio-cultural perspective, collaborative group work is viewed as a partnership in which the participants (students, or students and teachers), through their joint co-operative activity, develop their understanding (Mercer 1995, page 90). The role of the participants in supporting learning has been described as 'scaffolding': a process in which Bruner saw as

"... the steps taken to reduce the degrees of freedom in carrying out some task so that the child can concentrate on the difficult skill she is in the process of acquiring."


Thus scaffolding is concerned with supporting active learning through interventions so that the learning can develop more easily than in the absence of the intervention. The nature of interventions in primary students' learning has been described by Mercer and Fisher (1992). This work highlights the influence and role of the teacher in setting up computer based activities; intervening with students as
they work through the activities and relating the outcomes of the activities to
students' other experience.

In those computer-based contexts where students take the responsibility for
managing and organising their own activity, there is evidence that the influence of
the teacher, through task design, is crucial to the successful outcome of students
individual and group work. Furthermore in such groupings students take on roles
such as 'pupil-teacher' which, if accepted by other group members, are influential
in the management of group activity (Hoyles et al, 1992).

Within the context of science teaching, group work typically centres on practical
tasks. The nature and role of practical work in school science is the subject of
Chapter Two. However, it is sufficient at this point to acknowledge that many of
the features of collaborative group work described above are likely to be central to
science classrooms where computers are in use.

*Interactions in the learning environment*

In recent years, then the social dimensions of classroom life have been revealed as
significant contributors to pupils' learning. Gunstone (1988) has argued that there
are shared elements of Piagetian and social constructivist (Vygotskian) psychology,
which have relevance for science education. Both Piaget and Vygotsky could be
viewed as constructivists in the sense that they both see individuals as constructing
meanings from experience. As Gunstone (1988, page 85) points out, Piagetians see
development as occurring through distinguishable phases in which different forms
of reasoning are used. Constructivists, however, emphasise the particular content
areas in which conceptual reasoning operates.
For both Piaget & Vygotsky, social interaction was seen as the means by which cognitive growth occurs. In Piagetian terms, social interaction between peers can promote cognitive conflict, but for Vygotsky, interaction between expert and novice was a prerequisite to development of individualised high-level cognitive function. In Vygostskian psychology, it is the shared process of problem solving leading to joint solution, which characterises this view of cognitive development. Vygotsky's conception of the Zone of Proximal Development (ZPD) envisaged learners functioning, with support, at levels beyond that which they could achieve alone. Vygotsky defined the ZPD as ‘... the distance between the actual development level as defined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers.’ (Vygotsky, 1978, page 86). Social interaction is seen as the instrumental means whereby cognitive growth occurs because the more experienced partner supports the learner by structuring and modelling solutions to problems.

In describing how adults can support children’s learning Rogoff (1990 pp. 93-94) identifies aspects of the teacher’s role in the so-called ‘scaffolding’ process. Rogoff lists these role aspects as:

"1. Recruiting the child’s interest in the task as it is defined by the tutor.

2. Reducing the number of steps required to solve a problem by simplifying the task, so that the learner can manage components of
the process and recognise when a fit with task requirement is achieved.

3. Maintaining the pursuit of the goal, through motivation of the child and direction of the activity.

4. Marking critical features of discrepancies between what a child produced and the ideal solution.

5. Controlling frustration and risk in problem solving.

6. Demonstrating an idealised version of the act to be performed."

(Rogoff, 1990 page 94)

Rogoff draws attention to the iterative nature of scaffolding. It is a process in which the tutor is repeatedly revising and tuning their response to the learner in the light of the learner’s progress through the task. The six points listed above provide a useful checklist for studying teaching episodes and interactions involving computers.

Whilst pupils’ personal response to learning environments is at the heart of both developmentalist and constructivist learning perspective, studies of groups of pupils have revealed the contribution of social interactions to learning.

Within the context of science education, there has been a lot of research on pupils’ ideas and beliefs about scientific phenomena (see for example, Driver et al., 1985; Osborne & Freyberg, 1985). This research has sought to explore the ways in which learners develop their understandings of phenomena. It has resulted in a constructivist view of learning which has in turn informed development of
constructivist science teaching approaches, for example ‘CLIS in the Classroom: Approaches to Teaching’ (CLISP, 1987).

The constructivist view conceptualises pupils' understanding as being individually generated and so it can be described as 'personal constructivism'; it is influenced by the psychology of Personal Construct Theory proposed by Kelly (1955).

At the heart of this perspective lies the view that pupils' existing ideas and beliefs are a major influence on the interpretation and understanding given to newly encountered ideas (Driver & Bell, 1986). As Gunstone (1988) has pointed out, other features of the constructivist view of learning, described by Driver and Bell, are predicated on this central principle, these are:

- learning as construction of meanings;
- construction as an active and continuous process;
- meanings evaluated in relation to pupils' existing ideas;
- pupils' personal responsibility for engaging in the construction process; and
- the similarities between understandings constructed by different individuals.

These features have lead to the development of constructivist teaching approaches that can be generalised as a cycle of activity involving the need for teachers to probe pupils' existing ideas, the restructuring of these through activities which challenge existing ideas and lead to development of new ones, which are then evaluated by pupils and applied to new contexts (Driver, 1988).

More recently Driver et al. (1994) have developed a theoretical account of constructivist views of learning and teaching to reflect thinking about the nature of
scientific knowledge and the role of social processes in the classroom. The account presented by these authors (which attempts to integrate ideas from personal constructivism, social constructivism and knowledge of the nature of scientific understandings) serves to highlight the complexity of the science teaching-learning process. Moreover, it identifies the multifaceted nature of the process and the teacher’s role in it. Driver et al. (1994) see intervention and negotiation by an ‘authority’ (usually the teacher) as an essential part of students’ developing scientific understandings. For these authors, it is the nature of the dialogues in which pupils and teachers engage which is the critical feature of the process:

"The role of the authority figure has two important components. The first is to introduce new ideas or cultural tools where necessary and to provide support and guidance for students to make sense of these for themselves. The other is to listen and diagnose the ways in which instructional activities are being interpreted in order to inform further action. Teaching from this perspective is thus also a learning process for the teacher."

(Driver et al., 1994 page 11)

In the closing paragraph of this paper, Driver et al. point out the contrast between the problematic nature of science learning which results from the multifaceted character they describe, and the prevailing rational view of education. They see the need for pupils to develop "a critical perspective on scientific culture" (ibid. page 11); but they argue that students are socialised into scientific ways of knowing through "participating in the discursive activities of science lessons" (ibid. page
Thus for these authors it is pupils' engagement and participation in the dialogic process which is at the heart of science learning. Interactions between participants in science lessons then become the essential means whereby pupils acquire and secure scientific understandings.

The impact of social factors in pupils' constructions of scientific understandings has begun to be explored through research. Alexopoulou and Driver (1996) studied the nature of peer interactions and their influence on argumentation, in groups of students working in pairs and in tetrads. They reported that the pattern of argument was influenced by social interaction in the group. In groups of paired pupils, pre-existing group attitudes towards the task and towards each other, fundamentally influenced the process by which the group negotiated their meanings. More progress was made when groups saw interacting as being collaborative rather than competitive. In fours, it was the interrelation of group members' efforts rather than pre-existing attitudes which influenced progress in the discussion. Whether the raising of objections turned into personal conflicts determined the outcome of discussion to be progressive or regressive.

The authors suggested that in small groups social factors can sometimes prevent members raising their own objections to positions presented by their peers. The existence of conflicting perspectives only seemed to be an aid to discussion in small groups where the members were willing to explore differences openly without turning their disagreements into interpersonal conflict.
An important aspect Alexopoulou and Driver’s work was the suggestion that pupils’ understandings and expectations of the norms of classroom life are significant determinants of lesson outcomes:

“Implicit messages which are conveyed through everyday classroom interactions can have powerful effects on students’ perceptions of what is valued as well as on their interpretations of the nature of the learning process in general and learning science in particular.”

(Alexopoulou and Driver 1996 page 1112)

Within the current context, the presence of microcomputers in the laboratory introduces an additional ‘actor’ in the learning environment. I have discussed earlier in this chapter, the motivational effects of computers. Clearly the presence of these machines provides a further potential focus for interaction in the classroom. It is to consideration of this issue that I now turn.

The above discussion has sought to highlight the need for social interaction to figure in learning environments. Although such interactions are typically mediated through spoken language; other types of communication between people can contribute to the interactions. Non-verbal interactions can contribute to mutual understandings when people work together on a task. However, Rogoff, (1990 page 178) describes the work of Miller who claimed that ‘argumentation’ is the important dialogic exchange that leads to shared thinking, because it can involve resolution of differences leading to new mutual understandings.

A cultural psychological perspective puts dialogic interactions firmly at the centre of the learning process. However, Draper and Anderson (1991 page 96) have
cautioned that one cannot assume that the content of any exchange of dialogue necessarily corresponds to the content of learning made. The argument these authors present is based in part on a philosophical standpoint that an individual can never know that their understanding corresponds to another's intended meaning. The argument also draws on personal constructions of meanings, as being made by individuals through negotiated exchanges. In this view, messages 'sent' and 'received' can never be identical because the 'receiving' process involves individualised interpretation of the message. This view has methodological implications for studying interactions between learners at computers.

1.8 Interactions in computer environments

In this section, I want to draw on research on computer use which has generic implications, and which therefore relates to its use in science teaching. The use of computers in classroom settings can be conceived in several ways. In order to describe these uses, the following discussion draws on Crook's (1994) account of interactions in computer learning environments.

One can consider computer use as applying a teacher-pupil model of teaching and learning. In this model, the technology is used as an information 'delivery system' which can demand responses from a pupil to pre-programmed questions. Crook (1994) has labelled this type of computer use as 'computer-as-tutor' (Crook, 1994 page 11). In this model, the computer (acting as the teacher) presents pupils with structured information and questions which invite a response. As Crook points out, developers of educational software have sought to incorporate features which more closely resemble the kinds of interactions which take place between teachers.
and pupils in ordinary classrooms, and which involve information exchange and evaluative feedback.

Crook has noted that a frequent criticism of ‘tutoring’ educational software is that it constrains the learning experience (Crook, 1994 page 13). The constraining factors arise from the intrinsic design of the software and its mode of use in the classroom.

As technology has developed, more advanced software has emerged which permits greater sophistication in the ‘exchanges’ between pupils and machines. Such ‘intelligent’ software has arguably reached its current peak of development in so-called Integrated Learning Systems or ILS. In these systems, the software typically combines information delivery systems and sophisticated management software. The management system enables the monitoring of pupils’ responses to presented information and the responsive structuring of more individualised programmes to meet the pupils’ needs as determined by the management system. From the earliest development of ‘teaching machines’ to the current sophistication of ILS software, the use of these systems is conceived as individual pupils interacting with the machine. It is noteworthy that the 1998 UK ILS evaluations concluded that, whilst ILS provided a means of extending the range of learning opportunities for pupils, the benefits of the ILS approach were also considered to be related to the non-ILS teaching that pupils experienced (Woods, 1998). Subsequent development of some tutorial software has sought to further develop and exploit the links between the content of the tutorial software and other ‘off-computer’ activity in a more open approach to the ILS model (Rogers and Newton, forthcoming).
Crook has argued that some arrangements of pupils working at the computer (particularly in a 'one computer-one pupil' arrangement) can lead to separation of the computer activity from the main class activity (Crook, 1994 page 110). As Crook points out, this arrangement can appear advantageous to the teacher since those pupils 'occupied' by the machine reduce the demands on teacher time and so liberate more time for the teacher to devote to others in the class. However, the discussion above has sought to place high value of the social nature of learning, and in this sense, 'side-lining' pupils with the computer away from group interaction could be seen as offering a poorer experience that a non-computer alternative. Of course, this may not necessarily be the case, since the precise task and its mode of curriculum delivery will shape the pupils' whole experience. Nevertheless, there is at least a question over the relative value of 'self-contained' computer experiences.

**Group activity and computers**

In a 'one computer one pupil' mode of organisation the machine largely controls what the pupil does in relation to a task. However, the locus of control can shift where software is used to support pupils' activity in other ways. Rather than software itself being the centre of activity, it becomes a tool for pupils to deploy. It is into this category that data-logging software best fits, for it can be used as a means of collection and exploration of experimental data, which pupils can choose to employ.

Despite investment, computers generally remain a shared resource in schools. Typically computers are used to support teaching and machines tend to be used by
pupils working in small groups. Although group work at computers may be driven by limited computer availability, there is a body of research evidence that indicates benefits to pupils of this mode of organisation. Johnson, Johnson and Stanne’s (1985) study of pupils working on a computer simulation in different group modes reported that pupils organised in co-operative working groups perform better than groups organised in other ways (as individuals or intra-group competitors). These authors made a strong statement that

"...when teachers wish to maximise achievement in computer-assisted learning tasks they will be well advised to structure the lesson co-operatively rather than competitively, or individualistically. ... The combination of co-operative learning and computer-assisted instruction seems like a productive one for classroom learning.”

(Johnson, Johnson and Stanne 1985 page 676)

Drawing on this and other work, Underwood and Underwood (1990) suggest that group work at the computer should be organised in co-operative ways. Individual pupils working in such groups appear to take responsibility for their learning, share learning process and learn more effectively than competitive groups pupils (Underwood and Underwood, 1990 page 168). However, it is important to reiterate that research into non-computer based group work in primary school settings suggest that mere organisation of pupils into groups does not necessarily result in collaborative activity by the pupils (Galton & Williamson, 1992). This implies that tasks need to be structured in ways that encourage collaborative
activity between pupils working in groups. This reinforces the importance of the teachers’ role in planning the management of tasks and pupils.

The statements about benefits of co-operative group work at computers are supported by other more recent research. The work of the Spoken Language and New Technology (SLANT) project has reported that computer based activities can be effective prompts for pupil interaction and talk (Mercer, 1994). This work identified the important influence of the ‘acts’ (speech and behaviours) of pupils and teachers in shaping the practical use of software. Mercer describes ‘classroom events’ as being subject to influence by three sets of variables that contribute to use of software namely, computer, pupil and teacher variables, (Mercer, 1994 page 27). Although the focus of the SLANT project was on the types of talk occurring between pupils during computer activities, the identification of the factors that contribute to the context of pupils’ experience of events, is of significance. In relation to types of talk, Mercer describes ‘exploratory talk’ as being educationally useful because it involves reasoning and argument. These are features which, from a cultural psychology perspective, can contribute to pupils’ co-construction of understandings. The generation of exploratory talk is related to pupils’ ability to engage in this kind of interaction. One valuable finding of the SLANT project was that pupils needed to be taught how to use strategies which require them to reason and justify their positions i.e. they needed to be taught how to talk in ‘exploratory’ ways.

Mercer has presented a more detailed analysis of some findings from the SLANT project and has argued that teachers have a essential role in fostering ‘educationally
useful’ talk in pupil groups (Mercer, 1996). Mercer describes exploratory talk as exhibiting a cultural dimension which ‘embodies certain principles - of accountability, of clarity, of constructive criticism and receptiveness to well argued proposals...’ (Mercer, 1996 page 370). These attributes point to the kind of classroom climate that needs to be encouraged and understood for exploratory talk to be fostered. Indeed, the study reported by Mercer (1996) indicated that the occurrence of exploratory talk could be increased by engaging pupils in preparatory exercises away from the computer, in which the objective was to familiarise the children with ground rules for talk.

A number of interrelated themes emerge from the research described above which have implications for the study of computer based science activities. These are:

- knowledge as socially constructed;
- talk as the predominant medium through which knowledge is acquired;
- co-operative group work as a mode of classroom organisation encouraging interaction between pupils;
- teachers as organisers and managers of pupils learning experiences;
- established ‘classroom climate’ as influential in the learning experience.

What kinds of interaction take place in computer learning environments? In a study of interactions of forty eight first and third Grade pupils (6/7 year olds and 9/10 year olds respectively) working on computer-based tasks, Clements and Nastasi (1988) reported higher frequencies of behaviours associated with enhanced cognitive functioning in pupils working with Logo compared to pupils using ‘drill
and practice' software. Although both the Logo and drill and practice groups exhibited co-operative interactions, the authors attributed the higher frequency of certain cognitive behaviours associated with higher forms of reasoning, to the nature of the Logo environment. These authors were cautious in their data interpretation, but nevertheless suggested that the design of the Logo software presented pupils with problems "that must be negotiated, forcing social exchange and, therefore cent rational conflict and resolution." (Clements and Nastasi 1988 page 101). The authors suggested that these features of the pupils' experience have the potential to lead to cognitive and metacognitive growth, and further, that they should be tackled by pupils working in co-operative groups.

Computer as contributor

The computer-learner relationship can be viewed as self-contained in some respects. This view can throw light on the 'specialness' of the computer contribution to the teaching-learning dynamic. Computer use can be separate from other classroom activity in the sense that the relationship between computer and user can be less dependent on the direct influence of the teacher. If this is the case, then the pupil becomes more autonomous as a learner. This autonomy involves the pupil having greater freedom, responsibility and control for self-directing their learning. The curiosity aroused by computer systems, the challenges posed to pupils by well designed software, and the opportunities for self-direct learning, have been identified as features of computer supported instruction that can raise pupils intrinsic motivation to learn (Lens, 1994). Although in this self-contained view of computer use, the machine 'delivers' the curriculum experience to the
pupil, there is the potential for the pupil to control the pace of the process. The degree of control resting with the pupil depends, to some extent, on software design. Nevertheless, new technology offers the potential for a high degree of interactivity between machine and learner and there is a sense in which the computer contributes to the learning process. Thus the learning environment is constructed through the interplay between the actions of teachers, pupils and computers.

There is a subtle, but important, distinction to be made between computer use in which the machine could be seen as merely a passive presenter of information, and the more interactive style of use suggested above. With suitable software design, and through the actions of users responding in an interactive way to the information presented by the machine, the computer can become an additional player in the learning environment. Here then, group work with computers becomes more subtle because of the contributions made by software designers and the pupils using it.

The notion of the computer as a 'participant' and contributor to the learning environment presents a development of educational computer use. If one views the computer as a participant, then in there is a sense in which its contribution is of equal status to that of the pupils or teacher. In other words, there is a 'social' quality to the computer contribution.

1.9 Summary

The foregoing sections of this chapter have sought to sketch the broad context in which this study is set. The broader aspects of ICT use in schools have been raised
and aspects of its use which are pertinent to science education have been highlighted. The general qualities of ICT lend themselves to educational use in supporting pupils' learning and raising pupils' motivation, and types of ICT use and their relationships to different modes of instruction have been considered. An important part of the discussion has been the role of collaborative activity in learning and the potential contribution that ICT can make in this mode of working.

Within the context of science practical activity, collaborative group work is a frequent lesson format. This thesis is concerned with one ICT application used in science education - namely data-logging. There are a number of reasons for this choice, some of which are developed in detail in Chapter Three, but the major reasons for focusing on this aspect of ICT use in science concern the potential application of data-logging to science practical work.

Investigative practical work in science typically involves measurement and repeated data collection. As pupils progress in their science education, they are required to handle their experimental data in increasingly sophisticated ways. Gathered data is displayed in tables and as graphs and interrogated in order to answer scientific questions.

The need for pupils to work in these ways is driven by the requirements of the National Curriculum Orders for science. Information technology is required to be used to support pupils in their study of science. Moreover, the development of technology for data-logging is now at a point where its ease of use has never been greater. It is in regular use in many schools, and features routinely in some. However, data from OFSTED inspections indicate that general use of ICT needs
to be further developed. It is therefore timely to explore our understanding of how
data-logging is used in the classroom and how it can be managed to more
effectively exploit the new opportunities which software developments afford. It is
these issues which are the subject of this study.
Chapter 2

Some aspects of practical work in secondary science teaching

Introduction

The application of ICT to practical work is a relatively recent adjunct to a long-established aspect of science teaching. The use of ICT in practical science is considered in some detail in chapter three, however, the purpose of this chapter is to explore aspects of practical work in science teaching which provide the context of use for data-logging techniques. Here then, the focus is on the nature of school practical work and the debate over its relative merits.

The significance for this study of the debate on practical work is that it reflects the prevailing culture in which the application of computers to practical work occurs. Any meaningful study of the use of data-logging in practice requires understanding of the historical contexts that have shaped the contemporary climate in which it is deployed.

These influences will be felt directly at the school level and indirectly, more generally. For example, at the department level, decisions over provision of resources will have implications for the kinds of practical activities which teachers can choose. Of at least equal importance are the established routines of practical work and the ways in which these both reflect teacher's beliefs about such activity, and shape their (and their pupils') expectations of future practical activities. On the other hand, more general influences include decisions made nationally or by Local Education Authorities, over funding allocations for the
purposes of in-service education; and the decisions made by developers and
providers of software and hardware for practical activity. Thus there is interplay
between a range of factors which may have a bearing on the ways in which
practical science is taught in schools.

Thus, a broad view of what constitutes 'context' needs to be considered. The
subsequent sections of this chapter serve to develop what can be viewed as the
key elements of the contemporary context of science practical work.

2.1 The purposes of practical work.

Practical work has featured in school science since the early nineteenth century
but only became more widely established in the curriculum towards the end of the
century (Gee and Clackson, 1992). Although, in these early times, the type of
practical work was likely to have been predominantly teacher demonstration,
curriculum initiatives in the second half of the twentieth century promoted the
notion of pupils doing practical work for themselves (Hodson, 1990). As the
move to incorporate more 'hands-on' practical into teaching increased, so it began
to feature more prominently as an assessed component in public examinations.

Assessment of practical work in public examinations served to strengthen its place
in the curriculum and to drive its development still further. This trend can be seen
in the development of practical work assessment through public examinations at
age sixteen to the incorporation in the UK National Curriculum of practical
science as a separate attainment target.

It has been argued that the case for hands-on practical work has been presented so
strongly that it has come to be seen as "... the universal panacea, the educational
solution to all learning problems." (Hodson 1990 page 34). It is argued that in this climate, teachers may tend to use practical tasks as a matter of routine, without necessarily thinking through their purposes or reasons for this choice. It is possible, even likely, that the vigour invested in new ideas diminishes as they become familiar through routine use.

Hodson *ibid.* has suggested five major categories of teachers' justifications for practical work. These categories are:

"1. To motivate, by stimulating interest and enjoyment.

2. To teach laboratory skills.

3. To enhance the learning of scientific knowledge.

4. To give insight into scientific method, and develop expertise using it.

5. To develop certain 'scientific attitudes', such as open-mindedness, objectivity and willingness to suspend judgement."

(Hodson 1990, page 34)

Hodson argues that, on close examination these claimed purposes for practical work cannot necessarily be supported. For example, he cites evidence that the introduction of more practical work through initiatives such as the Nuffield curriculum projects did not encourage greater uptake of science studies or more positive attitudes towards the subject.

Hodson scrutinises each of the above claims made for practical work in the light of research evidence. In so doing he challenges the orthodoxy that practical work necessarily achieves the claims made for it. Moreover, he suggests that the
tendency for practical work to be used as a matter of routine results not only in teachers failing to recognise the weaknesses of its over use, but also a failure to fully appreciate the skills, qualities and attitudes it can promote. Hodson's view is that "... some teachers are able to use practical work successfully, with some children, to achieve some of their goals." (Hodson 1990, page 39).

In a later paper, Hodson (1992) has argued for a broader view of what constitutes practical work in school science. He suggests that any approach that requires pupils to be active participants and that has experiential qualities can be conceived of as 'practical' work. Hodson makes a strong case for practical work which is more carefully driven by theory so that pupils can notice salient features of an activity and are less distracted by the 'noise' of less carefully structured practical work. The notion of 'noise' in practical work is worth exploring a little further. If one views this as any factor which may distract pupils from the primary purpose of a practical activity, then it is possible to conceive of a number of different forms of such 'noise'. For example, poor quality ('noisy') experimental data can make connecting results to meanings more difficult; ‘attitudinal noise’ may arise from the degree of focused attention given to the task by pupils; or there may be heightened ‘technological distraction’ particularly in a lesson made more complex by the use of ICT.

Hodson argues for practical work that involves holistic investigations, that enable pupils to experience success and for which goals are carefully planned. The role of pupils' personal response to an activity also features prominently in Hodson's paper; he argues for pupils self-directing their investigations to gain experience
and to build their self-esteem.

It is noteworthy for the present study that Hodson (1992) identifies computer assisted learning (CAL) as offering many of the improvements he argues for. He acknowledges that CAL can be motivating for pupils, as described in Chapter 1. But he also sees CAL as offering pupils the opportunity to work with less 'pedagogic noise' than occurs with ordinary laboratory work. For Hodson, the concrete experiences of ordinary laboratory work present pupils with much information, only some of which is useful. For the pupils, distinguishing between the important and the unimportant presents difficulty and can inhibit understanding. Computer-aided approaches such as databases and simulations, can reduce the 'noise' because they eliminate the concrete experience. Thus they can allow pupils to spend more time on manipulating ideas and building understanding (Hodson, 1992 page 68).

2.2 Skills and processes in practical work

The notion that the purposes of practical work can be easily achieved together has been called into question. Three separate types of practical activity have been describe by Woolnough and Allsop (1985), these are:

- experiences - of phenomena
- exercises - to develop skills and methods
- investigations - open-ended problem-solving activities.

These authors suggest that close linking of practical tasks with science theory may be detrimental to the development of both these knowledge areas. Difficulty may
subsequently arise because of ambiguity of purpose which can lead to a lack of clarity for the learners: too much of what Hodson referred to as 'noise'.

Practical work in science involves a knowledge area that has come to be known as *procedural understanding*. This is concerned with how science is done and has been recognised in work done for the Assessment of Performance Unit (APU). In a study of pupils' investigations in secondary schools, Gott and Murphy (1987) identified the twin influences on pupils' performance of their procedural and conceptual understanding of science.

This division is reflected in the National Curriculum Orders for science (DfE, 1995) where Experimental and Investigative Science appears as a separate attainment target. Nevertheless, the need for this procedural understanding to be developed within specific science contexts is well established.

Prior to the National Curriculum a number of science schemes were developed which had at their heart the teaching of the 'process skills' of science. It was held that these skills could be acquired by pupils through experience and that they would be transferable to new contexts. However, Millar (1991) has argued that some of the cognitive processes which are used in science are too heavily context dependent and influenced by pupils 'common sense theory' for them to be seen as 'pure' and thus transferable skills.

According to Millar, these general skills (such as observation and classification) cannot be taught independently of context. That is to say that one purpose of teaching observation skills in science practical is to teach pupils how to make scientific observations of particular kinds. On the other hand, practical techniques,
and what Millar calls 'inquiry tactics', can be taught and improved through practice. Millar argues here that procedural understandings should be interpreted in terms of practical techniques and inquiry tactics.

Millar and Driver (1987) argued that our understanding of children's learning in science suggests that what pupils learn from a situation is heavily influenced by the constructions they bring to it. Applied to the case of practical science, this notion suggests that observations are unlikely to be objective and that:

"The empirical process which starts with observation and leads through interpretation to experimentation simply does not model children's learning."

(Millard and Driver 1987, page 50)

These authors also argued that a teaching approach based primarily on processes may be "fundamentally misguided" (ibid. page 51) because the interpretations and actions of children will depend upon their prior experiences and personal understandings of the context in which they are working.

These authors are critical of the process approach. For Millar and Driver, the research evidence suggests that children's knowledge is not organised around primarily processes which may be taught in widely differing contexts. They argue that research indicates that it is the 'surface features' of a practical experience which children most readily recall and that these are typically contextual features. The process skills are seen as being at a much higher level of abstraction and too distant from the experience for children to be readily transferable to new contexts.

In 1987 Millar and Driver argued for a rethink in pedagogy towards more active
approaches to practical work. This reflected the significance at the time of the developing understanding of 'children's science'; that is the notion of the learner as actively constructing meanings from their experience, applying prior understandings and teachers accounting for children's misconceptions.

2.3 Practical work in the UK National Curriculum

The discussion above has served to highlight two important aspects of school practical work. Firstly, the broad range of purposes claimed for practical work; and secondly, the debate over content versus process approaches to its delivery.

The inception of a National Curriculum for science teaching has at least clarified the purposes practical work in some respects. From its earliest versions, practical work figured significantly in the National Curriculum. Since 1989, some of the details have changed in the various revisions of the science Order. However, the notion of pupils exploring science through investigative work has remained prominent to date and was a significant feature of the 1995 version of the Order (DfE / Welsh Office 1995) which was in force at the time of this study.

Illustrative and investigative practical work

The apparent separation of practical work into a discrete attainment target known in 1989 as 'Exploration of Science' was accompanied by guidance on the future of other types of practical activity. This guidance emphasised that the other sixteen so-called 'knowledge and understanding' attainment targets should not be seen as non-practical. Indeed the importance of practical work to learning about the concepts of science was stressed, thus "... illustrative and confirmatory practical activities, whether class experiments or teacher demonstrations, play an
important part in the learning of new ideas." (NCC 1989a, page D1).

Exploration of science was seen as offering pupils a range of experiences. The guidance offered was that the aims of investigations were:

"To capture pupils' imagination in science by direct interaction with the materials, concepts and procedures of science in everyday and scientific situations.

To develop pupils' understanding of science concepts by their application to the solving of a wide range of problems.

To encourage pupils to consider the nature of science via the testing of ideas models and theories.

To provide situations where pupils can develop both individual initiative and the skills and attitudes needed for collaborative working.

To encourage pupils to observe the world around them from a scientific perspective and to raise questions and hypotheses in a form which can be tested.

To develop the procedural understanding (investigative skills, strategies and tactics) needed to solve problems and to test ideas models and theories."

(NCC 1989a, page D1)

More recently, Duggan and Gott (1995) have considered the various purposes of practical work within the context of the UK National Curriculum. These authors
have suggested the need for practical work of different kinds to be viewed in terms of learning outcomes for pupils. They argue that in a differentiated view of practical work, there is a clear role for practical work in helping pupils to acquire skills and strategies to support their understanding of science concepts.

Furthermore, it is within the context of whole investigations that these elements of investigative skill come together to enable pupils to find solutions to problems through investigative approaches. In this way, exercises in enquiry, observation and illustration for example, serve not just to advance understanding of associated science concepts, but they also serve to develop pupils' skill base for future investigative work.

Although the format of the National Curriculum Orders for science has undergone two major revisions since 1989, the aims for investigative work expounded in non-statutory guidance have not themselves been revised.

The current Order (DFE / Welsh Office, 1995) requires that pupils should have opportunities to use practical tasks and investigations across the range of science contexts. So the required use of illustrative practical activities as separate experiences from scientific investigation remains in place today; albeit across a curriculum structure significantly different from the original Order.

The prominence of investigative work in the National Curriculum is reflected in its assessment weighting. In the early years, the weighting attached to Experimental and Investigative Science (Sc1.) is equal to that of the other three subject knowledge Attainment Targets (Sc.2, Sc.3 and Sc.4) taken together. In the later years, each of the four Attainment Targets carries equal weight (25%) in the
It is perhaps not surprising that greater weight is attached to pupils' knowledge and understanding of the concepts of science encompassed within the three subject knowledge Attainment Targets (Sc.2, Sc.3, and Sc.4) at Key Stage 4. However, it is noteworthy that whilst the weighting attached to investigative work at Key Stage 4 is reduced, the skills and understanding that pupils are expected to master within science attainment target one (Sc.1) becomes increasingly sophisticated. It represents a progression in the demands and pupils' understanding of Experimental and Investigative Science as they move through school.

2.4 Procedural understanding in investigative work

The notion of progression in investigative work points to pupils' phased acquisition of a set of skills and understandings of how to 'do science'. In an attempt to consider these skills in terms of pupil learning outcomes, Duggan and Gott (1995) have suggested a two-component classification of the key elements of investigative work as 'skills' and 'concepts of evidence'. Together these two areas contribute to the procedural understanding which investigative work seeks to develop in pupils. Duggan and Gott conceive of procedural understanding as "... the ability to put together a solution to a practical problem from their own resources of skill and concepts rather than following a recipe from a worksheet or teacher." (Duggan and Gott 1995, page 139).

These authors see skills to include pupils' ability to use apparatus and instruments. Moreover, they include mathematical skills such as the ability to construct tables...
and draw graphs, which are frequently used in practical tasks.

Duggan's and Gott's term 'concepts of evidence' refers to the understandings which pupils require in order to obtain evidence from investigative work. For the pupils, the understandings in this area which are required include abilities to identify variables, to chose which of these is significant for their investigation and to isolate these. Variables should be controlled in order to construct a fair test.

Decisions need to be made about which variable to manipulate and how this can be done. This must be coupled with decisions about the type, number and frequency of measurements to be made of the dependent variable. Having obtained evidence, pupils are faced with decisions about how to present and interpret it. Pupils should consider what significance can be attached to their data, this means considering its reliability and validity, in particular for other audiences.

Each of these elements of investigation feature as strands in Experimental and Investigative Science in the National Curriculum. Here these understandings are a part of planning procedures; obtaining evidence; analysing evidence and drawing conclusions or evaluating evidence.

Thus the current shape of practical work in terms of National Curriculum science is one of a range of practical opportunities, set in science contexts, which serve to develop pupils' understanding of science concepts and to develop investigative skills. These elements of investigation can be developed and deployed within the context of whole investigations, for the purpose of giving pupils experience in synthesising them in a holistic manner.
2.5 Complexity in investigative work

It was suggested above that there is a progression of skill development in Experimental and Investigative Science. The notion of progression in the National Curriculum implies that increasing demands are made on the pupils as they move through the curriculum. In developing a model of the understandings required by pupils doing investigative work, Gott and Duggan (1995) have applied Bloom's taxonomy of educational objectives (Bloom et al., 1956).

Bloom's taxonomy offers a hierarchical classification of cognitive demand, which can provide a framework for analysis of tasks. Gott and Duggan (1995) use a four level classification to describe the possible 'content' of procedural understanding in investigative work. Their 'procedural taxonomy' includes the following four aspects, in order of increasing cognitive demand:

- Knowledge and recall of skills
- Understanding of concepts of evidence
- Application of concepts of evidence in unfamiliar situations
- Synthesis of skills and concepts of evidence in problem-solving

(Gott and Duggan 1995 page 34)

Gott and Duggan argue that it is only in investigative work that these understandings can be developed holistically. Thus it becomes important for pupils to gain experience of working in these domains and for the processes involved in doing so successfully to be made explicit to pupils. In this sense, the 'content' of the domains needs to be made clear to pupils so that they can make
'intellectual contact' with what they are doing. Through experience and direct teaching of this content, pupils' metacognition of investigative processes can be developed.

The foregoing discussion set out to highlight the idea that for pupils to apply their knowledge and understanding of investigation to solve a particular problem, requires them to work in areas of high cognitive demand. Pupils are expected to tackle demanding tasks when problem solving. Furthermore, research suggests that the difficulty pupils experience carrying out investigations is influenced by a number of factors. Among these factors, the type of task was seen to be of importance (Gott and Duggan 1995, page 51).

Investigative tasks can be characterised in several ways (Gott and Duggan 1995, page 49), but the structure of Sc1. in the National Curriculum typically requires pupils to engage in variable-based investigations.

The number and type of variables involved in any investigation contribute to its 'variable-structure' and complexity. Thus investigations involving single independent variables are likely to be easier for pupils than those with more than one independent variable. Additionally, variables which are continuous (for example, variation of temperature) are more demanding on pupils than categoric variables.

Research carried out for the National Curriculum Council (NCC) in the early 1990s (see Gott and Duggan 1995, page 47-50) classified investigations into four types based on their variable-structure. This classification is shown in Figure 2.1.
In this classification, task types 1 to 4 increase in their procedural complexity. In the NCC research, procedural complexity was considered (with pupils' age and the relevant science concepts), to be a major influence on the performance of pupils in an investigation. A second influential factor on pupils' performance was the openness of the investigation.

'Openness' is an important feature of investigative work in National Curriculum science. The structure Experimental and Investigative Science (Sc1.) implies that pupils should take responsibility for decisions about aspects of their work in this attainment target. However, the extent to which pupils may be permitted or encouraged in this will depend heavily on their teachers' purposes and the stage the pupils are at.

It follows from this that there can be degrees of openness in investigative activity.
depending on how much responsibility teachers want to cede to their pupils. Jones et al. (1992 page 5) have suggested that a science investigation involve three stages: defining a problem; choosing a method and arriving at solutions. They suggest that in each of these stages openness can be considered in terms of a continuum from closed to open as shown in Figure 2.2 below.
Figure 2.2 A Continuum of Openness

(After Jones et al. 1992 page 5)

**Defining the problem**

<table>
<thead>
<tr>
<th>Prescriptive:</th>
<th>Exploratory:</th>
</tr>
</thead>
<tbody>
<tr>
<td>variables</td>
<td>variables not specified</td>
</tr>
<tr>
<td>specified</td>
<td>specified</td>
</tr>
</tbody>
</table>

**Closed**       | **Open**

**Choosing a method**

| Teacher tells students what to do | Free choice of methods |

**Closed**       | **Open**

**Arriving at solutions**

| One acceptable solution | Many acceptable solutions |

**Closed**       | **Open**
An important feature of this model of openness in investigations is that it offers teachers flexibility in the way in which they encourage pupils to take responsibility for different parts of an investigation. In this way it becomes possible for teachers to adopt a differentiated approach to the teaching of investigative skills, which can be matched to the needs of pupils at particular points in their science education.

For any single investigation, its characteristics in terms of these three stages, could therefore be described in terms of three dimensions, as indicated in Figure 2.3.
Figure 2.3 Dimensions of an Investigation

- **Dimension**
  1. Process of defining a problem
  2. Process of defining a Method
  3. Solution

- **Open**
- **Closed**
The structural models of investigations shown in Figure 2.2 and Figure 2.3 highlight the fact that in the most open-ended situations, pupils are faced with a great deal of ambiguity in the task. In developing pupils' skills, experience and competence in investigative work, teachers often need to reduce this ambiguity. The reduction of ambiguity can make the task more manageable for the pupils; but there is also a risk of failing to challenge the pupils sufficiently to develop their competence further. When one also considers the organisational constraints facing teachers planning investigative work in the laboratory, the difficulty of achieving a successful outcome in truly open-ended tasks is daunting. Thus teachers need to be highly skilled in order to manage such tasks successfully.

The challenge facing teachers suggested above is perhaps reflected in a review of secondary schools published by the Office for Standards in education (OFSTED 1998). In the review, HM Chief Inspector of schools reports that:

"Whereas pupils have consistently demonstrated the ability to carry out routine practical tasks, the ability to plan, execute and evaluate their own investigations has only slowly improved despite the revision of Attainment Target 1 (Experimental and Investigative Science) made in the National Curriculum review."

(OFSTED 1998, page 132)

The OFSTED report goes on to stress the need for teachers to have clear objectives for practical work including the need to plan opportunities to develop 'constituent elements of Experimental and Investigative Science' (OFSTED 1998, page 133). The report further draws attention to the fact that data for the Third
International Mathematics and Science Study (TIMMS) reveals that English pupils were better at carrying out procedures than they were at applying their knowledge to explain outcomes from investigations. The same trend was found in the TIMMS data for most of the other countries (Harris, 1998). This finding could be, at least in part, a reflection of the higher intellectual demands of synthesising these knowledge areas, as discussed above. Nevertheless, the TIMMS data show that of the nine countries participating in the study, English pupils were amongst the best performers on the practical tasks.

2.6 Pupils' perspectives on practical work

The previous section has identified the potential difficulty of investigative work for pupils. This difficulty arises because of the high cognitive demands of the skills and understanding used in investigative work; and because of the ambiguity which is a characteristic of open-ended work. Whilst these factors present teachers with organisational and management challenges, for pupils, as relatively inexperienced investigators, they may represent a greater challenge.

At the beginning of this chapter, the view that pupils find practical work motivating was discussed. Hodson (1990) has briefly described literature which calls this view into question. He suggested that a strategy likely to make practical work more motivating for pupils would be to adopt investigative approaches which became more personalised. In Hodson's view increased personalisation can be achieved by involving pupils more in decisions both about what to investigate and how to investigate it. Clearly, there is a tension here between the rewards reaped as a result of pupils' increased motivation in such open-ended approaches
and their increased demands as discussed in the previous section.

What should be acknowledged is that pupils have different needs in practical work. These needs must encompass the conceptual and cognitive domain which investigative work seeks to develop. Moreover, there is a need to recognise the personal investment required of pupils if these are needs to be satisfied. It is in the context of wanting to encourage pupils to make this personal investment that due recognition needs to be given to affective aspects of pupils' responses to practical work.

Science teachers are routinely working with groups of pupils whose individual needs will vary considerably. This clearly calls for a variety teaching approaches to meet pupils' individual science needs; as well as their individual motivational needs in the science context (Hofstein and Kempa 1985).

Hofstein and Kempa sought to describe pupils' preferred modes of learning in relation to motivational patterns. Drawing on other research, the authors discussed four previously suggested motivational patterns seen in pupils. The patterns were named: 'achievers', the 'curious', the 'conscientious' and the 'socially-motivated' (Hofstein and Kempa 1985, page 223). The authors suggest that enquiry-oriented science activities where pupils are required to make judgements were suitable for pupils who were motivated by curiosity. It is noteworthy then, that this type of activity is likely to be less motivating for pupils who fall into the remaining three categories of motivational patterns.

More recently, has been argued that greater attention needs to be paid to affective domain factors in science learning generally, because these factors impinge on
pupils' engagement with tasks (Watts and Allsop 1997). These authors address this issue within the context of conceptual change; however, they seem likely to be of equal significance in investigative work. Here, pupils need to develop and apply the higher order conceptual understandings in order to carry out successful investigations.

Within the context of National Curriculum science, there has been relatively little research on pupils' attitudes to investigative work. A study of these issues has been reported within the context of the Northern Ireland National Curriculum (Jarman and McAleese, 1995). In Northern Ireland, the National Curriculum was introduced a year later than in England and Wales, although it followed a similar structure.

The Jarman and McAleese study involved a part (n = 118) of a survey of pupils in Key Stage 3 in a variety of school types. This sample were interviewed about their perceptions of science. The authors reported that investigations were enjoyed by about half (49%) of the respondents, but 31% of the pupils disliked them. In this survey, the pupils' reasons for enjoyment of investigations centred on the degree of independence they afford to the pupils. However, 33% of the pupils also stated that the difficulty of carrying out investigations was a reason for their dislike of this kind of activity. In this sample it was also found that 79% the pupils perceived themselves as doing investigations only once a year. This finding links to the need to develop pupils' experience and self-confidence in investigations; but it is interesting to note the positive nature of many pupils to investigations as contexts in which they can exert greater control over their activity.
2.7 Contemporary contexts and innovation

The preceding sections of this chapter have sought to identify issues in the area of practical work in science pertinent to this study. It is necessary to revisit these issues in order to more clearly define the contemporary context in which data-logging tasks need to fit.

The views of teachers indicate that there is a range of perceived purposes for practical work in science teaching (Hodson, 1990). In broad terms, these purposes are concerned with developing in pupils skills attitudes and understandings of science as a practical activity, and secondly, they address affective domain factors.

The inception of National Curriculum science has brought the purposes of practical work in a sharper theoretical focus. From a science perspective, practical work can be seen as contributing to pupils understanding of the substantive concepts of science. Additionally, investigations are uniquely placed to develop pupils' procedural understanding of practical science. In National Curriculum science, both these forms of practical work contribute to an important aspect of pupils' experience. Pupils' need to be taught how to investigate; and within National Curriculum science the opportunity exists to plan a differentiated approach to the teaching.

Investigations involve a body of conceptual understandings which pupils need to master. There is a hierarchy of cognitive demand in investigative work, where application, synthesis and evaluation can be seen as higher order cognitive processes. The variable-structure and degree of openness also contribute to the
complexity and difficulty of investigations.

For science teachers, the planning and management of investigative work with pupils is demanding: it is not a low level skill. Although the National Curriculum has been established for some years, teachers have had to adapt to the new approaches to practical science required by the Orders. Evidence from research and reports from OFSTED suggest that the rethinking required to achieve these changes in approach takes time.

Many pupils respond positively to opportunities presented by open ended investigative work. However, the ability of teachers to capitalise on this depends in part on setting investigative tasks in contexts which pupils find engaging. There may be a tension here between this factor and the demands of teaching the substantive concepts of National Curriculum science. Moreover, not all pupils find the relative freedoms of investigative approaches appealing.

Teachers' understandings of these issues contribute to the way in which they construe practical work in their lessons. It the complex interplay between these factors which contributes to the context of practical work.

Science teachers are required by the National Curriculum to incorporate ICT into their teaching. It is into this complex context that ICT must be set. Any such innovation is likely to be interpreted within existing practices of practical work. In this sense, the innovation may be accommodated within current practice. However, the challenge is to achieve innovation in ways that allow new opportunities presented by ICT to be appreciated and exploited.
2.8 Summary

The National Curriculum provides a framework which shapes the purposes and types of practical work carried out in contemporary science education. Of particular importance in National Curriculum science is the role of investigative work and this involves not only acquisition by pupils of practical skills but also sophisticated understandings of investigative strategies and evidence.

Evidence suggests that practical work appeals to many pupils, addressing issues of affect and motivation. Nevertheless, some pupils appear to dislike investigations because of their intrinsic difficulty. The range of curriculum purposes of investigative work and types of investigation presents a challenge to teachers designing suitable activities to secure these purposes. Added to this, pupils need opportunities to gain experience and develop understanding of investigative work. Taken together, these factors create a complex problem for teachers planning investigations. This complexity indicates that careful thought is necessary in planning investigative tasks for pupils.

The foregoing discussion leads to the first important research issue in this study, namely: what are the features of tasks designed by teachers?

This chapter began with a discussion of the purposes of practical work in science education. There has been debate in the literature on this issue, which has led to the call for a broader view of what constitutes practical work and clearer understandings of its purposes. The potential contribution of ICT to this broader view was indicated and a more detailed discussion of this potential that is presented in chapter 3.
Chapter 3

Microcomputers in science practical work

Introduction

Computer approaches in science teaching now include a wide range of possible applications, from the use of generic software, such as word processors and the Internet, to dedicated applications such as CD-ROM material and data-logging software. This chapter focuses on the use of microcomputers in secondary school science practical work. The major purpose of this chapter is to consider some of the prospects for data-logging methods in the laboratory, as identified by research, and to describe something of its current practice. These insights will help to frame and define the focus for the research presented here which is the subject of chapter 4. It should be noted that outside the UK, data-logging methods are sometimes known as microcomputer based laboratories or 'MBL'. Although the term 'MBL' could encompass a range of possible computer applications in science education, for the purpose of the present discussion, it is used as equivalent to the term 'data-logging'. To begin the discussion, it is necessary to look briefly at the origins of computers in practical work in schools, since these have been influential in determining the current position.

3.1 Developing computer use in science education.

When microcomputers were first introduced into schools, science teachers were presented with a new tool to support their teaching. The use to which the computer was put largely reflected the attributes of machines and the available software. In general terms, the approach to computer use was to view the machine
as an additional and novel teaching resource. Computers were used in classrooms as an 'add-on' resource which was accommodated within existing plans and teaching approaches. For example, the teaching of kinetic theory of matter could be supported by software modelling the behaviour of particles under different conditions. This type of computer use provided teachers with additional teaching resources, sometimes enabling presentation of material in dynamic ways and allowing some degree of learner control which was not possible using ordinary video, for example. When the BBC microcomputer became available during the early 1980s, the availability of a simple programming language enabled teachers with an understanding of computer technology to write their own software.

Initially, then, computer use could be viewed as technology driven, because people began to explore what the new technology was capable of. Activity was driven by what was technically possible, and software designers explored and exploited opportunities presented by the attributes of the technology itself. For example, interfaces were developed to allow measurements to be made and displayed by computers. Later software developments enabled such measurements to be recorded and displayed graphically on a computer screen and so, with these developments, data-logging was born.

As the use of computers developed in science teaching, understanding of their educational potential began to emerge. There was a shift of interest in computer use from computer-supported teaching towards teaching with the computer. In other words, a teaching rationale began to emerge, which sought to exploit the potential of computers for teaching and learning. This change of emphasis could be viewed as a paradigm shift in the sense that, rather then being technology-led,
software development and computers use came to be educationally or learning-led; Rogers (1987), for example, described the usefulness of computers as laboratory ‘tools’.

The shift of emphasis suggested above is subtler than the distinction might imply. One can envisage interplay between technology-led and learning-led computer development. The need to develop technology can be driven by a desire to be able to achieve particular educational goals. Equally, new educational possibilities become apparent once teachers begin to use the technology and become familiar with it. The balance between these two driving forces for development can shift and the relationship between them is therefore better viewed as iterative. The importance of this interplay in driving development should not be underestimated. It is, perhaps, a characteristic of the process of innovation, that the familiarity that accompanies use of a new tool can promote a desire to find new uses or new avenues for its further development. Indeed, scholars of diffusion of innovations have recognised ‘reinvention’ of innovation as an aspect of the processes that follow implementation of innovation (Rogers, E., 1995 pp. 174-180). Reinvention of innovation can be viewed as having positive or negative effects. For users of new technology, for example, one can envisage that reinvention permits a degree of ‘customisation’ of approach, which might be desirable if it facilitates its wider use in a particular context. On the other hand, undesirable reinvention could impoverish the innovation and reduce its intended impact on learners. This argument further serves to highlight the importance of teachers’ views and actions in adopting and using computer technology in science classrooms. Looking back on early computer use in science education, it needs to be understood that the
insights that came through increasing familiarity with computers could not be broadly appreciated or exploited in earlier times, as they now are. Nevertheless, some authorities, notably Rogers (1990), did argue that information technology had implicit potential to support learning in science.

What emerges from the view of educational computer use described above is that there have been two sets of influences that have shaped classroom use of computers. One set of influences derives from the features of software and hardware, which are a manifestation of their designer's conception of purpose. These influences are constrained in part, by the state of technological development at a given time. A second set of influences arises from teachers’ ideas of how makes use of software in a particular teaching situation - developing pedagogy for using ICT in science teaching. The range of considerations that may weigh in the teacher’s planning of how to use it will, in turn, shape the practical use to which technology is put in the classroom.

Increasing familiarity with new computer ‘tools’ can lead to a deepening appreciation of their teaching and learning potential and to a more informed approach to planning their use in the classroom.

The state of development of computer use in science education has now reached a point where fundamental questions can be asked about software design and classroom use of new technology. These questions arise because of the understandings that have emerged about computer use. A particularly important aspect of these new understandings has been an appreciation of the role played by the computer in science learning environments, and this was discussed in Chapter One. It has begun to be appreciated that there is something special about
computer-use in the classroom that can contribute a new quality to the teaching-learning environment.

3.2 The case of data-logging

In science education, practical work is often organised as a small-group activity in which pupils share. One can envisage that practical contexts can provide suitable settings in which many of the interactions which offer learning potential, as described in Chapter One, can occur. It is important to reiterate that merely organising pupils into groups for an activity does not, of itself, ensure the establishment of a productive learning environment. Indeed, it has been suggested that group work can generate too much talk, which may impede pupils progress (Underwood and Underwood, 1990 page 160); and some research on computer-based tasks has indicated no apparent gain for a group-based approach over individual pupils working on the task (Light and Colbourn 1987, quoted in Underwood and Underwood, 1990 page 161). What this research evidence indicates is that the ways in which the teacher prepares for, organises and manages the pupils’ activity during a computer-based task, are likely to be of significance in securing the benefits of the approach.

The use of data-logging software typically involves the use of a computer to support a practical activity. Data-logging involves measurement and recording of data, and its subsequent display and analysis using software. Although the computer is instrumental in the practical setting, it is the science involved in the practical activity that is the intended primary focus of pupils’ attention. What research evidence is there that data-logging activities might bring benefits to learning in science?
In order to begin to answer this question, it is necessary to consider the way in which data-logging activities fit into the science curriculum. Writing in 1990, Rogers discussed the place of information technology in the then new Science National Curriculum. Rogers argued that IT use in science provided opportunities to contribute to the development of pupils' 'IT capability' - a concept that featured in consultation documents on the place of Technology in the curriculum (NCC, 1989b) and, later, in non-statutory guidance for IT capability (NCC 1990 page A1). Pupils' IT capability concerned the following four aspects of IT use:

- 'knowledge about applications of IT and about IT tools such as word processors, data bases, spreadsheets and software for processing sounds and images;'
- the skill to use appropriate IT tools effectively;
- an understanding of the new opportunities IT provides;
- knowledge of the effects and limitations of IT.'

(NCC 1990 page A1)

In addition to notions of pupils' IT capability, Rogers (1990) discussed the IT knowledge requirements of the then science Order and, importantly, the potential of IT to support pupils in the exploration and investigation of science. He argued that there was a good fit between the curriculum need for developing pupils' IT capability and the use of IT tools for science teaching purposes. The processes of 'collating, storing, retrieving, searching and sorting of data, the sequencing of instructions, questioning integrity of data, exploring patterns and relationships,
testing hypotheses.' (Rogers 1990 page 254), figured prominently both in science education and as aspects of IT capability.

The potential usefulness of IT to support aspects of investigative science had been discussed earlier; writing in 1987, Rogers signalled the potential of microcomputers to:

- extend our powers of observation;
- increase quality of measurement;
- record data in economical and informative ways
- facilitate interpretation by providing large amounts of high quality information
- provide calculating and analysing aids for data investigation;
- communicate results to highlight their significance; and
- provide motivation through early feedback.

(Rogers, 1987 page 219)

Many of the potentialities Rogers ascribed to microcomputers are direct consequences of their attributes rather than being features explored and tested in research settings. It is noteworthy that, at this relatively early stage, Rogers suggested that other contextual factors needed to be considered by teachers planning to use these new computer tools (Rogers, 1987 page 224).

Rogers’ early aspirations for computers in science education were echoed by those expressed by Thornton (1987) working in the United States of America. Drawing on research, Thornton suggested that microcomputer-based laboratories
(MBL) offered certain pedagogical advantages within a physics curriculum. These advantages were:

- learning enhancement through an extended range of investigations;
- ease of use of computer tools - permitting users to attend to the science rather than the tool;
- encouraging critical thinking skills by removing the drudgery of data collection and manipulation;
- encouraging peer learning;
- more effective teaching of graphing skills by directly linking graphs with physical events;
- making the abstract more concrete by immediate feedback of symbolic representations;
- reducing science anxiety by helping anxious users feel in control of their learning; and
- being effective for the under prepared student because the MBL tools make it easier for less experienced learners to gather data.

(Thornton 1987 pages 235-238)
Scaife (1993) suggested that the contribution of computer technology through data-logging was derived from their calculating speed, memory capacity, endurance of data collection over extended time periods or in hostile environments, data manipulation features, the impact of real time presentation of data, and the motivating effects on users of 'high-tech' equipment (Scaife, 1993 pp. 83-84). Again, these benefits derive largely from the attributes of software. Scaife further described features of then contemporary data-logging equipment and the range of opportunities presented by the development of increasingly user-friendly hardware and software. Scaife was optimistic that continued technological development would improve user-friendliness still further and broaden the range of application opportunities in science as new sensors were developed. Scaife signalled that the introduction of new technologies into science classrooms brought changes both to the type of activities pupils could undertake using the new technology and to the roles of teachers in lessons featuring new technology. He therefore argued that introduction of ICT influences the methods, content and aims of education (Scaife, 1993 page 84).

A consideration of some of this relatively early literature reveals that the value of data-logging technology was seen largely in terms of the technological advantages offered by computers over traditional measurement and recording methods. Properties of calculating speed, storage capacity and data retrieval, data manipulation, automated graphing and the potential to develop new practical approaches emerged as beneficial features of the data-logging method. Yet, attributes of the approach that may offer benefits to learning were also identified; in particular, a number of features of data-logging were viewed as offering the
potential to support pupils' thinking about data. Time savings and reduction in the drudgery of data collection were considered to offer the prospect of pupils spending more time thinking about data interpretation (Barton and Rogers, 1991; Barton, 1993) and the immediacy of data presentation on-screen was considered to be a motivating factor for pupils (Barton, 1993). Moreover, data-logging methods were seen to present opportunities for teachers to set investigative scenarios for pupils' practical work; software allowed pupils to find answers to scientific questions both through the ease of data collection and by providing tools to explore data (Rogers, 1987; Barton and Rogers, 1991; Harrison, 1997).

In practical activity, pupils need only to make decisions about what parameter to measure, in a suitably designed experiment, and to select the appropriate sensor, to be able to record high quality data. But, as Harrison (1997) has pointed out, the computer does not replace skills in experimental design, identification of variables, and data interpretation. Nevertheless, quality data is assured in data-logging methods because the electronic sensing device removes the high skill demand associated with traditional instruments, and so there is a concomitant error reduction in data collection (Rogers, 1987; Harrison, 1997). With development of a range of sensors and software, the possibility arose of shifting the emphasis of activity from data collection to more focused consideration of the scientific problem itself (Rogers and Wild, 1994).

Development of data-logging software has meant that experimental data, which has been collected electronically, can be rapidly displayed on a computer screen, typically as a \( y-x \) graph. Further refinement has lead to the creation of analytical
tools, as intrinsic features of the software, which allow for sophisticated display and exploration of graphical data (Rogers, 1995; 1997).

In principle then, the development of analytical software tools well supports an exploratory approach to data analysis and interpretation. In addition to basic operations, such as reading point values from graphs, there is the potential for pupils to use software tools more creatively. Consequently there is some scope within the data-logging approach for pupils to devise their own strategies for using software to investigate phenomena (Harrison, 1997). Furthermore, the attributes of the data-logging method offer scope for these software-supported approaches to analysis and interpretation to be deployed in a wide range of science practical settings. New types of investigations of transient or of long-term phenomena, which are at best problematic with ‘traditional’ approaches, become manageable using ICT.

Thus there is considerable scope for pupils’ investigative work using data-logging. To reiterate, this scope derives from two sets of new opportunities, the first concerns the wider range of practical contexts that can be explored. Secondly, there is the potential for pupils to investigate the electronic data they have collected.

Earlier in this Chapter, it was suggested that, in the field of data-logging, there has been a balance between technology-led and learning-led software development and this is reflected in the literature which has shown a shift in emphasis from descriptions of software features to more careful consideration of their benefits to learners in science. The question therefore needs to be asked of what research evidence there is of the contribution of this approach to learning in science.
practical work. In the early 1990s, the direct answer to this question was relatively little! Indeed, the lack of published research about data-logging was identified with the publication of the first significant collection of research papers in the field (Tinker, 1996 page 5). Tinker's volume presented a broad view of research in the field, encompassing research perspectives, a consideration of aspects of MBL and learning, and development of hardware and software systems. It is necessary for the present discussion, however, to retain a focus on aspects of classroom use of data-logging methods.

In a review of literature concerning the effect of microcomputer-based laboratories (MBL) on science learning, Mary B. Nakhleh (1994) considered this question in three areas. First, the contribution to students' understanding of graphing; second, the development of science concepts; and third students' understanding of scientific experimentation. These three areas provide a useful framework for discussion of the possible benefits of data-logging. The following section considers some of the issues raised in Nakhleh's 1994 review and attempts to update these with more recent research findings, particularly from a UK perspective, since this reflects the context of the current research described in this thesis.

A widely cited paper in the field is that of Mokros and Tinker (1987). Their research indicated that the value of the MBL method derived from the four attributes; namely:

- the multiple representation of data;
• real-time graphing allowing pupils to associate the emerging graph with the physical experimental events;

• pupils' effort could be focused on graphical interpretation rather than their construction; and

• pupils could investigate in a scientific manner.

Real-time MBL has been shown by Brasell (1987) to be most effective in enabling pupils to relate a physical event to a graph, compared to computer-based approaches where there was a delay between the physical event and its graphical representation on the computer screen. Brasell suggested that the improvement shown was due to the motivating effect of pupils being able to connect the real-time experimental event with the developing graphical image. Moreover, it was suggested that the improvement occurred because the real-time processing of data by the computer reduced the demands on students' long and short-term memory for information processing.

In the UK, Phillips (1986) suggested that graphical display of data could act as a 'store' of information and so become a memory aid for users because there was no need to store raw data in the user's head. So the graph reduced the cognitive demand for information processing.

Linn, Layman and Nachmias identified the memory-support attribute of the MBL environment as significant in research indicating that MBL helps students to understand and use graphs (reported in Nakhleh 1994). Nachmias and Linn have also indicated that students using MBL have shown more critical awareness of data, being able to identify causes of unreliable graphs such as scaling errors (see
Interestingly, Nakhleh (1994) has described the work of Adams and Shrum, which showed no significant difference in students’ performance on graphical construction or interpretation between MBL and traditional methods. However, a change was reported in students’ attitudes to the MBL approach over time, in that the computer came to be regarded by the students as a tool that freed time for students to do other tasks.

In contrast, Voogt (1996) reported an increase in students’ graphing and science reasoning skills in an inquiry-based MBL environment. This research also reported teachers’ perceptions of increased student motivation in the courseware curriculum investigated by the study. Interestingly, the study also indicated the importance of teachers adopting suitable behaviours to promote an inquiry-based approach. A further interesting feature of Voogt’s research, pertinent to the present study, were the complexities associated with implementing the computer courseware approach. These complexities included technical problems with equipment, but also the need for teachers to understand how to integrate the new technological approach with established teaching approaches (Voogt, 1996 page 222).

In the UK, Friedler and McFarlane (1997) conducted research into the impact of data-logging on graphing skills in secondary pupils. Using a pre-test and post-intervention test strategy, they found that fourteen-year-old pupils showed gains in graphing skills which were not necessarily replicated in groups of sixteen year olds. However, these authors were cautious in their interpretation of findings, particularly since the intervention activities were not the same for the two age groups.
Barton's (1997) comparative study of graphing using computer and non-computer methods has highlighted the flexibility afforded by the computer approach. Real-time plotting has time advantages over manual methods, in particular in encouraging pupils to focus on trends and patterns rather than individual data items. A further important aspect of Barton's study was the potential for engaging pupils in talk about data. The teacher could prompt this discussion, and Barton suggested that the combination of real-time data display and prompt teacher intervention could be a powerful stimulus for discussion about data.

Kelly and Crawford's (1996) work on discourse in MBL environments in 12th Grade Physics classes has indicated that the computer plays particular roles in these settings. These authors' analysis of discourse indicated that computer representations are meaningless unless the students bring them into conversation. Thus there is a sense in which the computer contributions play a part in the social interactions in the laboratory and in the development of scientific understandings. Students invest some authority in the computer contribution. This can be as a source of support to their developing thinking when the students use the computer for example, to support an argument. Alternatively, the computer can become a 'group member' in the sense that it may trigger responses and reactions from students as information is presented.

The computer emerges as a focus for pupils' talk again here - an important feature that can contribute to the learning experience in computer-based laboratory activity. Of particular significance is the social dimension to these group interactions. Here is the potential for computer-based activity to provide contexts that can encourage interaction between groups of pupils and there is the potential
for discussion and argument with pupils making or defending a case. These sorts of interaction seem likely to secure pupils’ learning about graphical interpretation and the concepts associated with the scientific context in which the pupils are working.

Considering the acquisition of science concepts, Nakhleh and Krajcik (1993) studied students’ understanding of acid, base and pH concepts. They used various technologies (indicators, pH meters, computers) to investigate the effects on interactions of different levels of information provided by the different technologies. The authors speculated that MBL would engage students in more active thinking because of the high level of information provided by the computer throughout the experiment. The students in the study were asked to provide a commentary of their activity, which the authors then analysed using a protocol analysis approach. The main findings of the research indicated that there were more verbalised procedural statements from MBL group. The authors considered that this could be because students had to enter data into the computer. There was a decline in the frequency of the IT group’s analytical statements but these statements were qualitatively more meaningful than the other non-IT groups. The authors speculated that the MBL-generated graph had piqued students’ interest and caused them to draw harder on their long-term memories. Students using IT reflected more analytical thought processes, as defined by increased speculation, increased prediction, increased ability to relate these observations to concepts. This increased speculative activity resulted in MBL students producing more acceptable and unacceptable understandings, which the authors suggested had implications for teaching in that there was a need to develop teaching approaches
which could address students' unacceptable understandings and shift these
towards more acceptable ones.

Nakhleh's (1994) description of research into the influences of MBL on students
understanding of scientific inquiry identified several aspects indicative of support
for investigative work. The flexibility of MBL appears to afford opportunities for
students to engage in cycles of experimentation, and students' confidence in their
own abilities to design experiments, interpret data and draw conclusions. MBL
has been seen as an appropriate environment in which to develop scientific
reasoning skills. It has further been suggested that MBL does not so much teach
students how to think but rather frees them to think about what their experimental
data means. Thus the integration of MBL with other teaching protocols can
provide students with opportunities to develop skills in integrating their
knowledge and understandings.

These findings are supported by those of Rogers and Wild (1996) in the UK
which have indicated the importance of teachers adopting an exploratory style and
investigative approach in order to exploit the new opportunities afforded by data-
logging.

In a review of research, Weller (1996) considered the benefits of new technology
for science learners. With respect to data-logging, research indicates that the
opportunity to collect and work on first-hand experimental data offers genuinely
scientific experiences to pupils. Moreover, data-logging can contribute to pupils' 
skills in scientific inquiry; and add to their understanding and interpretation of
graphically presented information.
In North America, the Technology-Enhanced Secondary Science Instruction (TESSI) project, where a wide range of technology was fully integrated with carefully structured teaching approaches, has reported findings that pupils in IT-rich settings began to work in more independent ways (Pedretti et al. 1998). These researchers have identified the importance of the social dimension in pupils' personal response to this learning environment. Like Rogers & Wild (1996), they recognise that factors other than the attributes of the technology appear to be influential in the successful integration and use of new technologies in the classroom.

To summarise the above discussion, research indicates that data-logging has considerable potential to develop pupils' abilities to understand and interpret graphs. This benefit derives from the immediacy of dynamically produced graphs in real time data-logging, which helps pupils link experimental events with the graph 'image'. The reduction in demands on pupils' memory achieved by the computer presented graph enable pupils to invest greater mental effort and attention to more interpretative activity. Pupils appear to be more engaged by computer presented graphs, and they interact with the computer in ways that suggest they draw on the machine as an information provider and as a tool to answer their questions. The computer can be a powerful stimulus for collaborative group activity, of a kind that seems likely to benefit learning; affective domain factors also appear likely to be important in these settings. The combination of a computer presented graph with appropriate questioning, is a powerful stimulus for pupils' talk. The teacher's role extends beyond appropriate intervention, to setting
tasks in suitable contexts with suitable supporting inquiry-based teaching approaches in order to derive the maximum benefit from the data-logging method.

3.3 Data-logging - the implementation gap

From the above discussion, it seems with the introduction of computers into classrooms, that there are three sets of influences that contribute to learning environments. These are the actions of the teacher, those of the pupils, and the ‘actions’ of the computer. These three sets of influences and their relationships need to be considered in the further study of data-logging in the classroom.

Despite a growing body of research evidence indicating potential benefits for the data-logging approach to practical work, its use in UK schools has grown slowly. An National Council for Educational Technology (NCET) survey of data-logging use in UK schools reported in 1993, indicated that only 11% of schools used data-logging for more than three hours per year, 35% reported no use at all (see Rogers and Wild, 1994). More recently, information from the Office for Standards in Education (OFSTED) suggests that IT is generally under used in secondary schools (OFSTED, 1998). Anecdotal evidence of the use of data-logging in schools seems to indicate that its use remains relatively sparse despite improvements in ease of use and sophistication of more recent software. Recent Surveys of ICT in English schools, reported by the DfEE in recent years, indicate that a significant percentage of schools report little use of ICT in secondary science; in the latest report the figure reporting little ICT use was 49% (DfEE 2000).
There are likely to be many factors that influence teachers' decisions to use data-logging approaches. Lack of suitable equipment may be a problem in some cases, but issues such as teachers' personal confidence in using ICT and their understanding of how to use it in the teaching laboratory may also figure in these judgements. The demands on teachers in the contemporary context have also been considerable, and there is currently a range of pressures on teachers, which may detract attention from investing the necessary time and effort in developing data-logging in science teaching.

Several authors have discussed the problems and opportunities facing science teachers employing ICT in their teaching for example Barton, 1993 and Newton, 1997. Most recently, Tebbutt (2000) has identified barriers to ICT use in three broad areas: shortages in computers and related hardware, lack of teacher expertise and inclination (for some) to use computers coupled with a lack of access to machines to address these issues, and finally the lack of clarity of teaching purpose when faced with a wide range of possible options and generic software. In addition to these factors, Tebbutt raises the need to consider issues pertaining to teachers' workload and pupil characteristics, which might also influence adoption of ICT approaches over others.

From the late 1990s to date, there has been more systematic investment in ICT skills training for teachers. For example recent curricula for initial teacher training in England and Wales (DfEE, 1998) have emphasised the importance attached to use of ICT in subject teaching. For serving teachers the New Opportunities Fund ICT training initiatives (NOF 1998; TTA 1998) have set out to raise the level of ICT skills of experienced teachers. However, Tebbutt (2000) has questioned
whether the structure of these training programmes will adequately meet the needs of teachers whose inclination and motivation to use ICT in their teaching is low. This issue raises the question of how people can be persuaded of the benefits of using ICT over 'traditional' approaches and it seems unlikely that skills training alone will achieve this.

3.4 The need for more research

In order for some of the benefits of data-logging to be more widely appreciated, ways need to be found of winning teachers' support and of finding approaches to using the technique in the routine teaching laboratory. This means finding ways of working with data-logging in real classrooms - the typical circumstances in which science teachers regularly work. Although some of the research discussed above is classroom-based, writing in 1994 Nakhleh called for more 'real-world' research in this field. Unless the use of data-logging can be researched in these settings, many of the benefits claimed for the method will remain achievable only in carefully controlled research settings.

For these reasons, the present study is concerned with research into data-logging in secondary school settings. It is intended to explore and understand the influences on what might be achieved with data-logging in everyday classrooms, and which shape teachers' decisions about how they teach. It is concerned with what is currently achievable with a view to identifying avenues for future exploration. Of particular importance is the need to consider the ways in which the introduction of the computer into the science teaching laboratory changes the teacher's role. These themes are developed in the next chapter, which seeks to define a set of research questions.
Chapter 4

Research Issues

Introduction

The preceding chapter explored aspects of the potential contribution of data-logging technology in the science laboratory as identified through research. The analysis was set against the background of the development of computer use in classrooms because this provides a sense of the context in which science teachers currently operate.

A case has been argued for directing the research into current use of data-logging in the 'real world' of classrooms. To what extent can the claims made for data-logging be secured in these classrooms? What features of the current practice of data-logging appear to help secure the benefits? What further aspects of practice need to be put into place to secure the benefits? These questions set the broad focus of this thesis. The purpose of this chapter is to consider these questions further in order to identify issues for further study.

4.1 Teachers' skills in teaching with ICT

Teachers are instrumental in shaping classroom contexts: central to the science teacher's craft is the skill to plan and orchestrate pupil activities to meet specified learning outcomes. It is through the experiences organised by teachers that much of pupils' learning is mediated. However, a socio-cultural view of learning is based on the idea that the classroom culture in which teachers and pupils function is itself constructed by their individual and shared perceptions of a whole range of current
and past experiences. This viewpoint presents a challenge for any study of data-logging classrooms that involves an outsider undertaking a research study, since outsiders cannot have been party to these historical events. Despite this limitation, a focus on task design and their presentation and management with pupils provides some potentially useful insights into the data-logging classroom.

As discussed in Chapter Three, research indicates that the contexts in which ICT tasks are set is of at least equal importance to the features of the technology itself, in determining the learning benefits for pupils. To the extent that recent software developments enable more demanding tasks to be set for pupils, ICT seems to be under-exploited. Where these capabilities are seen to be exploited, there seems also to be a history of an 'investigative climate' in the classroom (Rogers & Wild, 1996). This means that further research needs to include consideration of context and classroom 'climate'.

Developments in ICT have not tended to follow a demand for better teaching tools from teachers. Rather, technologically-minded teachers see what they can do with newly available hardware and software. This is not surprising, but it has perhaps had the effect of generating a culture of pragmatism in which much of the literature available to science teachers, has focused on novel ways of using ICT to do 'everyday' experiments. For teachers, the benefits have mainly been concerned with making the practical work more convenient, for example by facilitating easy data collection. Perhaps it has been assumed that this convenience would, of itself, bring benefits for pupils’ learning.
It is possible that the shift from using computers to adapt traditional experiments towards using it to develop new ones represents a typical development in the implementing of innovation. One can envisage that this type of development would require a deeper level of understanding and experience of using ICT than knowledge and skill in software and hardware operation. Such a deep understanding might include knowledge of the properties of software and appreciation of how these properties can lead to benefits for learners (Rogers and Wild, 1996).

In some schools, the levels of ICT resources have meant that it has not been possible for teachers to easily become fluent and practised in the use of ICT. Other demands on teacher time and limited budgets have added to the difficulty for teachers improving their ICT awareness. In this situation, it is not surprising that where ICT is used more extensively, it is as the result of the efforts of committed technophiles. As discussed in Chapter Three, recent Government programmes to invest in development of teachers' skills and confidence as users of ICT for teaching are perhaps some recognition of the need to raise ICT skill levels in the larger proportion of science teachers.

There has been an apparent tendency of science teachers to assimilate new ICT-based approaches within their existing repertoire of teaching formats. For teachers to accommodate and exploit the particular attributes of ICT for learning seems to demand a critical level of resource provision and personal ICT awareness. Against this backdrop, the attributes of ICT that may improve pupils' learning and the decisions taken by teachers in relation to learning with ICT, have received
relatively little attention. Again, this is an area for development that the Government ICT training programmes seek to address.

Advances in technology and falling hardware costs now mean that the range of equipment available to teachers is greater than ever before. Consequently, teachers are faced with the need to make choices about teaching approaches in practical science, which can include decisions about ICT. These decisions need to identify the learning benefits of a particular approach and the contribution ICT can make to this. Consideration of matters such as these will inform the ways in which teachers design learning activities and this leads to the first research issue for the present study: describing the features of data-logging tasks designed by teachers.

4.2 The value of analysing the learners’ tasks.

The primary purpose of data-logging methods is to support pupils in the collection and analysis of measurements in order to find answers to scientific questions. Within the context of such activity, one approach to task analysis is to consider the structure of tasks. Two important features of investigative practical tasks were described in Chapter Two. First, the location of the task on the ‘open - closed’ task continuum; second the number and type of variables included in the design of the activity. For teachers using data-logging, decisions about these two dimensions of task design define the ‘task arena’ in which their pupils will act. For this reason, the potential of any task to allow pupils to engage in the analytical and evaluative aspects of National Curriculum Experimental and Investigative Science is either constrained or liberated by design decisions.
Bloom's Taxonomy of educational objectives provides a framework against which tasks can be judged for their cognitive demands (Bloom et al. 1956). Although originally designed as a means of allowing teachers to relate educational objectives to cognitive processes, Bloom's taxonomy has been adapted and used for different purposes. One useful feature of the taxonomy is that it provides a hierarchical classification for objectives, which enables classification of an activity in terms of its cognitive demands. This approach has been used to develop a taxonomy applicable to procedural aspects of investigative work (Gott and Duggan, 1995). It can also provide a means by which task setting could be better targeted to pupils of differing abilities.

Kerry (1985) reported a study of science teaching using task analysis. This study examined 640 tasks set by teachers for first year, mixed ability science classes in comprehensive schools. Tasks were sorted into groups and a classification emerged from this process based on teachers' own definitions of their intentions in setting the tasks. The derived categories were then judged for their cognitive demands using a modification of Bloom's taxonomy. Using a different methodology (task description through teacher diaries) a related study was made of Primary classrooms.

The findings of Kerry's study revealed a greater proportion of higher order tasks set in Primary than in secondary classes and "the relatively trivial nature of many comprehensive school classroom tasks" (Kerry ibid. p53), across the curriculum. However, the demands of combined science tasks were relatively more sophisticated than in other subjects.
Kerry's study, of course, pre-dates the science National Curriculum Orders which require pupils to engage in a broad range of practical tasks, including investigations, as discussed in Chapter Two. However, the 1998 Ofsted review of secondary education 1993-1997, indicates that despite revision of the Orders, there has been only slow improvement in pupils' ability to plan, carry out and evaluate their own investigations (OFSTED 1998, page 132). In both this 1998 Ofsted review and a later annual report (OFSTED 1999), attention has been drawn to the relatively narrow range of investigative tasks which pupils have been offered. Moreover, these tasks have often been executed by pupils “... to a format prescribed by the teacher.” (OFSTED 1999 page 35) rather than in a more open approach.

Consideration of the opportunities presented in data-logging tasks to challenge pupils in the higher order cognitive domains of application of ideas, synthesis and evaluation is an important aspect of the present study, since the potential of data-logging technique to support this type of activity is high (Harrison, 1997; Rogers, 1997).

Task setting needs to consider the demands of the task in relation to the pupils for whom it is intended. This approach implies that there needs to be a match of tasks to pupils in terms of cognitive demand but also in relation to students' preferred modes of learning and different motivational patterns (Hofstein and Kempa 1985). One conclusion from the Hofstein and Kempa study is the difficulty of achieving any good match between teaching strategy and motivational approach in heterogeneous classes. The authors conclude that there is a consequent need for a
varied set of approaches in order to meet different motivational needs of as many pupils as possible.

4.3 The value of studying the classroom climate

The way in which tasks are presented is perhaps a more subtle influence on pupils' activity: teachers can 'frame' tasks in ways that influence how open-ended they are. In addition, the style in which tasks are set can influence the way in which the pupils tackle problems. The question of activity style is important for the current discussion. Here, style is viewed as concerning how lessons are taught rather than what is taught; it is concerned with the ethos created by through the communication between teachers and learners (Newton and Rogers, 1996). For example, the style could be exploratory and investigative; alternatively, pupils could be asked to confirm ideas from other experience. The approach could be questioning, alternatively ideas could be presented to pupils in a more 'cut and dried' style. Pupils could work collaboratively or competitively. Furthermore there are questions over the roles will the teacher adopt in the lesson and how might they intervene in the pupils' activity. For example, will they adopt a high profile in the lesson or sit back and let the pupils manage the task?

These choices of approach contribute to the classroom ethos in which pupils work. They reflect something of teachers' beliefs about science education. They also present a set of issues for consideration in the study of data-logging classrooms. It is important to appreciate that classroom climate cannot easily be defined nor its impact on the activity of pupils and teachers (and researchers) readily explored. The difficulty arises because, whilst they may be exposed to shared events,
participants will make personal interpretations of these. So, pupils’ perceptions of a particular style of task presentation may be at variance with the teachers’ intentions and perceptions, or indeed those of researchers.

Research has been reported of the development and use of so-called ‘Classroom environment inventories’ in a wide range of countries and contexts. Typically, these instruments have been designed to probe and describe pupils’ attitudes (Fraser, 1977; 1978) and their perceived and preferred classroom climates (Fraser et al. 1993). These instruments provide a potential means of exploring aspects of the predominant style within a particular episode of data-logging.

The practical organisation of data-logging tasks in the classroom presents teachers with a further set of decisions. For example, teachers might consider whether data-logging will be a whole class activity or part of an activity circus. Will pupils work as individuals or in groups? If pupils work in groups will they be organised as pairs, triads or even tetrads? How will roles be assigned to group members? Will these be pupil decisions or will the teacher allocate pupils to roles? What is the relationship between the computer-based work and other activity?

From the above discussion, the following themes emerge as pertinent to the present study of data-logging classrooms:

- What are the features of data-logging tasks designed by teachers for pupils?
- How are the activities organised and managed by teachers and how does this determine predominant style of the lesson activity?
- What are the roles of pupils and teachers in data-logging lessons?
4.4 Interactions in lessons: the value of studying the discourse.

Talk is a prominent feature of classroom activity and there is a long-established body of research into its nature and roles in the learning process. For example, in a pioneering study, Douglas Barnes (1969) presented an observational analysis of the classroom use of language in the early years of secondary education. This study did more than describe the nature of episodes of classroom talk: it raised questions about the purposes of such talk. Barnes' work also raised pedagogical concerns about ways of developing teachers' appreciation of the use language in the classroom to promote effective teaching and learning.

Later work in this field has identified how the roles that learners adopt contribute to the social interaction within working groups and also contribute to the context in which talk related to subject content take place (Barnes and Todd, 1977). This work importantly identified that learners could negotiate understandings away from the teacher's control and that this could encourage greater independence.

More recently, drawing on the Primary School context, Mercer (1996) has presented a research based analysis of the role and quality of children's' talk in collaborative group work. Mercer's argument is presented around three themes: knowledge construction as mediated through children's shared talk; education as culturally and linguistically based; and the roles of teachers in encouraging children in talk of particular types. Mercer presents a persuasive case for the importance of talk in classrooms. He draws on an extensive literature-base grounded in observational and experimental research. Of particular interest to the present study is Mercer's account of the different analytical categories of children's talk.
developed in the Spoken Language and New Technology (SLANT) Project (Mercer 1996 page 368). Here, “Three ways of talking and thinking” (page 369) are described. These categories of talk are labelled ‘Disputational’, ‘Cumulative’ and ‘Exploratory’. Mercer offers analytical descriptors to help characterise the talk in each of these categories. These are summarised in Table 4.1.

Mercer sees Exploratory talk as educationally more useful than the other SLANT categories: “Compared to the other two types, in exploratory talk knowledge is made more publicly accountable and reasoning is more visible in the talk. Progress then emerges from the eventual joint agreement reached.” (Mercer, 1996 page 369).

Mercer further offers a multilevel analytical framework for describing talk. This framework addresses the linguistic, psychological and cultural functions of talk. These levels of analysis can be mapped across the three talk categories as shown in Figure 4.2.
Figure 4.1 Characteristics of the Analytical Talk Categories used in the SLANT Project

<table>
<thead>
<tr>
<th>Disputational talk</th>
<th>Cumulative talk</th>
<th>Exploratory talk</th>
</tr>
</thead>
<tbody>
<tr>
<td>disagreement,</td>
<td>repetition,</td>
<td>critical</td>
</tr>
<tr>
<td>individualised</td>
<td>confirmation,</td>
<td>constructive</td>
</tr>
<tr>
<td>decision making,</td>
<td>elaboration</td>
<td>statements offered for</td>
</tr>
<tr>
<td>few attempts to</td>
<td>uncritical</td>
<td>joint consideration,</td>
</tr>
<tr>
<td>pool resources,</td>
<td>positive.</td>
<td>challenges justified</td>
</tr>
<tr>
<td>little constructive</td>
<td></td>
<td>alternative hypotheses</td>
</tr>
<tr>
<td>criticism,</td>
<td></td>
<td>offered.</td>
</tr>
<tr>
<td>short exchanges,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>assertions and</td>
<td></td>
<td></td>
</tr>
<tr>
<td>counter-assertions.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(adapted from Mercer, 1996 page 369)
Figure 4.2 A summary of levels of analysis of talk applied to the SLANT analytical categories

<table>
<thead>
<tr>
<th>Level of Analysis</th>
<th>Mercer's Analytical Categories of Talk</th>
<th>Exploratory</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Linguistic</strong></td>
<td>Disputational</td>
<td>Cumulative</td>
</tr>
<tr>
<td>(content and function of talk)</td>
<td>Assertions counter-assertions</td>
<td>Repetitions, elaborations</td>
</tr>
<tr>
<td>(talk as thought &amp; action)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Cultural</strong></td>
<td>(considers the nature of educated discourse and the reasoning patterns valued in “the cultural institutions of formal education” (Mercer 1996, Page370)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Using the analysis presented in Figure 4.2, characteristics of talk can be identified which exhibit some of the attributes of 'Exploratory' talk and which may reveal the speaker's reasoning (these aspects are 'greyed' in Figure 4.2). These characteristics reveal talk as a representation of thought and this analysis provides a potential means of probing children's developing ideas within a learning situation: a 'place' to look for evidence of learners engaging in higher order analytical and interpretative activity during episodes of data-logging practical work.

Mercer goes on to discuss the role of the teacher in fostering certain types of discourse. Drawing on the experience of the SLANT project, he cites the researchers' disappointment at the quality of much of the project's recorded talk. This was viewed as being a consequence of the children operating a disparate set of ground rules.

This judgement led to the SLANT teachers and researchers discussing the kinds of ground rules they wanted children to use and this was followed by the class teacher using some awareness raising activities with the pupils away from the computing environment. They agreed to stress the importance of:

- sharing all relevant information and suggestions;
- having to provide reasons to back up assertions and opinions and suggestions;
- asking for reasons where appropriate;
- reaching agreement about what action to take if possible;

"..."
accepting that the group rather than any individual was responsible for decisions and actions and responsible for any successes or failures."

(Mercer 1996, Page 371)

The teaching intervention led to an increase in frequency of exploratory talk when in group-based computer tasks. Researchers also reported apparent increased involvement and enthusiasm for the task; but acknowledged that this may be due to novelty of new ways of talking in the lessons.

Mercer also argued for greater collaborative activity between researchers and teachers so that research feeds more directly into practical classroom applications.

Teaching approaches that establish co-operative collaboration and which present tasks in ways that require information sharing are likely to foster exploratory talk.

There is an important link here to the nature of the classroom climate and the presentational style adopted by the teacher described earlier in this chapter.

An approach similar in some respects to that of Mercer has been reported from an Australian study (Wild and Braid, 1996). This study explored verbal interactions in groups of children aged approximately ten years working on computer-based activities. The groups were organised by ability and worked on either word processing or computer simulation tasks. The children’s talk was recorded and analysed. These researchers categorised talk as socially oriented, cognitively oriented, not directly relevant or off task. The study revealed a prevalence of cognitively oriented talk in co-operatively organised groups of either structure, which the authors took to be indicative of higher order cognitive processing.
However there were differences reported in the relative proportions of cognitive or socially oriented talk in each condition. Cognitively oriented talk was further analysed using a classification developed by Tough (1976) for use with younger children. Using this further level of analysis of cognitively oriented talk, Wild and Braid reported a higher proportion of 'directing' and 'reporting' talk than of other cognitively oriented talk types such as logical reasoning, predicting, projecting and imaging.

The authors claimed that task structure, software and group organisation each influenced the interactions in children working together on computer-based activities.

The rarities of talk indicative of logical reasoning and prediction, which Wild and Braid described, is of significance for the present study. The preponderance of directing and reporting talk could also reflect a difference in the order of these different types of cognitively oriented talk. It might further, as the authors suggest, be a reflection of the nature of the task being undertaken by the children. This later point reinforces the significance to the present study of aspects of task design and presentation discussed above.

Wild (1996) has reported a study of Primary-aged children's verbal interactions in computer settings, in which the emergent classification had similarities to Mercer's categories of talk from the SLANT project. Of particular interest is the recognition in Wild's study of a distinction between 'conflicts' which can be resolved either co-operatively or competitively, and 'disputes' which remain unresolved. Wild uses the descriptor 'connected talk' to included interactions which can take the form of
hypotheses or ideas which are "proposed, elaborated, explained, defined, questioned and/or justified by two children in conversation." (Wild 1996 page 71). In Wild’s analysis it is suggested that these ‘connected’ interactions can arise from both co-operative and conflicting exchanges. The findings of this study did not reveal consistent patterns in the interaction types observed. This led the authors to suggest that influential variables needed to be investigated, although these were not identified.

A second strand explored in Wild’s study was the emergence of metacognitive components in the interactions between subjects. The evidence for these components derived from analysis of talk of the ‘connected’ type. The metacognitive components identified by Wild are listed in Figure 4.3.

Figure 4.3 Metacognitive Components in interactions

- Deciding what needs to be done
- Allocating resources and roles
- Selecting performance strategies
- Monitoring and predicting outcomes
- Combining performance strategies
- Understanding and acting upon consequence

This section has focused on the value of attending to talk in data-logging classrooms. Such attention offers a potential window through which something of pupils’ thinking whilst engaged on tasks may be revealed. This is perhaps a bold
claim and one that has been questioned in the literature (Draper & Anderson, 1991). Nevertheless, talk remains useful research camera with which to capture understandings of exchanges taking place in classrooms.

The studies described above have involved work with primary aged pupils and some in the early years of secondary education. There is a lack of literature reporting similar studies with pupils in the later years of secondary education, where pupils are likely to encounter more of the higher order aspects of the Experimental and Investigative Science demands of the National Curriculum.

However, Jay Lemke has presented a detailed study of the nature and roles of talk in the learning of science with older pupils in the United States (Lemke, 1990). Lemke’s work provides an inventory of activities in science lessons, including episodes of dialogue of different forms and purpose. In many respects Lemke’s analysis adopts a linguistic approach concerning the structure and functions of language in science lessons. However an important feature of this work is that it identifies the use of language in science as a vehicle for constructing scientific understanding. Thus through engaging in discussion about phenomena and observations, pupils acquire the language of science: in Lemke’s terms, they learn to ‘talk science’.

Lemke’s ideas have informed Mercer’s work on the nature and role of specialist discourse. It is a theme which has been of increasing interest in recent years and which has added importance to the social dimension of learning (Sutton, 1992; Driver et al 1994). For the present study, it serves to provide a further theme for exploration of data-logging activities in secondary science teaching, namely: the
opportunities in data-logging lessons for communicative interactions between pupils, and between pupils and teachers.

### 4.5 Towards a conceptual framework

The foregoing discussion has identified a number of factors that contribute to the context of data-logging lessons. These factors need to be considered as issues in the present study because its purpose is to describe the contribution which data-logging lessons can make to pupils' learning in real-world science classrooms. These interacting components are represented in Figure 4.4.

The components considered thus far in this discussion are concerned with the actions and attributes of teachers and their pupils. In addition, the resource base from which the teacher works has also been considered as potentially influential. However, in a data-logging lesson, the potential contributions of the ICT components need to be included in this analysis. An account of some major research findings on the impact data-logging in science teaching was presented in Chapter Three. From the perspective of clarifying research issues, which is the focus of this chapter, a central question is the teacher's purpose in using data-logging technology. However, at its best computer software provides a degree of interactivity, which can arise from the information presented to users by the software. In other words, the computer software makes a substantive contribution to the learning environment.

Thus three broad sets of issues need to be considered in this study. Firstly, 'teacher issues' concerning the design, organisation and management of activities, and the style of their presentation in class. Second, 'pupil issues' concerning their roles in
an activity, experience and learning needs. These two sets of issues are represented in Figure 4.4. In addition the third set of issues derive from the contribution of software and ICT; these influences are discussed in the section 4.6.
Figure 4.4 A conceptual framework for the study of a data-logging lesson.
4.6 Considering the contribution of software.

Approaches to the evaluation of educational software typically fall into two broad categories: predictive approaches and interpretative approaches. Predictive approaches focus on the potential of educational software. They involve judgements about software suitability, which may be informed by the evaluators’ experience or by checklists that focus on generic software features. The predictive approach to evaluation differs from interpretative evaluation, which sets the evaluative process within the context of use of the software. Thus interpretative evaluation may involve the evaluator's ‘projection’ of the software-in-use in the classroom, or it can involve evaluation of software actually in use by pupils.

Interpretative approaches evaluation therefore adopt a holistic view of software in use, which extends evaluation beyond 'cold’ consideration of software features, towards the contribution made by the software in the learning environment. In turn, this means that evaluative tools need to consider the interplay between components of the learning environment into which the object of the evaluation (the software) will be introduced. This view of software evaluation has been described by Squires & McDougall (1996) as a ‘situated’ approach.

The essence of a situated approach to evaluation is the view that all the components of a learning environment, both people and artefacts, interact and contribute to the learning process (Squires & McDougall 1996). This approach seeks to consider the distribution of intelligence during the classroom use of a piece of software, i.e. the contributions made by the teacher, the pupil and the software itself. The contribution of the software is effected through the decisions
made by its designer. So there are three 'actors' contributing to the situation of a software package used in an educational setting; two live actors (teacher and student) and one passive actor (designer).

Earlier in this chapter, themes were described which need to be explored in the present study. Squires and McDougal have offered an approach, known as the Perspectives Interactions Paradigm (Squires and McDougall, 1996), which sits well with the 'multi-issue' analysis indicated in the present study. Squires' and McDougall's work considers the software contribution to the learning experience through an exploration of the interacting components of a learning environment, all of which contribute to and so 'share' in building the learning environment.

The three sets of interactions considered in the Perspectives Interactions Paradigm (PIP) can be summarised as follows.

1. The Teacher-Student perspective stresses the distributed nature of cognition and considers:

- the organisation of computer use in the classroom
- classroom dynamics associated with small group work
- the relationship between computer-based and off-computer activities
- the extent to which students might take responsibility for their own learning
- the amount and nature of teacher intervention that might be appropriate
- teacher roles and styles of classroom management.

(Squires and McDougall, 1996 page 153)
2. The software Designer-Student perspective considers tasks from a constructivist standpoint, in terms of:

- learner control
- challenge
- scope
- complexity
- exploration
- expression (learners' own theorising and experiment encouraged)

(Squires and McDougall, 1996 page 154)

3. The Designer-Teacher perspective considers curriculum relevance and should:

- identify implicit curriculum aims
- match explicit and implicit curriculum aims to perceived curriculum requirements
- consider the possibilities of subverting explicit and implicit curriculum aims to curriculum requirements
- consider the educational possibilities of software which initially has no explicit or implicit curriculum aims.

(Squires and McDougall, 1996 page 155)

The approach developed by Squires and McDougall lends itself to evaluation of a more meaningful kind than predictive evaluation. Importantly, it is an approach
that can be used for interpretative evaluation; a feature that makes it suitable for
the present research study involving software in use in the classroom.

4.7 Research issues identified.

The evaluation tasks identified by the *Perspectives Interactions Paradigm* listed
above present a development of the research issues to be explored in the present
study. The Research purposes of the present study are to:

- consider the prospects for data-logging methods in real world classrooms;
- identify current practice;
- identify influencing factors which constrain its use;
- identify 'assisting factors' which promote its effective use
- identify approaches which can more fully exploit data-logging technology
  for pupils.

The discussion in this chapter has identified the value to the present study of
examining the features of data-logging activities used in classrooms and classroom
ethos. The contribution to the classroom ethos made by the ways in which planned
activities are presented and managed by teachers, and the roles that teachers and
pupils adopt has also been indicated as worthy of study. In addition, the potential
of the computer as a focus for collaborative activity that can foster a productive
environment for learning science has also been raised. These themes give rise to
the following research issues that the present study sets out to examine and which
provide a framework for discussing the findings of the study.

The issues identified in this chapter can therefore be listed as:
Issue 1 What are the features of data-logging activities designed by teachers?

Issue 2 How are these activities presented, organised and managed?

Issue 3 What roles are adopted by teachers and pupils in data-logging lessons?

Issue 4 What evidence of productive interaction between 'actors' can be found in data-logging lessons?

The next chapter presents a discussion of and rationale for the methodologies adopted to explore these research issues.
Chapter 5

Methodology

Introduction

This chapter describes the approaches used to gather empirical evidence about the use of data-logging technology in some secondary school science settings. It sets out a brief account of the early work done in the study in order to help the reader to understand the methodological choices made in the main part of the study and the practical constraints that influenced these choices.

It is important for the reader to understand that the study was carried out over a four term period during 1997-1998. As the empirical work progressed it became essential to review and evaluate the usefulness of the chosen research instruments. These were refined (and in some cases rejected) during the course of the study. In this important sense, a chronological account of how this phase of the work was conducted may not allow the reader to fully appreciate the iterative process that was gone through in the study and which has led to the content of the preceding chapters of this thesis. Nevertheless, for the sake of clarity this chapter sets out a chronological account of how the empirical work was conducted.

The phases of the study involving empirical work were as follows.

1. Informal observations of a small number of data-logging lessons in two schools. The purpose of these exploratory observations was to gain a sense of what might be possible in terms of more formal observation techniques in the main part of the study.
2. Contacts made with a number of schools selected because of the known experience in use of data-logging techniques in science lessons. Selection of sites for main study was achieved through convenience sampling.

3. Main study phase which involved regular visits and observations of data-logging activities over two extended periods in one school and visits to two other sites by invitation as data-logging lessons were scheduled. Data gained during these visits was subjected to ongoing analysis to record findings and inform subsequent visits. The information gained in this phase of the study provided the main body of data on which this thesis is based.

4. Follow up visits to conduct semi-structured interviews with the teachers whose classes had been observed. This provided a means of further exploring issues raised by the classroom research.

The timeline for the study is included here as Figure 5.1.
Figure 5.1 Timeline of Case Studies

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Key
- •  Periods during which single lesson observations were made
- H  Periods of school closure
- → Periods of regular weekly observation
5.1 Some philosophical considerations

An important feature of the research presented here was that the research questions could be explored through observations of students and teachers working within normal classroom settings. This research stance raises the question of the philosophical nature of the research. That is, whether the research position adopted lies within the Positivist or Interpretative research paradigms, or drawing on both, somewhere between them. This is an important matter because it reflects the stance driven by the research questions and it is reflected in the methodological choices made for data collection as well as in the interpretation of findings (see Easterby-Smith et al., 1994 page 80).

The arguments set out in chapter four led to research questions that essentially require exploration and description of the events surrounding use of data-logging methods in real classrooms. This requires the collection of observations and accounts of classroom events that cannot be predicted with certainty in advance. The researcher is therefore of significance as the agent of the data collection processes that set out to ‘capture’ aspects of classroom events.

It is necessary to be clear about the role of the researcher in this endeavour because the processes of selecting what should be recorded and what meanings might be attributed to events are processes of interpretation by the researcher. They are therefore subjective interpretations that will be influenced by the researcher’s beliefs and values. The research approach is therefore set in the interpretative paradigm rather than in a strictly positivist or ‘scientific’ mode.
Morse (1998 page 62) see qualitative research strategies as 'tools' that are indicative of particular types of data collection instrument and which have implications for the usefulness and application of findings. They suggest that research questions that set out to describe *practices* are supported by an ethnographic research design and that questions seeking to understand *processes* are supported by a grounded theory strategy (Morse, 1998 page 63). These research strategies, Morse suggest, lead to qualitative data sources. In the case of ethnography, suitable data sources include interview data, field notes and participant observation, whilst interview data support a grounded theory approach (Morse, 1998 page 63). A mixture of data sources has the potential to provide a range of perspectives on the research issues and the association of particular methods with a research strategy need not be viewed as rigid. For example, Morse (ibid) indicates that the use of participant observation and diary method can support the grounded theory research strategy.

At this point it is necessary to acknowledge that the theoretical perspectives outlined above are influenced by the practical constraints of a particular research project. As will become apparent later, for the present study limitations of time and resources and issues of access to suitable research sites constrained the research presented here.

**Case Study**

This section describes some of the characteristics of case study in order to justify the methods used and to offer the reader the opportunity to scrutinize them. For the purpose of this study, a collective case study approach was adopted.
Cohen and Manion (1994) describe the purpose of case study as being 'to probe deeply and to analyse intensively the multifarious phenomena that constitute the life of the unit [case] with a view to establishing generalizations about the wider population to which that unit belongs.' (Cohen and Manion, 1994 page 106-107).

However, there is some debate in the literature as to what precisely a case study is. As Stake (1998) puts it: "Custom has it that not everything is a case. A child may be a case. A doctor may be a case - but his doctoring lacks the specificity, boundedness, to be called a case." (Stake, 1998 p87)

This observation hints at one of the essential qualities of a case study research strategy, namely its particularity. Robson (1993) takes a broader view of what may constitute a case study. He suggests that case studies "can be done on a group, on an institution, on a neighbourhood, on an innovation, on a decision, on a service, on a programme and on many other things." (Robson 1993, p 146).

For the present study the choice of a case study approach has been driven by practical as well as theoretical considerations. The newness of data-logging and the wish to study how it was used point to the need for empirical approaches. The rarity of schools making extensive use of data-logging methods, difficulties in gaining access to them and limitations of research resources, were three influential factors in this study. Taken together, these factors indicated a small-scale, closely observed study of the use of data-logging methods.

In selecting a case study approach for the present study, the writings of Robert K. Yin have been influential. Case studies, according to Yin (1994) can be descriptive, exploratory or explanatory in their purpose, as can other approaches.
Arguing the value of case study approaches, Yin considers the various choices that face the researcher. Amongst the methodological options are experiments, surveys, histories, archival studies and case studies. The choice of research approach needs to be driven by the nature of the research questions being studied, but Yin acknowledges that these research strategies need not be mutually exclusive so that it is possible, for example, to use a survey within a case study. However, Yin points out that:

"... we can identify some situations in which a specific strategy has a distinct advantage. For case study, this is when ...a "how" or "why" question is being asked about a contemporary set of events over which the investigator has little or no control." (Yin, 1994 Page 9).

Other research into the use of data-logging methods has highlighted the important influence of context on realising the potential benefits of the approach (Rogers and Wild, 1996). These authors drew a distinction between those benefits of data-logging that were attributable to the intrinsic qualities of computer methods, and those whose origin lay in the method of computer application in the classroom. It is the latter set of benefits that seem most dependent on the context of use. In order better to understand these contextual factors, it is necessary to study data-logging methods in the classroom, in the hands of teachers and pupils.

The aspiration to pursue this approach sits very well with Yin's definition of the scope of case study as "... an empirical inquiry that ... investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident." (Yin 1994, p13).
It is because of the importance of context that a methodological approach was required which allowed this aspect to be explored in the present study.

In seeking to further define case study, Yin identifies certain technical characteristics of the approach that are derived from the indistinct boundary between the ‘object’ of study and its context. Thus, Yin sees case study as an inquiry which:

"...copes with the technically distinctive situation in which there will be many more variables than data points, and, as one result relies on multiple sources of evidence, with data needing to converge in a triangulation fashion, and as another result benefits from the prior development of theoretical propositions to guide data collection and analysis." (Yin 1994 page 13)

Yin's typology of case studies for research purposes identifies them as descriptive, explanatory or exploratory case studies. Yin's view of the case study approach is that it represents a methodological option that may be selected because of its suitability for investigating a particular set of research questions. This view contrasts with that of Robert E. Stake who offers the view that "Case study is not a methodological choice, but a choice of object to be studied." (Stake, 1988 page 86).

Thus, Stake emphasizes the object of study i.e. the case as being at the heart of the case study. A strength of Stake's emphasis on the uniqueness and particularity of the case rests in the consequent caution that must be attached to any generalizations one can make from findings. This cautionary note is important for
the present study; for whilst the current climate of heightened interest in the application of ICT to science education raises the need to better understand its classroom use, it is necessary to acknowledge the limitations on the generalisations about ICT use that can be made from this study.

In seeking to define the limits of the case, Miles and Huberman suggest that “There is a focus or ‘heart’ of the study and a somewhat indeterminate boundary defines the edge of the case: what will not be studied.” (Miles and Huberman 1994, page 25). This statement acknowledges that any case study approach has its limitations, if only because of what it is manageable to include in the study. As will become apparent later, for the present study these limits were defined by the constraints of working in ‘real’ classroom settings as well as what was manageable by a lone researcher.

Stake describes three types of case study, based on their purpose in relation to the subject of study: these are intrinsic, instrumental and collective case studies. Intrinsic case studies are those in which the case of particular interest; the purpose is not, as Stake puts it “theory building” (Stake 1998, p88), but rests in the researcher’s intrinsic interest in the case itself.

A second type of case study is that which Stake describes as instrumental case study. Here the purpose of studying a particular case rests in the light it may throw on some other issue. In instrumental case study, the case itself is of secondary interest to the issues it seeks to illuminate. In the third category, collective case study, Stake sees as “instrumental study extended to several cases” (Stake 1998, p89). The purpose of collective case studies is that they may provide better understanding about other cases. Collective case study may allow comparisons to
be made between individual cases, and may allow for greater generalization from findings. As Miles and Huberman put it:

"We argue ... with much recent practice to support us, that multiple case studies offer the researcher an even deeper understanding of the processes and outcomes of cases, the chance to test (not just develop) hypotheses, and a good picture of locally grounded causality." (Miles and Huberman 1994, p26).

An important feature of case study is that in seeking to understand the case, the researcher needs to draw on a mixture of methods in order to obtain answers to questions. This stance reflects the reality that different questions might best be answered by different approaches but, in keeping with the interpretative research strategy, it also provides an important means of exploring issues from different perspectives. The use of multiple 'research cameras' to explore questions is known as methodological triangulation. Stake (1998) describes triangulation as "...a process of using multiple perceptions to clarify meaning, verifying the repeatability of an observation or interpretation." (Page 97).
5.2 Early school visits and the search for ‘classroom cameras’

As explained in Chapter 4, a review of literature led to identification of four general areas worthy of further study namely:

**Issue 1** What are the features of data-logging activities designed by teachers?

**Issue 2** How are these activities presented, organised and managed?

**Issue 3** What are the roles adopted by teachers and pupils in data-logging lessons?

**Issue 4** What evidence of productive interaction between ‘actors’ can be found in data-logging lessons?

Thus the broad focus of the research concerned what teachers and students do with ICT in practical science lessons. Clearly, in order to explore these questions, one needs to go into these classroom settings and take a look at what is going on. An important approach would be to attempt to study what the ‘actors’ say and do when using ICT. The question arose as to how to ‘capture’ what the participants are doing in ways that lend themselves to the recording and analysis of normal laboratory life. In order to begin to tackle this issue, several extant observation instruments were researched. A justification for doing this was that by using instruments ‘off the shelf’, one could benefit from the proven validity and reliability of the instrument.

With hindsight, given the need to select research instruments appropriate to the question being investigated, this seems to be a naive assumption. There is a genuine risk that the questions asked are driven by the instrument rather than explored by it. Nevertheless, the study of existing instruments proved useful as a
means of helping to focus on pertinent issues for study. The instruments selected for use at this stage of the study are listed in Figure 5.2.

![Figure 5.2 Early thoughts on classroom cameras](image)

Flanders Interaction Analysis (Flanders 1970)

Science teaching observation schedule (Eggleston et al., 1975)

Talk categories from Wild and Braid (1996).

Copies of these instruments were taken into a school to assess the feasibility of using category systems 'live' in the science laboratory. A visit was negotiated to a local comprehensive school and two sessions taught by the same experienced physics teacher were observed. The first of lesson was with a group of Year 7 students who were working on a practical task involving wiring of simple electrical circuits; this lesson involved no ICT. The second lesson was a Year 12 Physics A-level group practical; these students were using BBC microcomputers, Sense and control interfaces, light gates and 'Motion Laboratory' software in small group investigations of momentum.

The primary purpose in this visit was to consider the practicalities of using observation schedules, recording techniques, field notes etc. in order to get a feel for what was possible in these working settings. In addition a 'contact summary form' was designed (based on Miles and Huberman, 1994 page 53) to record the researcher key observations and reflections and to provide a chronological record of the research (please see Appendix 1).
Many important practical matters emerged as a result of this early school visit. These will be discussed as three groups of issues - teacher issues; student issues; and implications for research. The discussion is included here because it will help the reader to appreciate some of the factors that shaped the methodological decisions that underpin this thesis.

Teacher issues

The most prominent feature of the teacher's activity during these two lessons was just how busy he was. Apart from the concerns of the lesson in hand, the teacher had significant school managerial responsibilities; these were very apparent prior to the start of one observed lesson. They also intruded into the lesson when a colleague from another department interrupted the lesson with an urgent query. Thus for this teacher (and probably all teachers) there seemed to be many demands on his attention. Day to day, teachers face hard choices about how much time can be devoted to the various aspects of their role, and what priority to give to any single task which has to be done. From the research viewpoint this was an important reaffirmation of the many demands on teachers' time. It was a reminder of the need to be realistic in the additional demands that the present research could create for the participating teachers.

Regarding the teacher's role in organising and managing the students, a lot of the teacher talk appeared to relate to general classroom management. This included dealing with administration and latecomers; setting the lesson scene, giving instructions, supervising distribution of materials and allocation of tasks; dealing with disputes etc. Only a very small proportion of the talk at the start of the lesson was science related. The teacher dominated the talk and student contributions
were limited to responses to the teacher's questions. This was especially the case
in the Year 7 class; much less 'activity management' talk was apparent in the
Year 12 group which tended to be calmer and more interactive, no doubt
reflecting the effect of group size on the style of teacher, the experience of the
students and the nature of the classroom interactions.

Once the lesson activity was underway, the teacher seemed to spend a lot of time
acting as 'trouble-shooter' dealing with the technical problems the students were
experiencing with the equipment. Sometimes, the teacher took the opportunity
occasioned by solving a technical problem, to ask students a task-related question.

*Student issues*

The Year 7 students spent quite a lot of time listening to the teacher. They had to
take in a lot of information about the task itself and how they were to work. Once
the students were set on task, they were very enthusiastic, although from their
actions, it appeared that some groups were very unclear about what they had to
do. It is one thing for the teacher to have explained the purpose to a group, how
the students interpret this could be quite different. This indicated the need for
teachers to reinforce information and check what the students understand through
these exchanges. This is not easy when whole classes are working on small group
practical tasks; misunderstandings are sometimes only slowly revealed through
the students' activity, and there is an element of chance in the teacher happening
to witness an event which might indicate a misunderstanding. There may be many
occasions when students' errors or misconceptions are not detected, purely
because the teacher was engaged in some other activity.
Although the teacher worked as hard as possible to service the needs of the working groups, each received only a small fraction of teacher time. There were long wait times for the students when some were distracted into off-task ‘side’ activities, some of which were disruptive to other groups.

Observations of the Year 12 students working with data-logging equipment revealed that there were far fewer occasions when the students became distracted into side talk. There was some side talk but this seemed to occur in ‘natural’ pauses in the main task, or formed part of the social talk associated with the students managing their experiment.

These students were familiar with the software and seemed to have no major problems operating the ICT. However, their progress in the investigations was still hampered by technical problems to do with other equipment. They had problems keeping the model vehicles whose motion was being studied on the tracks, or with compensating for friction.

These informal observations did not reveal much about the use of ICT, but a number of issues were apparent relating to the demands on students in practical lessons which they needed to master to complete a task successfully, and which could have implications for my future research. These are listed in Figure 5.3.
Figure 5.3 Issues in pupil practical work

In practical work students need to be able to:

Listen to a lot of teacher talk particularly at lesson starts.

Be attentive.

Sort important information from the unimportant.

Retain a lot of information in different forms relating to the experiment.

Negotiate with their peers about what to do.

Negotiate their role in the group.

Recall useful information at appropriate points in the lesson.

Know where to start.

Manage unfamiliar equipment.

Be persistent with equipment failures.

Be resilient when pleas for help seem to be ignored by the teacher.

Write it all down.

5.3 Implications for this research

1. The problem of capturing the talk

The opportunity to ‘eavesdrop’ on the students’ talk during the first school visit revealed that there would be difficulties in studying students’ talk. The classroom
was a busy and noisy environment. The background noise generated by thirty students moving equipment and furniture, interacting with each other and with the teacher was considerable. This would make quality recordings hard to produce. It also meant that distinguishing individual contributions to talk was difficult. These problems would be less significant in smaller classes, but typically only post sixteen groups are small.

It was hard to get close enough to the students to hear what was being said or to see what was done with equipment without intruding into the group. This meant that there was a balance to be struck between finding reliable means of obtaining data through observation and the extent to which that data can be seen as reflecting the natural classroom talk of the students.

2. The problem of the observer’s role

There is a body of literature concerning various methods of classroom observation, which considers their relative merits, (see Robson, 1993 for an overview). The degree of participation in the activity by the observer clearly affects the situation under study and the nature of any recording techniques used. There is therefore a trade-off to be made in the role adopted by the researcher and the kinds of data that can be gathered.

There are several of issues relating to possible research approaches here that concern the extent of the observer’s participation in the research setting. Atkinson and Hammersley (1998) caution that the view that a non-participant observer plays no role at all in a research setting may not always be the case. They describe a ‘fourfold typology’ (page 111) of participant observation from complete
observer, through observer as participant and participant as observer, to complete participant. However they caution that characteristics of the observer and the nature of the research setting can lead to variation even in this typology.

To some extent these alternatives reflect different methodological stances and ethical questions of how open the researcher wishes to be about their role with the subjects. It is important to recognise that each approach has benefits and costs associated with it. Ultimately, a choice of approach must be made most appropriate to the questions being investigated, ethical considerations and the constraints of the research setting. For the present study, the value of the 'participant as observer' role rests in the opportunity it provides to 'get close' to the research setting and to be able to ask participants questions. The success of this approach is dependent on the quality of the relationships and trust between the researcher and participants. Consequently this choice demands that the researcher works to build that trust. Robson (1993, page 197) points out that the role might have a greater effect in disturbing the research setting than other less interventionist approaches to participant observation. On the other hand (and interestingly, for the present study) Robson also indicates that in some settings, for example those involving innovation, the participant as observer can encourage more reflection by participants. If true, this holds the prospect of deeper and more useful revelations from the research.

3. The problems of working with new technologies

A major focus of this study is students' use of ICT. Although ICT systems can facilitate data gathering and presentation, difficulty arises because the necessary hardware and software needs to be managed with some skill. Robson (1993 page
197) highlights the difficulty of maintaining the dual roles of participant and observer in research and this problem is further complicated by ICT. With the relative newness of ICT, and the apparent inexperience of teachers and pupils as users of it in science, there is a risk that close involvement as a participant could force the researcher into the roles of teacher or technician at the expense of the research role.

This concern indicated that from the research viewpoint there were advantages to be gained of seeking settings where there was a relatively mature experience of using IT for data-logging in science. In these settings one might anticipate that many of the technical problems experienced by novices would have been overcome. In more mature settings one would expect to find data-logging being used in ways where the research interest in the contribution it can make to students experimental work could be explored with a minimum risk of the researcher’s attention being sidelined into other activity.

4. What might be revealed in talk?

Observations of the Year 7 and Year 12 students during initial classroom visits revealed that there was no obvious flow to their talk. It was often punctuated by interruptions. A lot of assumed ‘thinking’ by students is revealed through their actions and is not necessarily verbalised. Moreover, any attempt made by the researcher to attribute meanings to talk and action is necessarily a personal interpretation of these events. There is no reason to assume that an interpretation would accurately reflect the students’ thought. This is a crucial issue for any attempt to use discourse as a window on the speakers’ thought and it has been the subject of scrutiny in the literature (Draper and Anderson 1991). These authors
have argued that whilst one may accept the importance of social interaction and
dialogue to learning, video tapes and recordings of dialogue do not provide
directly useful evidence of this (Draper and Anderson, 1991 page 105).

During the first school visits, informal observations indicated that there was a lot
more operational talk concerned with manipulation of apparatus and software,
than there was analytical and reflective talk. Much of the student talk was about
the routine of doing the experiment. In these initial observations it was impossible
to judge how far this feature of their talk reflected the students’ lack of experience
or the way in which the particular lesson observed was set up. Nevertheless, it
raised the prospect that talk about data or other experimental outcomes would
form only a part (and probably a very small part) of all the talk that would be
encountered for this study.

So much talk seemed to be operationally related concerning the ‘objects’ of the
experiment i.e. the items of equipment and what was to be done with them. This
meant that the students’ talk could appear vague and unclear. Without knowledge
of the experimental details, a statement such as “that goes there” is meaningless to
the observer. Some kind of record of the procedure was therefore required order to
make sense of these utterances. A lot of communication appeared to occur through
non-verbal signals with students gesturing and pointing to items of apparatus for
example.

All this seemed to point to the need for any talk to be studied within the detailed
context in which it occurs, and the need for techniques that can capture the
richness of the communication between the participants in a group situation. Such
approaches are quite consistent with a socio-cultural view of classroom research.
However, this issue is further complicated when one considers that in ICT settings, the computer interface can become an additional participant in these interactions, providing information, requiring input of commands etc.

5.4 Some data collection instruments appraised

The amount and diversity of activity in a typical practical science lesson is so great it is challenging for a solitary researcher to study it all. Observation schedules can provide a means of focusing attention on those features that are of particular interest to the researcher. Such schedules typically invite the observer to record activity of the subject at regular time intervals. The duration on the interval needs to be short enough so that the record is sufficiently sensitive, but not so short as to be impractical in use. On the other hand, longer time 'slots' can make the schedule more manageable but result in a coarser observation record.

A further issue in using observations schedules relates to the design of the coding categories themselves. Reference has already been made to the difficulty posed by using an instrument ‘off the shelf’ since they were designed with a specific purpose in mind which may not be the same as the required purpose. Both the instruments taken into this first school visit proved to be inappropriate because they were too focused on the teacher’s actions for the present interest in students’ use of ICT to be well served. Importantly, these instruments pre-date the wider use of computers in schools and so do not consider the part played by computers or the interactions of students and teachers with these machines.

Rogers and Wild (1996) reported a study in which an observation schedule was applied to secondary school students data-logging in a variety of science lesson
contexts. This study used a purpose-designed instrument in which coding categories were chosen to correlate with the science National Curriculum, others being added where necessary. One minute time segments were used in the instrument. The findings from this study indicated that in ICT settings students spent more time discussing results than in non-IT settings. However in both settings only a small proportion of time was spent in reflecting on interpretation and evaluation of data - typically much more time was spent in the preparatory phases of the experiments.

Rogers and Wild did not set out to explore the detail of students’ talk. In some respects their observation schedule was too coarse to explore the nature of students’ discussions and any reflections on data, or indeed what other matters may occupy the students’ attention. One ambition of the present research was to look for evidence of the ways in which data-logging can contribute to students’ understanding of science investigations, in particular the ways in which students deal with and interpret their experimental data. This focus clearly required some means of examining students’ conversation.

5.5 Summary of issues arising from first school visits.

The first forays into school raised many practical questions and theoretical issues which informed the design of the research. These have been discussed above but are listed for clarity in Figure 5.4.
Teachers are busy, the demands made by the main study should be realistic and not add to their workload.

Teacher talk is more common than student talk.

Most talk seems to be related to activity management; talk about outcomes seems very dilute.

Operational talk predominates; this may be reduced if the task is straightforward and familiar to the students.

Communication between participants occurs in many ways of which talk is but one; these other ways need to be recorded.

Sense can only be made of talk with understanding of the context in which the talk takes place; so the researcher will need to be the recorder and transcriber of recorded talk.

Talk is an imperfect window on students' thinking.

Recording of talk will be difficult because of noise, the smaller the class the better.

Teachers spend a lot of time 'trouble-shooting' practical work; the experiments need to be well rehearsed to minimise the impact of this.

Students may not correctly interpret the purpose of an activity; teacher reinforcement essential or some other prompt (a worksheet?).

Students are easily sidetracked and need to be engaged and supported to successfully stay on task.

Older, more experienced students are better able to stay on task, and to resolve the technical problems they encounter.

Students need too be multi-skilled to learn successfully from practical situations

Getting close to students without intruding on their work is hard; need to get to know the group to get close.

Observation schedules can generate a lot of data, but they need to be constructed with care to suit the research purpose and to be manageable in practice.

There are compromises to be made in terms of research stance.

IT poses new problems because it is unfamiliar to teachers and students; it needs an experienced teacher in a mature IT setting to minimise the impact on practice of the novelty of the technology.

Mature settings may permit more use of software tools to support analysis and interpretation of data.
5.6 Further thoughts on 'classroom cameras'.

*The importance of classroom environment.*

From a socio-cultural perspective, one would expect that students' perceptions are a key feature shaping the context in which any learning occurs. Although the focus of this study is on what contribution data-logging can make to students' practical work, student attitudes or perceptions of working with IT may be important influences on this. In order to explore this question, instruments were sought which could measure aspects of students' perceptions of their learning environment. The primary purpose in doing this was to find some means of gauging the influence of the 'history' of their experience on students' expectations of ICT work in the hope that this could throw light on any findings in their talk.

Classroom environment inventories have been devised and validated for a number of teaching contexts by Fraser *et al.* (1993). Consideration was given to whether these instruments could be used in science ICT settings. The dimensions of classroom climate considered to be particularly relevant to the present study were:

- degree of open-endedness in the tasks students were given
- investigative approach
- social relations (in so far as these contribute to fostering of effective working groups for practical activity).

As mentioned above, Rogers and Wild (1996) indicate the importance of contextual factors in encouraging students to make the most of the potential benefits they claim for using IT in experimental work.
One advantage of choosing an inventory 'off the shelf' is that the items have been validated with large numbers of students; many more than could be done if a purpose-designed scale was invented for this study. This decision involved some compromise because they were not exactly what was needed. The most recent computer environment inventories have been used in a geography context although a recent science-based instrument has been reported (Levine et al., 1996)\(^1\).

These instruments are perhaps most useful in assessing changes in students' perceptions over time, or after some kind of intervention. They allow comparison of students' preferred styles of working and perceived actual styles. The instruments described have been used with older students, but the level of language used in them was high and the linguistic style addressed a US audience.

**A trial run in schools**

In order to try and assess the potential usefulness of this approach to my research, a composite classroom environment inventory in which items were selected that claimed to measure perceptions of Social Cohesiveness (SC); Open endedness (OE); Investigation (IV); Innovation (IN); and Resource Allocation (RA) (see Appendix 2).

This instrument was administered to two groups of students in two different upper schools (one Year 10 group and one Year 11 group, both of mixed ability). The aim was to ask for feedback on the structure of the instrument; whether it was understood and how laborious the students found it. The students who filled in the

\(^1\) It was not possible to obtain this instrument despite contacting the author.
inventory gave some critical written feedback. The inventory was found to be too long and items were seen to be repetitive or inappropriate. The teachers on the other hand saw the instrument as a potentially useful device for seeking students' views.

The outcome of this exercise was a little disappointing. The kind of information sought by the instrument could be more readily gained through talking to small groups of students, albeit that this would deny respondents their anonymity. In the end it was decided that having focused attention more on the impact of ICT on the students experimental work, the avenue of class environment was not one to explore extensively for the present study. It was anticipated that study of the activity formats and presentation styles adopted by teachers could provide the required insights into the type of class environment that they created.

Furthermore, it was felt that some aspects of classroom environment, for example Social Cohesiveness, were likely to be subject to influence by the established relationships within the pupil group. The two classes of pupils studied in Case 1 and Case 2 were especially convened for a period of curriculum enrichment activity at a start date that coincided with the beginning of the main study. As a result the group had not yet established working patterns and relationships within the context of the enrichment lessons.

5.7 The need for suitable research sites
The previous chapter described, the research evidence that indicates that teachers are influential in determining the extent to which the advantages of ICT use are realized in practice. In the case of data-logging methods, which are the subject of
this study, evidence from school inspection information indicates that their routine use is not widespread (OFSTED, 1998b).

Rogers and Wild (1996) have suggested that aspects of the operation of data-logging equipment for collecting data predominate in pupil's practical activity. Moreover, the time saved by the electronic gathering and presentation of data did not appear to be much used for more interpretive aspects of experimental work. Since this project initially sought to explore the ways in which the use of data-logging methods could contribute to the development of pupils' interpretive skills, there was clearly a need to gather research data in schools where the use of data-logging was well established. By focusing on more 'mature' settings, it was anticipated that evidence could be sought of the potential contribution of data-logging methods to the higher order skills of experimental science, and of features of classroom environment necessary to achieve this potential benefit. The need to work in such settings posed a number of difficulties in relation to finding suitable sites for study. As indicated above, anecdote suggested that they would be a subset of schools using data-logging equipment.

A list of possible research sites was drawn up following consultations with colleagues in the Local Education Authority advisory service, and with others at Leicester University. This resulted in a list of eight secondary schools, six of which were in the local county and two in different counties.

A letter to the head teacher invited each of the eight potential 'research schools', to participate in the research project. It was intended that this initial contact could secure the head teacher's support for the research and minimise the risks of schools later withdrawal from the study. From the above description, it will be
clear that no attempt was made to standardize a procedure for selection of research sites. With the small number of possible sites and past experience of the difficulties with gaining access to possible research schools, the only realistic option was to use those schools that had expressed willingness to participate in the research. Thus the approach to selection of research sites adopted was non-probabilistic.

From a methodological perspective, the selection of research sites described above could be classed as 'convenience sampling' or 'opportunity sampling' and was a non-probability sample (Cohen and Manion 1994 page 88). The selection process was guided by the need to conduct the work in settings with some experience of the use of data-logging methods; in that sense the selection of the eight schools originally contacted could be described as 'purposive' (Cohen and Manion, 1998 page 89).

Initial letters were followed up by telephone contact and a school visit. During the visit the broad purpose of the study was explained and the extent of possible support sought.

It will be apparent that there was a close link between the development of research issues, classroom observations and the choice of data collection approaches used in this study. Each of these aspects of the experience reported here informed the others as the research progressed. The approaches adopted emerged from a complex mix of reading about methodology, practical classroom experiences and what was realistically possible in everyday classrooms. So the research could be viewed as being grounded in this experience with issues emerging from the
research process and developing from it guided by the literature and the research questions.

This methodological approach exhibits some features of an interpretative research known as grounded theory, developed by Glaser and Strauss (1967). However, it is important to note that grounded theory involves the emergence of theory from detailed analysis of qualitative data. This approach implies that there are no preconceptions about theory, since, strictly, new theory emerges from the data and is grounded in it. Clearly, in the present study, the issues for research and the theoretical background to these issues outlined in the preceding chapters represent a set of constructs that inform and define the study presented here. Therefore the research approach adopted cannot strictly be described as grounded theory. Nevertheless, to the extent that this study set out to explore the extent to which the claims made for data-logging technology could be seen in real classrooms, the research focus is directed towards description and exploration of 'real world' experience. It therefore exhibits features of a grounded theory approach which may lead to new practical and theoretical understandings of these 'real world' settings.

An important feature of a grounded theory approach is the need for 'constant comparison' of data and emerging ideas. The purpose of this process of comparison is to enable the researcher to become

'..., sensitised to similarities and differences as a part of the exploration of the full range and complexity of a corpus of data, ..., used to promote conceptual and theoretical development.' (Pidgeon, 1996 page78).
The research approach adopted here therefore calls for comparison within and between the case studies. The literature set out for this study forms the theoretical basis for the study and provides frameworks for reflection on the case study data presented.

5.8 Further thoughts on Experimental and Investigative Science

As the preliminary work for this study progressed, a shift of research concerns occurred towards exploring the contribution data-logging might make to pupils’ experience of practical experimental work. In turn this led to further consideration of the 1995 National Curriculum Science Orders that were in force during the course of the present study; in particular, those parts of the Order relating to Experimental and Investigative Science (known as Science 1 or Sc1). The initial intention was to use this curriculum framework as a means of focusing on the skills and expected outcomes from students’ practical work. It was anticipated that one could then look for evidence of these curriculum components within the context of data-logging investigations.

Capturing the students’ activity

For an observer, all that can be recorded of students’ activity is their visible actions. In order to relate this to the process of investigation (Sc.1) the activity needs to be analysed or categorised in some way. An observation schedule is one way of recording this activity.

To this end an observation schedule was produced that would be applied whilst simultaneously audio recording a working group of students. The schedule sought to broaden the observation categories used by Rogers and Wild (1996) and update
these in the light of the 1995 revision to the National Curriculum Orders. The researcher had experience of using Rogers and Wild schedule as a member of the research team for that project. There were no problems in the mechanics of filling in the schedule once a decision was made about which category of activity applied.

As a starting point the classroom observation schedule used by Rogers and Wild (1996) was explored. This instrument was refined so that it more adequately reflected aspects of investigative science as set out in the 1995 National Curriculum Order. It was also included some additional categories intended to enable the use to record pupils' analytical responses to data. This instrument is included as Appendix 3.

The instrument was used during the lesson observations for Case study 1 between mid-April and June 1997. In the light of the observations during this period, the instrument was modified slightly prior to the second case study. The sole difference in terms of coding categories between the two instruments was that the two categories concerned with selecting and handling apparatus were combined to a single coding category in the revised version. This was considered to be justifiable, since the focus for the instrument was to record interpretative behaviours rather than matters of operation and manipulation of laboratory apparatus.

A further development of the revised version of the schedule (Appendix 4) was that a summary box was included to enable the researcher to record specific features of the task that the pupils were being asked to address. As discussed in Chapter Two, the design features of a practical task determine its complexity and
its scope. Therefore, at this stage of the study, it was felt necessary to record both the features of the task itself in terms of the structure and type of variables the pupils were being asked to consider, and the scope of the task as determined by the way in which the teacher set the activity for the pupils. The features of the revised observation schedule are explained in the annotated graphics included as appendices 4b and 4c.

In the main part of the study, the opportunities to use this observation schedule were limited. These limitations arose for two main reasons; first, the requirements of managing a time-based observation schedule, audio tape recordings and the need to record other salient features of lesson activity proved to be unmanageable for a lone researcher. Second, the schedule had been designed to capture more detailed evidence of pupils’ analytical activity, after they had collected experimental data. In fact, the greater emphasis in the lessons observed for the present study was on the data collection activity and so there were very few opportunities to use the observation schedule to explore the ways in which pupils analysed or interpreted experimental evidence. These factors indicated that the evidence base in this area would be weak and for this reason the use of the schedule was abandoned in subsequent cases, in favour of more naturalistic observations. Despite these problems, the design of the schedule served a useful purpose in shaping the researcher’s thoughts about salient features of the classroom activity.

A second problem was to explore the student’s thinking as they work through a task. This again might be related to aspects of Science 1 at the appropriate Key Stage, but what could be the source of data for any such analysis? Further, how
can these two types of information (actions and thoughts) be treated as evidence for the contribution of ICT to students' progress through a task?

*Capturing students' 'thinking-in-action'*

One possible approach to probing pupils' ideas about their work was to explore the written record of their work: their report of what they did. The problem with this approach is that it may just produce an account of what the pupils did without the reasoning that went into the work. It is the reasoning that will lead to the development of students' skills and understanding of 'Experimental and Investigative Science'.

To some extent this problem could be overcome by structuring students' tasks in such a way that there are prompts to encourage them to justify their actions and decisions. However any account of what students did is, of necessity, completed after the event and could involve some selective reporting on the student's part.

The ideal would be to capture the students' thoughts-in-action, as the task is carried out. One possible 'window' on this is to record and analyse what students say when carrying out the task, in the belief that their talk is an expression of their reasoned thought. The assumption of a link between thought and expressed speech is questionable, as has already been indicated (Draper and Anderson, 1991). There is reason to suppose, and common experience suggests, that not all thoughts are manifest in speech. This means that one cannot assume that a person's utterance on a subject represents the totality of their reasoning. Indeed an utterance is likely to be an outcome of their reasoning; the public statement of the product of a chain of thought; and not the reasoning itself. There is a consequent danger of the
researcher attributing to an utterance, a process of reasoning leading to it, which did not in fact occur. Despite these weaknesses, a study of talk at least held out the prospect of some insights into the students' ideas during a practical activity.

5.9 Further indications from the literature.

Protocol Analysis

Some researchers have adopted the use of Protocol Analysis in order to study the reasoning involved in a task (Nakhleh, and Krajcik, 1993; Green and Gilhooly, 1996a, 1996b). This approach involves the transcription of recordings of participants' speech while carrying out tasks under 'think aloud' instructions. The rationale for this approach is that subjects are asked to verbalise all their thoughts when carrying out a task, they are not asked to justify these thoughts. Some training of subjects is required to familiarise students with the technique. The researcher's role is to analyse these verbalised thoughts for reasoning patterns and strategies.

This approach was rejected for several reasons. An important aim of this research was to study the use of computers in natural classroom settings rather than under experimental conditions. The main reason for this was the desire to retain a 'real-world' approach to the research. Any findings or claims from this research needed to be applicable to ordinary classrooms rather than being seen as products of purely experimental settings. This meant that it was not appropriate for a researcher to intervene in the normal running of a class by encouraging what students might perceive as unnatural behaviours in 'think aloud' activities.
Secondly, it was hoped that in a carefully designed and presented task, it might be possible to structure the students' activity in such a way to encourage collaborative group work in which participation in the group would necessitate members in verbally justifying and reasoning through their actions in a joint task.

A third reason was that it has been reported that children commonly think aloud when confronting problem solving tasks. It seems that this verbalisation helps children to understand new experience and aid their long-term learning (Berk, 1994). For the present study, taking these considerations into account, an appropriately designed task might provide a context in which collaborative and reasoned talk could occur.

**Encouraging collaborative group work: establishing ground rules.**

Evidence from the SLANT project indicated the need for students to be made aware of their behaviour in collaborative group work. This finding drew largely on Galton and Williamson's (1992) work that indicated that in a lot of so-called group work in Primary Schools, there was very little collaborative activity. The SLANT team sought to establish ground rules in order to encourage 'Exploratory talk' which Mercer (1996) has argued to be educationally useful.

For Case study 1, the science teacher who had agreed to participate in the research selected a class of pupils for study. The characteristics of this group and the laboratory work they undertook during the course of this study are explained in Chapter 6. Here, it is necessary to explain that this class had not worked together before and so it was felt necessary to encourage them to think about how they could work cooperatively together on the ICT-based tasks they would encounter.
For this reason, and drawing on the work of the SLANT project an activity was devised in which the pupils were asked to consider some rules for working in a group. These rules were presented to the pupils and they were asked to decide as individuals on the importance of each rule for them, this activity sheet is included as Appendix 5. The activity included the option for pupils to add their own ground rules for group work. One the pupils had competed this task the responses were collated and a copy of the finalised list of the class’ ground rules was presented to each pupil; this final list is included as Appendix 6. It was felt that the process of producing the class list of ground rules was important. First, it had a serious purpose of wanting to raise the pupils’ awareness of their own behaviour and contribution to group work. Second, it was hoped that the activity would show that the teacher and researcher took the pupils’ ideas seriously and that we were interested in what they thought and what they had to say about their work in science.

The value of talk to learning.

As described in Chapter Four, there is a body of literature that asserts the value of talk in learning. Much of this literature is rooted in the work of Barnes and Todd carried out in the late 1970’s (Barnes and Todd, 1977). In more recent times, there has been an emphasis on students’ individual understanding of science concepts. Most notably, this has occupied a number of researchers working from the personal constructivist perspective. The importance of the social context in students’ learning is becoming re-established. Greater interest is being focused on interactions between learners working together in collaborative groups. In particular the nature and quality of verbal interactions has become the subject of
research activity including some substantial studies in the UK e.g. SLANT, and now TRAC projects (Wegeriff et al., 1997) and in Australia (Wild and Braid, 1996).

The potential contribution which talk can make to students' understanding of science concepts has also recently been studied (Alexopoulou and Driver, 1996). This study considered question of group size in relation to peer collaboration. It commented that some studies see pairs of pupils as optimal because it means that peers cannot opt out of the discussion process; others, however see tetrads as optimal because the wider range of ideas presented fosters argument and discussion. The Alexopoulou and Driver study showed that a pattern of argument was influenced by social interaction. In pairs, pre-existing group attitudes towards the task and each other fundamentally influenced the process in which the group negotiated their meanings. There was more progress where groups saw interacting as collaborative rather than competitive. In fours, it was the interrelation of group members' efforts rather than pre-existing attitudes, which influenced progress in the discussion. However, in small groups social factors can sometimes prevent members raising their own objections. Existence of conflicting perspectives is only an aid to discussion in small groups where the members are willing to explore them openly without turning their disagreements into interpersonal conflict.

Alexopoulou and Driver found that in progressive discussions, more of the talk involved questions and evaluations of each other's suggestions. In regressive discussions, peers tended to repeat their predictions and explanation so that the discussion moved in circles.
5.10 Data Collection

Plans for tape recording and studying pupils' talk

Drawing on the issues outlined above, it was intended to make tape recordings of pupils' talk whilst they were engaged in a practical data-logging task. The prospect of taking this methodological approach was not entered into lightly. The recording, transcription and analysis of pupils' talk is problematic for a number of reasons, not least of which is its time-consuming nature. Moreover, Barton's (1997) study of talk from video tape recordings of pupils working on a science activity under controlled conditions indicated the scarcity of pupils' talk. Thus the prospect was raised, in the present study, of small rewards for a large investment of time spent studying transcripts of such talk. Despite this, it was decided to tape record small groups of pupils working on their task. This was done using a lapel microphone and radio transmitter attached to a pupil and a table microphone on their workbench.

Clearly the use of such recording equipment is potentially intrusive and one must acknowledge that there can be no guarantee that the pupils' behaviour and talk would not be influenced by the presence of the equipment. Despite these threats, it was anticipated that, over the course of the study, the pupils would become accustomed to seeing the recording equipment in the laboratory so that the effects of its presence might fade with time.

For case study one, episodes of pupils' talk were recorded on several observation visits. These recordings were transcribed and analysed for episodes of talk that were indicative of pupils' application of scientific ideas or commentary on data.
collected during the practical activity. The transcripts of pupil talk are included as appendices 7a to 7d).

In the other case studies there were fewer opportunities to tape record pupils' talk. These reduced opportunities were a consequence of the type of activity taking place in the lessons. The details of this for each case study are discussed in Chapter Six.

*Follow up interviews with case study teachers*

Following the observation phase of the research, follow up interviews were conducted with four teachers involved in the main study and with two other teachers who had been involved in the pilot phase of the study. The purpose of these interviews was to provide an opportunity to explore these teachers' views and experience some aspects of the use of data-logging in science education and to provide means of following up on issues arising from the observations of classes.

The interviews adopted a semi-structured format based on a schedule of questions (see Appendix 8). The schedule was not allowed to overly direct the interview, which was allowed to follow the natural course of the conversation. This meant that each interview addressed the issues listed in the schedule, but not necessarily in the order shown in the Appendix. Further, additional issues raised in the interviews in response to the direction of the conversation were welcomed.

The interviews were transcribed and the unedited transcripts returned to the interviewees. The interviewees were invited to check the transcripts and to delete,
correct or amend any part of it. No such amendments were made by interviewees beyond corrections of occasional typographical errors made by the researcher!

This process helped to secure interviewees informed consent to the content of the interview. The transcribed interviews are included as Appendices 9a-9e.

For each case, observational data of several kinds was collected. These data included field notes made contemporaneously from observations of lessons, records of issues arising from informal discussions with the teachers, and reflective notes written up by the researcher subsequent to the lesson observations. Where appropriate, documentary evidence in the form of teaching materials, records of school Ofsted reports were also used to inform the accounts of the cases.

In addition, formal observation of lessons using a schedule to record the types of pupil activity occurring and audio tape recordings of pupils' talk during practical tasks were made. Pupils' reactions to the data-logging activities were explored using a pupil diary sheet for some lessons.

At the end of the observational phase in each case setting, a semi-structured interview was conducted with each teacher. This interview explored issues relating to the teachers' views of data-logging in practice. Its purpose was to provide a means by which observational data collected during lessons and the researcher's interpretations of these could be validated. Thus the range of data collection instruments used in the study provided several means of considering each case.
It is important to note that since the research was based in real classrooms, with the expressed purpose of exploring practice, it was necessary for the researcher to stand back from the classroom activity as much as possible. As a result of this minimum intervention approach, control of the activity in class rested with the teacher not the researcher. For this reason it was not always possible or appropriate to use particular data collection methods in a particular lesson episode. Consequently, although the use of a range of evidence-gathering methods offered the prospect of meaningfully exploring each case, it was not always possible to use each method to the same extent in each case study.

Figure 5.5 Data Sources

- Field notes
- Pupil worksheets
- Lesson observation schedule
- Pupil 'diaries'
- Audio tape recordings
- Interview notes

Case study Four – a complementary approach

The literature review presented in the first three Chapters of this thesis led to consideration of aspects of the teacher's role in designing and presenting data-logging tasks to pupils being prominent part of this study. This reflects a chief
feature of most pupils' experience of science lessons - they are organised and managed by their teachers. It is likely that there will be considerable diversity in the approaches adopted by teachers in developing pupils' skills in using data-logging software. This diversity presents a problem for research into benefits of the data-logging approach because it makes control over pupils' learning experience much harder to achieve.

During the course of this study, a software delivered tutorial system became available that was designed to develop pupils' skills in using *Insight* data-logging software; the tutorial software is known as *Understanding Insight* (Logotron, 1998). Further details of this aspect of the study are described in the introduction to case study four in Chapter Six, but here it is necessary to state that the value of the opportunity to include use of the *Understanding Insight* software in the present study rested in the fact that the task content and its mode of presentation to the pupils was controlled not by the teacher but by a software management system that formed part of the programme.

During case study four, *Understanding Insight* was used with six groups of Year 9 pupils working in pairs, there was an equal numbers of boys and girls. All the pupils were volunteers who worked on the computers in four lunch-time sessions lasting 45 minutes each, and a fifth session for a semi-structured interview with a researcher. None of the pupils had previous experience of *Insight*, thus, during the evaluation, *Understanding Insight* carried the main burden of introducing and instructing pupils in the use of the main features of *Insight*. At the outset the two researchers refrained from giving pupils a detailed explanation of either piece of software save that of outlining their purpose and how to get started. Pupils
worked through four basic ‘lesson’ modules and one ‘experiment’ module. For the latter, the activity was mainly focused on analysing previously recorded data rather than setting up apparatus. Pupils were encouraged to alternate in their use of the keyboard and to discuss aloud their ideas prompted by the tasks set within the *Understanding Insight* program. During the sessions the researchers adopted a strategy of minimum intervention but kept written notes on the response of pupils and the chief topics of discussion. In the final session pupils were given a semi-structured interview to ascertain their thinking and views on a range of aspects of the software-mediated tasks. Throughout, the focus of observation was broader than operational consideration of software features; for this investigation it was considered important to record observations which would permit reflection on the context in which the software was being used so that a ‘situated’ evaluation could emerge (Squires and McDougall, 1996).

The development of this software, and its evaluation that draws on some aspects of the findings presented in Chapter Six of the present study, have been reported in Rogers and Newton, 2001 (forthcoming). Formal acknowledgement and thanks are recorded here to Laurence Rogers at the University of Leicester, UK, for making the *Understanding Insight* software available for this research and for participating in collecting some of the interview data for this case study.

**5.11 Approaches to analysis of data.**

For each case study a mixture of data sources were generated as discussed above. At the start of the study, it was intended to use software to support the data analysis. To this end, all lesson observation notes and transcripts of tape-recorded dialogue from classroom episodes and interviews were prepared in a word
processing package. These text files were created in a format that could be imported into specialist software for supporting the analysis of qualitative data. The particular software used was QSR NUD*IST, which was the package available in the institution where the researcher was based. This software permits the researcher to code, search and retrieve data, and to explore relationships between data sets; it also has the potential to support 'theory building' where ideas generated in the data analysis process can be tested with the data sets imported into the software.

At the outset of the present study, it was anticipated that the range and quantity of data likely to be collected required the use of software to support its analysis. In practice, the NUD*IST software provided a useful means of storing and retrieving data 'items'. The more sophisticated analytical tools available in NUD*IST were not necessary for the present study; using the four research issues identified in Chapter Four as the framework for analysis proved to be manageable using the editing features of a word processing package. Thus the main approach to analysis of the case study data was to use each of the research issues from Chapter Four as 'themes' against which data items could be collected and examined. It is this approach which is used to present the findings from the case studies presented in Chapter Six and the interview data in Chapter Seven.

5.12 Summary

This chapter has set out the methodological approaches adopted and their development. An argument has been presented for a collective case study approach to the research based on the issues to be explored, which were set out in Chapter Four. The selection of suitable research instruments was driven by the
needs of the research, informed by literature, and by the practical constraints imposed by the need to work in routine classroom settings.

The four case study sites selected for this research provide complementary settings in which the use of data-logging methods could be studied. It should be noted that the practical difficulties of being able to employ the range of planned data collection approaches in each case study brings limitations, in terms of generalizing from the findings, to the research presented here. Nevertheless, it represents what was achievable in the context of this 'real world' research, and it is necessary to consider the interpretation of the case data presented in Chapter Six and Chapter Seven in the light of the limitations imposed by the research contexts.
Chapter 6

Case studies

6.1 Introduction: Case study data and research issues

This chapter presents descriptions of the case studies through which the research issues identified in Chapter Four are explored.

The school settings that were observed form the basis of the case studies presented here. In order to present the discussion, the general features of each case will be described, so that the reader has some understanding of the background. Each case is then described against the framework of research issues developed in Chapter four. The research issues to be explored through each case are listed below.

**Issue 1 What are the features of data-logging activities designed by teachers?**

This issue is explored through a case-by-case consideration of:

- the openness of the pupils' task;
- the skill level and previous experience of pupils in data-logging activities and investigative work;
- the potential of the task to generate meaningful data in relation to task objectives;
- the value added by ICT to the task.

**Issue 2 How are these activities presented, organised and managed?**

This issue is explored through a case-by-case consideration of:
• the organisation of ICT resources and pupil groups;

• the style of task presentation to the group;

• the confidence and experience of the teacher with ICT in the classroom.

Issue 3 What are the roles adopted by teachers and pupils during data-logging lessons?

This issue is explored through a case-by-case consideration of:

• the means of independent working planned for pupils - pupil responsibility in the task;

• the roles adopted by the teacher.

Issue 4 What evidence of productive interaction between ‘actors’ can be found in data-logging lessons?

This issue includes the types and purpose of teacher intervention during activity, and the interactions between pupils in the activity.

This issue is explored through a case-by-case consideration of:

• features of data-logging practice which were a focus for talk between pupils or between pupils and teachers.

The following sections will argue that the practice of data-logging in school science, in the cases studied, is shaped by the interplay between multiple factors which contribute to the context of its use. The decisions and actions of teachers using data-logging activities and their pupils’ reactions to them present part of a complex mix of influences on the potential outcomes of data-logging tasks.
6.2 Case Study 1

6.2.1 General features of Case 1

Case 1 was set in a City Technology College and is the first of two cases set in this school. A technology-rich school, it is sited in an area of 1960s overspill council estates although there are some areas of private housing; the school’s catchment was therefore predominantly working class.

The school’s 1997 Ofsted inspection report (OFSTED 1997) indicated that the college had a population that is largely white but with approximately 12% of pupils of other ethnic origins. At the time of the Ofsted report, approximately 38% of pupils were entitled to free college meals, which was twice the national average.

Being established as a Technology College, the school has a remit to support development of innovative teaching approaches using ICT. These approaches, including the use of ICT in science teaching, were praised in the schools' most recent (prior to the present study) Ofsted inspection. The 1997 Ofsted inspection reported that

"Pupils’ progress in science is good. This is seen most clearly in the development of practical skills and of scientific concepts and ideas through pupils’ time in the college."

The Teacher

The teacher in the first case (known here as T1) was a senior member of the school staff. He had responsibility for managing the science curriculum area as well as

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1 To protect the anonymity of schools, quotations from the Ofsted reports are not specifically referenced.
certain other whole-school responsibilities. T1's senior position in the school conferred certain advantages in terms of being able to make decisions about organisational matters that had a bearing on the research. He was able to make decisions at first hand, without always having to seek consent from senior colleagues, although in the interests of his department, he did consult colleagues where this was felt to be necessary or desirable. Indeed, the positive relationships between the teacher and his departmental colleagues were identified as a positive feature in the school's inspection report. Ofsted identified the science department as benefiting from good leadership and visionary management from the science team leader.

T1 was an experienced science teacher who was also experienced in research, having previously worked on Assessment of Performance Unit projects. He had also been involved in other research projects connected to the application of ICT in science teaching and so had an informed view of the demands of classroom research. T1 had also worked closely with manufacturers of data-logging hardware to develop and trial teaching activities using the equipment. Some of these data-logging activities had been incorporated in to T1's own science teaching.

Science ICT Resources

The science department made use of 'stand-alone' PC machines, the College computer network, lap top computers and hand-held 'pocket book' machines. T1 expressed a preference for using the pocket book computers for data-logging. This was for several reasons. He had found these machines to be robust in use and to be a cost-effective alternative to lap tops. The pocket book computers had advantages
over laptops in their power management systems and T1 considered the data-logging software on them to be adequate for most of his purposes, particularly with younger pupils. At the time of the study, the choice to use pocket book machines precluded certain types of data-logging activity; for example, the software available on these small computers did not support 'timing' functions.

The pupil group

As part of their studies, pupils in the early years at school 1 had periods of enrichment activities timetabled weekly. These enrichment activities were intended to extend and complement the mainstream curriculum. Pupils were offered a range of activities from which they could choose.

When negotiating involvement in this research, T1 offered to use this time to run an 'ICT in Science' enrichment activity. The purpose of this was to provide an opportunity for participating pupils to broaden their experience of using ICT in science contexts and to develop their skill levels in using the computer equipment.

T1 was able to offer the opportunity for the researcher to work with a group of eighteen mixed Year 7 and Year 8 pupils during a double lesson (two consecutive fifty-minute lessons) of enrichment time. The activity took place in the third term of the 1996/97 academic year, so that the pupils were at the end of their year of study; the pupils were twelve and thirteen years of age.

The enrichment lessons

At the planning stage, a meeting was held between T1 and the researcher to discuss the possible format of the lesson activity. T1 was willing to be as flexible as
was consistent with the stated aims of the enrichment activity. In practice this meant that the pupils needed to gain experience of several ICT applications, namely data-logging, the Internet and use of CDROM material.

**The types of task**

T1 planned a structured set of three activities for the pupils. These activities were set within the theme of ‘Greenhouse effect’; the selected tasks were:

1. a data-logging task involving temperature measurement.

2. a research task using CD-ROM materials

3. a research task using the Internet.

In planning these activities, the teacher consulted with the researcher regarding the scope of each task in relation to the broad purpose of the research. This approach, driven by the teacher, resulted in a series of lessons that were organisationally highly structured. The pupils were assigned to working groups of three and a rota was drawn up for the duration of the enrichment that assigned groups to activities. It was planned that each group would work on their assigned task for two sessions.

At the first meeting of the group of pupils, the teacher introduced the activities in broad terms. The pupils were told that the enrichment provided them an opportunity to develop their ICT skills within a science context. It was explained that there would be a circus of three ICT-based tasks.

The context for this activity was the greenhouse effect. The teacher already had designed and tested a data-logging practical activity set within this broad theme.
Additionally, the theme lent itself to exploration using both CD-ROM and Internet resources that were planned as part of the ICT experience for this enrichment class.

6.2.2 Findings from case 1

Issue 1 task features.

Using a data-logging experimental procedure, pupils were invited to explore whether the presence of high levels of carbon dioxide (a greenhouse gas) affected heating and cooling of ‘air’. The data-logging activity was a tried and tested experiment in which pupils had to measure the temperature of the gases contained in two plastic drinks bottles. One bottle contained air enriched with carbon dioxide; the other contained ordinary air. The temperature was measured using temperature probes and recorded in real time using a Logit data-logger connected to an Acorn pocket book computer running Logit software. The bottles were heated using a 60 watt electric light bulb.

This task had been invented by the teacher and was one that he had had previous experience of using with pupil groups.

The task was based on a pupil worksheet which was written by the teacher (Appendix 10). The worksheet included a schematic diagram of the experimental set up. However the teacher took considerable time at the start of each lesson, to explain to the pupils how to set up the equipment. This was done within the context of an activity problem, so that the pupils were given an overview of the lesson activity.
The result of this approach was that the pupils were presented with a clearly defined activity. The problem under study, its method of investigation, the experimental set up and decisions about measurements and their recording and presentation by the software were each planned for the pupils. In these first sessions, the task was tightly controlled by the teacher.

The purpose of the enrichment was to provide pupils with opportunities to develop their skills in using ICT in science. To this end, the use of such a tightly defined task could be appropriate when a lesson objective is to teach pupils to operate the data-logging equipment.

The activity itself had potential to develop a number of skills beyond data collection. But the teachers' objectives for the lesson did not extend beyond the need to develop the pupils' skills in using the equipment at this stage. At the end of the activity pupils' conclusions about the science issue being investigated were expressed in largely qualitative terms. Pupils described which of the two bottles heated up quickly or cooled quickly; there was no requirement within the structure of the task for pupils to explore data more deeply than this.

The data-logging activity was highly structured to provide the pupils with guidance as they worked through it. The task presented pupils with a defined problem and method and so could be classified as closed. The pupils' response to the data collected from the activity was not defined by the task protocol.

The teacher gave the pupils instructions on what they had to do in addition to providing them with copies of the worksheets and methods. These sheets provided questions and prompts to pupils' discussion.
The format of the lesson was controlled and prescribed by the worksheet and the teacher's instructions and guidance to the group of pupils. Thus the lesson was focused on familiarising the pupils with the data-logging equipment and with the principles of the data-logging approach to experimental measurement.

**Issue 2 task presentation and organisation**

During the classes there was well-organised management of the pupils - the pupils were assigned to groups by the teacher and a group rotation though the tasks was also planned. At the first group meeting there was an explanation to the pupils of the purpose of the enrichment. There was also explanation to the pupils of the prospects of what they would be doing week-by-week. This strategy meant that all the pupils knew that they would eventually experience each of the ICT activities.

Regarding the data-logging activity, this task was the main focus of the enrichment from the research perspective. The data-logging task in this class was prescribed by procedure given to the pupils by the teacher. This procedure was developed and tested by the teacher and was one of several that had been produced within the science department.

Although the data-logging activity was tightly defined with little obvious scope for pupils to explore their own ideas, the teacher set the task within an exploratory context. The presentation of the task to the pupils enabled it to be presented as challenging. This was achieved through the teacher's introduction to the lessons. At the first meeting of the group, the teacher explained that there would be opportunities for all the pupils to do a range of different ICT tasks. The teacher demonstrated just the data-logging equipment to the group as a whole so that they
would know what they would be doing in general terms. The teacher showed the
group the equipment they would use (LogIT data-logger, temperature sensors,
pocket book computers), and how to set it up. The teacher thought that this would
need to be re-emphasised at each meeting.

The teacher had some stimulus material from a newspaper article which served to
set the task in a context which it was felt the pupils would find interesting. This
material concerned the use of a potential 'greenhouse gas' in the manufacture of
famous brand training shoes. At the time, branded training shoes were of
considerable interest to young people!

This approach helped the teacher's objective to put the activity in a real-life
context, which might be familiar to some of the pupils. The pupils were then
introduced to greenhouse effect as the focus topic and asked to answer three
questions on their own about what they know already about the topic. They were
reassured that it was acceptable to give 'don't know' answers since, from their
perspective, the aim of the activity was to find out about the topic. It was the
newness of the task and the pupils' unfamiliarity with data-logging methods that
enabled the teacher to raise interest in the activities that followed.

Pupils were given the information about how the class would be divided into
groups for activities next time, although allocation of groups to tasks was deferred.
The teacher also controlled the allocation of pupils to working groups. There were
two groups of three pupils (single sex, single year group) on each task in the two-
week rotation through the circus of activities. This was planned in advance and
done briskly and without fuss during the lessons.
Issue 3 Roles and responsibilities

The roles of the pupils were largely defined by the task. There was equipment to be collected and assembled into a functioning experimental set up. Pupils did this by following the worksheet schematic diagram, the teacher's verbal instructions, the teacher's demonstration, and the advice given by the teacher as the pupils were working. Within their groups, the pupils organised themselves. Some pupils took the lead and others followed; how this was established was not clear. It was possible that the pupils had worked together before and had established working patterns from what they knew of each other from different contexts.

During the active phase of the lesson once practical work was underway, the teacher supported the pupils by moving from group to group. Experimental set ups were checked by the teacher and questions asked of the pupils. Some of these questions were related to the experimental set-ups and later, to the pupils' observations of their results. What emerged from this was that the teacher's interventions in the pupils' work served a number of purposes. The interventions were sometimes focused very specifically on the operation of equipment. On other occasions the teacher asked questions to do with pupils' observations. Occasionally an intervention apparently triggered by one event lead the teacher to take the opportunity to talk to the pupils about a related or even different issue. So there were instances of statements from the teacher which re-focused the pupils attention on the task or to highlight the purpose of the activity.

In this classroom the teacher circulated, prompted the pupils, probed their observations and understandings. Throughout the lesson he was circulating and
supporting the groups of pupils. He intervened in the pupils’ work with careful
questioning strategies to explore their ideas and to lead them into other ways of
thinking about what they were doing. The pupils responded well to these
interventions and gave the impression of being able to engage in this kind of
interaction.

**Issue 4 Interactions – pupil interactions**

Study of the transcripts of talk occurring during the data-logging task reveals a
number of interesting features. The kinds of talk which occurred are related to the
various phases of the pupils’ experimental activity.

First, a large proportion of the recorded talk is of a type which might be termed
“Operational Talk”: talk concerned with pupils setting up and managing
equipment; this finding is consistent with those of Rogers and Wild (1996). It is
not surprising that this kind of verbal interaction occupied so much of the lesson
time. These pupils were novice ICT users. They might be expected to direct much
of their attention to equipment issues, since they were becoming familiar with
setting it up and using it. In the process they encountered problems of positioning
of sensors or of managing software that needed to be solved in order to get the
experiment working. Of course, these are important aspects of pupils’ developing
skills in National Curriculum Experimental and Investigative Science (Science 1);
and they form a part of any practical activity.

Once the experiment was set up and the data is being logged, a proportion of the
pupils’ talk related to the gathering display of data. During this second phase of the
practical work, pupils were observed reporting to each other on the data. These exchanges constitute a verbal commentary on the data. In real-time data-logging, the graphical display provides pupils with the data in a format which seemed to encourage its qualitative description and comparison. The following recorded exchanges illustrate the point (note that the computer display shows the two line graphs and a digital display of the numerical temperature values being recorded by the temperature sensors):

S1: It's working.

S2: Number 2 is a bit higher {S1 hmm's agreement} (indecipherable) is the carbon dioxide...

S1: So, there's only a tiny, tiny gap isn't there. {Note: referring to the graph display on the palm top computer which shows two lines.}

S2: Mmm, the carbon dioxide. Number one's slowly stopping, stopping around the same place.

S1: Number 2 is building up isn't it?

S2: Well it's stopped, it's going down a bit.

S1: It's balancing around the forty point isn't it? {Note: the pupil is perhaps having problems here with reading a decimal scale. The computer display shows the two line graphs and a digital read out of the temperature values being recorded by the sensors.}

... {long pause without utterances, data-logging continues}
S2: It’s gone up now, the air’s gone up.

(indecipherable)

S1: There may be a possibility of going up to twenty degrees centigrade. Number 2, that one isn’t going up much, just hovering.

This episode reveals a further interesting feature of pupils’ description of the emerging data. There are examples in the talk of phrases that describe patterns in a line graph or trends in data. This finding supports Barton’s (1997) comparative study of graphing. When one listens to the pupils talking about the data or reads a transcript, one gets a sense of the pupils’ ‘feel’ for the data. For these pupils, the data is doing something. Words that describe the graph as rising, building, going up, hovering, dropping; convey images of the data in action. The pupils’ choice of words seems to refer to the ‘behaviour’ of the graph as a dynamic, changing form; something like a movie of the data.

This feature of pupils’ interactions with the output from data-logging experiments may provide a new opportunity for helping pupils to get to grips with the meaning in graphs of their data. Graphs drawn manually from data present pupils with a complete, static image of all of the data. On the other hand, computer drawn graphs from real-time recording allow the data to be revealed bit by bit.

The prospect of pupils speculating about what the graph might do next may help them engage with the data more meaningfully. It may encourage them to look for trends to help predict future patterns in the data, as in S1’s last utterance in the above exchange. As Kelly and Crawford (1996) suggested, bringing the computer
graphical representation into conversation enables the pupils to draw on it to develop ideas and justifications. The following sequence of exchanges between a group of Year eight boys emphasises the point:

S1: What's the temperature?
S2: They're both, no no no ...
S3: Which one's Y? (Note: this refers to the digital display of temperatures and time scale (y axis); pupil apparently not clear about the relationship between the graph and these numerical displays)
S2: One, two, I reckon, yeah, because look at the temperatures; one, one, Y is 22.77 and 2 is 22.7, so number 2 is rising and number one is just staying.
S3: Number one's rising,
S2: They're both rising.
S3: None of them has overtaken yet.
S2: It looks like its gonna overtake.
S3: It looks like its going to, it might.
S2: It has! They're not the same, oh my life! Two's taken over, two's 23.4.
S3: It's taken over quite a bit, only just taken over though.
(Pause)
S3: Carbon dioxide's hotter.
In this exchange the pupils’ comparisons of the two data sets have the flavour of a race. The collaboration between the pupils revealed in these exchanges, and the elements of competition they introduce into their descriptions of the emerging data, seem to focus their attention on the data.

An important skill in Science 1 at Key Stage 3 and Key Stage 4 is the ability of pupils to identify trends and patterns in results. At Key Stage 3, pupils need to be able to use results to draw conclusions and make a decision about the results in relation to their predictions. Progression at Key Stage 4 requires that the relationships between variables be considered; this may demand a more quantitative approach. Encouraging pupils to consider data qualitatively as a first step is likely to allow them much easier access to the meaning of the data, than if they have to grapple with manipulation of quantitative data to construct a graph and then to describe any trends. The higher order skill of quantitative description of the variable relationships may be more successfully accomplished as a result of familiarity with trends in the data.

However, a study of pupils’ performance in graphical tasks, carried out on data collected under the auspices of the Assessment of Performance Unit (Swatton and Taylor, 1994); reported that many pupils only most readily described the obvious features of graphs. They also appeared to see graphs as “pictures” of one variable rather than as a representation of a relationship between variables. The authors suggest that the ability to describe relationships between variables is dependent on pupils understanding what a graph represents and on helping them to acquire the
vocabulary required to translate the graphical image into an appropriate verbal form.

In my own studies of pupils' talk about their real-time graphs, there are examples of pupils' perceptions of the graph as a single variable image. However, there are two features of the data-logging graph which appear to offer the pupils the potential to develop a deeper understanding of the variable relationship displayed by the graph. Firstly, the graph is produced as it happens in time. This may serve to emphasise the time variable because it becomes a more prominent feature of the graph than in a 'static' graph produced after the event. Further, a software feature which automatically re-scales the time axis as the experiment progresses, may emphasise the graphical image as having two variable components. These two features may help to direct pupils' attention more effectively to meaningful parts of the graphs.

A second useful characteristic of the experiment described is that it generates two data sets which are simultaneously displayed by the computer. This encourages the pupils to make comparisons between the two lines on the graph. It appears to prompt pupils to look at features of the graphs a little more critically. In short, there is potentially much more for the pupils to observe and to talk about in the real-time graphical display than in traditional graphs. This finding supports those of Barton's comparative study of computer-aided graphing (Barton 1997).

Teacher interventions

It has been indicated above that much of pupils' talk about their graphs is of a descriptive nature. The ability of pupils to describe trends in graphs is, of course,
an important skill and one which can help pave the way to pupils successfully articulating the variable relationships shown by graphs.

It is likely that some pupils may be able to describe patterns in graphs using the kind of everyday language illustrated above, without appreciating the underlying meaning or significance of the graphs themselves. There is no reason to suppose that exposing pupils to real-time graphs will of itself lead pupils’ developing this deeper understanding. On the contrary, one might expect that, as with many other skills, pupils need to be guided in their thinking and taught how to tackle these problems.

A significant feature of the recordings made in the present study reveals that the quality of the pupils’ talk about their data improves in discussion with the teacher. This is illustrated in the following two edited extracts:

Extract 1: exchange between some Year seven girls and the teacher.

Teacher: Right what’s happening now?

S1: They’ve gone..

S2: They’ve broken away, its gone from 20 to 22.

... 

TEACHER: Which is the one with the carbon dioxide? That one there?

S2: Number 2

TEACHER: That’s number 2. ... Did they both start off at the same?
S2: No, number 2 was a bit ahead.

TEACHER: Ahead slightly, what do you mean by ahead?

S1: It was slightly hotter.

TEACHER: By how much? Did you ...

S2: About ten degrees.

TEACHER: When you say ten degrees do you mean...

S2: the second number.

TEACHER: Right that's point one degree, yeah?, because these are ...

(Note: an interruption occurred at this point)

TEACHER: OK, so these are 22 degrees now, that's the decimal point and then its "points", tenths ... of a degree. OK? So the difference at the moment is 1.5 degrees, one and a half degrees approximately. OK?

Extract 2: An exchange between a Year eight boy and the Teacher.

TEACHER: You know that you've had to adjust your lamp? Will that affect the way your graph looks, do you think?

S1: Yeah.

TEACHER: How might it change the way the graph looks?

S1: Er, when it moves closer the graph goes higher but when it moves away it start to stabilise.
TEACHER: So, might that confuse you when you look at the graph to compare the two bottles?

S1: Yeah, it might actually!

TEACHER: Can you see any point on the graph where you think that might be where you’ve moved the bulb?

S1: There.

TEACHER: What’s happened there?

These exchanges indicate that pupils can identify important features of their graphs and relate them to their experiments. However, the teacher has a key role in directing the pupils’ attention to these features and in prompting their thinking. By asking open questions which encourage the pupils to formulate their own responses, teachers can help pupils think more critically about their data.

Interventions form a significant part of this teacher’s repertoire of monitoring strategies. But the interventions seem to be purposeful. It appears that one result of interventions can be to get pupils back on task – a behavioural management outcome. Pupils get more than information from a teacher intervention, they also get re-assurance and encouragement which can sustain their interest and motivation through a demanding task. In other words they can check their understanding with another person and not have to rely solely on their own judgement.

In addition, the teacher seemed to use the intervention opportunity to move the pupils on in the activity. This appeared to have the objective of helping the pupils
to get more out of the task by directing their attention to be more engaged with it.

For example:

P1: so we press 'enter' when we're ready?

TCHR: start logging, press enter when you're ready, But get the gas in, don't start till all the tablet has dissolved and then ... what about the other rubber bung? but yeah this has got to be in the middle so you'll need some blutack to make sure that that one's in the middle as well

P2: that one over there?

TCHR: yeah, that's OK. The question is are they equidistant - equal distance away from there. OK yeah? Just wait till its ... you don't want the pressure to build up in there, you just want the air to come out ... and what's going to replace the air?

P2: }

P1:} {together} carbon dioxide.

TCHR: there's gonna be carbon dioxide in there, and then put this in, What's the blutack for?

P2: }

P1:} {together} to keep it (the sensor) in place

TCHR: and also what else?

P2: So no carbon dioxide gets out
TCHR: well done! no carbon dioxide gets out. OK and then you need to switch that on obviously, get logging straight away.

And, later on in the lesson:

TCHR: what are you seeing girls; anything happening?

Pi: not really

TCHR: why do you think its not happening - very much? Any ideas? Is it getting hotter at all?

Pi: a bit its just hovering

TCHR: so what’s causing it, what’s making it rise in temperature, where is the energy coming from?

Pi: there (pointing to bulb)

TCHR: OK, so if the energy’s not going in what are you gonna do to try and get it hotter?

Pi: move it closer.

Teacher questions are an important means of re-focusing the pupils' activity and keeping the various elements of the investigation in the forefront of their thinking. The questions help to direct pupils' attention appropriately. This seems to be of importance in tasks which are made complex either because the approach or equipment is new, or because there is a lot of procedural 'noise' which makes it hard for the novice to know which of the many events they are exposed to are significant. Perhaps, left to their own devices, pupils would not take these
opportunities; if they did notice experimental events, they may not appreciate their significance. The teacher intervention helps to maximise these opportunities, provided that they are noticed or anticipated by the teacher as a result of prior experience with an activity.

Pupils' knowledge and understanding of their investigation tended to appear explicitly only when there was an intervention by the teacher. The interventions, using skilled questioning techniques which prompted the pupils rather than lead them, are akin to notions of scaffolding with appropriately timed fade. This finding highlights the need for such interventions or some other means of structuring the pupils' activity e.g. through well-designed worksheets.

Observations for the present study indicated that some student groups spent time during the data-logging practical apparently doing little more than watching the equipment log the data and present the graph. Analysis of the students' lesson diaries revealed that whilst many particularly liked handling the equipment and doing the experiment, they also disliked passively watching the experiment. The following were some of the students' diary comments:

- *I didn't enjoy just sitting around and just watching the bottles and the palm top*

- *I did not enjoy watching the lines going up or down or staying the same*

- *I did not enjoy waiting for the temperature to rise and watching it rise.*
These statements suggest that the apparent waiting times could lead students to become bored with their experiment. There is a danger of students being "switched off" and not engaging with the activity or its outcome, or being distracted into some side activity.

If this risk is to be avoided, there is a clear need for the students’ activity to be carefully structured. One option may be to get students to write up their experiment during the wait time, but this strategy deprives them of one of the key benefits of real-time data-logging, as suggested above. Better perhaps for the students to be encouraged to think about their data as it appears on the screen, by providing some prompting strategies or activity.
6.3 Case Study 2

6.3.1 General features of Case 2

Case 2 is the second of two cases set in a City Technology College (CTC). The general characteristics of the college are as described under case 1. Visits for case 2 were made to the college during the term following those for Case 1 i.e. during the Autumn term, 1997.

The Teacher

It was originally planned to follow up case 1 pupils working with the teacher, however that teacher's responsibilities as a senior college manager meant that he was not able to commit time for a further cycle of the research study. However, the teacher (T2) involved in case 2 was encouraged by his department head to become involved in the project.

At the time of the research, T2 had been teaching for a comparatively short period. A mature entrant to the profession, T2 was in his second teaching post at the CTC. A chemistry specialist, this teacher had no additional responsibilities beyond his teaching duties. He was an enthusiastic science teacher with a strong interest in the use of ICT, as might be expected in the environment of a CTC. However, he was less experienced than T1 both as a science teacher and as an ICT-user.

Science ICT Resources

The range of ICT resources available in case 2 was similar to that for case 1. However, the location of T2's teaching base was separated from the main science facilities. Whilst this and other similarly located rooms were served by their own
preparation facilities, it nevertheless presented additional logistical difficulties for
the teacher in organising resources. There was a single stand-alone PC in the room,
but the shared ‘pocket book’ computers and sensors needed for data-logging
activities were located away from this room. This meant that when they were
required, they had to be ordered through the science technician at least a week in
advance.

Although the science technician suitably serviced the department, these factors
made significant organisational demands on T2. It also meant that resolving
problems that arose during lesson use of ICT equipment was more difficult. The
teacher occasionally found himself having to re-organise his plans because of
equipment problems and inaccessible support to rectify them. On some occasions
this dealt a ‘fatal’ blow to the lesson plan such that substitute activities needed to be
found at the last minute. There was a contrast between the ability of T2 and of T1
to martial resources for practical teaching. This contrast could be explained by
differences in experience of the two teachers, however it is possible that status also
played a part. T1 as the head of department was likely to have benefited from the
positional power associated with his role, a benefit not necessarily available to T2.

Consequently several factors influenced to the ability of T2 to secure the resources
needed for delivering his planned activities. These factors included the
geographical situation of his teaching base being apart from other science
laboratories; the logistics of ordering and organising equipment which needed to be
relocated for T2 to be able to use it; and the ‘political’ aspects of T2’s situation in
respect of his relationships with teaching and technician colleagues and his relative
ability to command resources. Nevertheless, once secured, these resources provided the same range of teaching opportunities as in case 1.

**The pupil group**

As described in Case 1, pupils at the CTC in Years 7-9 were regularly timetabled for activity lessons designed to enrich their other studies. The pupils in case 2 were a group of Year nine pupils who were timetabled for their enrichment time. This particular pupil group was of mixed gender and mixed ability. In one of the first meetings, it became apparent that some of the pupils had not selected this enrichment activity; they had been allocated to this particular group by the enrichment co-ordinator. Some of the pupils made it plain to the teacher that they would prefer to be doing something else, asking if was possible to change group.

**The lessons and the types of task**

It had been negotiated with T2 that an 'ICT in science' enrichment be offered and, from the research perspective, it was intended to look at aspects of ICT use with older pupils than had been involved in case 1. In contrast to Case 1, these enrichment lessons were not pre-planned in consultation with the researcher. The reasons for this were that the research focus was intended to explore the use of data-logging in the teacher's hands and that it was assumed that, being in Year nine the pupils would have some prior experience of using the data-logging technology from other science lessons.

At the first meeting of the group, the teacher explained that the aim of the lessons was to use ICT in science.
As indicated above, T2 had not apparently planned a 'circus-based' series of lessons. A whole-class approach was adopted. Pupils were not assigned to groups but worked in friendship groups. The teacher's plans were not discussed with the researcher in advance of the lessons. The teacher's approach to these lessons was organisationally less structured than in Case 1. Although the teacher took time at the start of each lesson to explain the aims for the activity, pupils pursued the tasks in a less structured way.

The first lesson

At the first meeting of the group the lesson ran from 13.10 to 15.40 with a lunch break between 14.00 - 14.35. There were seventeen students listed for the enrichment activity but they were not all present. The first meeting was not straightforward, because some pupils arrived late and there was some confusion over who should or should not be in the lesson. The start to the lesson was complicated by clashes with sporting enrichments, which were likely to remove some pupils on occasions. The irregularity of some pupils' attendance presented the teacher and the pupils with potential continuity problems.

At the start of the first lesson, the teacher demonstrated the data-logging equipment the pupils would use. This involved using LogIT data-logging boxes fitted with 'checkit' displays and sound, light and temperature sensors. The students were organised into groups of two or three.

The teacher encouraged the pupils to explore the equipment saying 'play with it - find out what the sensors do'. There were some equipment problems. The pupils explored what could be done with the sensors and the LogIT - learning what the
control buttons did. Some of the pupils liked singing into the sound sensors! One pupil, said 'how will this help you in real life?'

After an initial period, the pupils settled and began to explore the data-logging equipment and familiarise themselves with it. The first part of the lesson soon came to an end and the equipment was collected in over the lunch break. After lunch the group reassembled. There were eight remaining students the rest were either absent or involved in team sports activities that clashed with the enrichment module.

For the second part of the lesson, the teacher gave instructions as the pupils worked on the task. The practical task involved placing ice cubes in a boiling tube with a temperature sensor connected to the LogIT, and gently heating the tube to melt the ice. There were no computers out, so the students were using the data-logging 'checkit' displays and temperature sensors as digital thermometers. This method involved no storage of data or its subsequent retrieval into software. Indeed the students were asked to draw pencil and paper tables to record temperature readings every 30 seconds.

This group activity was very focused: 'Sir, the heat's going down' to which the teacher replied 'can you think of reason for that?'. Another pupil referring to the soot collecting on the outside of the glass tube, observed 'Sir, there's burning at the bottom of the test tube'. The lesson ended without any science-focused conclusion to the task.

Overall the lesson was very much teacher directed. The data-logging equipment was used for collecting data but not for 'logging' (in the conventional sense) for later study. Rather, the equipment was being used as digital thermometers.
Although this type of use was not really exploiting the potential of the technology, this was the group’s first lesson together. It could be a useful way of familiarising pupils with the assembly of the equipment at a basic level. However since these were Year nine pupils in the technology college, it could be expected that they would have seen and used this kit before.

**The second lesson**

The group met for their second lesson the following week. The lesson started a little late but the teacher gave an introduction on line graphs and asked the students to draw graphs from the previous week’s data on melting ice - the episode described above.

The Teacher gave the pupils a title and graph axes on the board and offered advice on suitable axes for the graph because of the awkward scale. This is drawn in 50-second intervals, even though but the pupils’ data was recorded at 30-second intervals.

The pupils manually plotted their graphs - this was a slow process and there was quite a lot of social chitchat as they drew their graphs. The graph drawing appeared to be mechanical - the pupils were not really engaging with the data, they were talking about other matters. This phase of the lesson drew to a close as the lunch break approached.

After lunch the class resumed and the teacher introduced the next data-logging activity. This was a chemistry practical using acid and thiosulphate to investigate rates of reaction, although the teacher did not set the task as an investigation into rates of chemical reaction.
Teacher explained how to set up the apparatus, the pupils looked interested at the prospect of 'acid'. Once the teacher had demonstrated the method. The pupils got on with the task, which involved using light sensors beneath beakers containing acid and thiosulphate. The beakers and sensors were shielded by aluminium foil except at the surface, to allow daylight to enter the beaker and be detected by the light sensor. The LogIT with checkit displays were being used as digital light meters rather than for data storage.

The teacher intervened in the pupils’ activity from time to time to check group progress: 'how will we know when it has finished reacting?' However, for most of the lesson pupils were setting up their equipment.

There were a number of problems with the experimental procedure but there was no discussion of the endpoint, and no identification of uncontrolled variables (especially varying light levels in the room which would effect the measurements taken by the pupils). There were problems with the experimental design in relation to variables and the purpose of the activity was not really explained to the pupils. The group were mixed in their apparent interest in the task as revealed by their engagement. Some of these problems were attributable to the lunch break interrupting the lesson flow; others seem due to the way in which the activity was conceived by the teacher.

The third lesson

This lesson was a re-run of the previous week’s experiment involving exploring rates of chemical reaction using hydrochloric acid and sodium thiosulphate.
However, the task was presented to the pupils as a task to generate display work prior to a planned inspection visit by OFSTED.

The first twenty minutes of the lesson was spent setting up equipment, two pupils (Christian and Kevin) adopted a serious approach with the equipment carefully set up.

After some time the teacher stopped the group to introduce them to the variables to be investigated. A table was drawn on the board indicating volumes of water, acid and thiosulphate to be used for each experiment. The pupils were asked to record the time; but the time for what, was not explained.

Two boys (Neil and Craig) were not really engaged in the task; they were absent during the previous week and so did not know what was going on. They just watched and toyed with equipment. Another pupil, Natalie, just watched passively not apparently doing very much at all. The teacher chided Natalie who responded with ‘I’m watching’.

Some pupils were having to check how to read 5 cm$^3$ in a 100 cm$^3$ measuring cylinder. In this respect, the equipment provided for the pupils was not well matched to the task protocol. Again no computers were in use in the lesson, just Checkit displays attached to Logits to provide digital meters.

The researcher directed one groups’ attention to the data-logging checkit and asked ‘what’s happening now?’ ‘It’s gone up’ was the reply. This was an unexpected result probably due to the variations in natural daylight which the sensor detected. This was an uncontrolled variable in the experimental design; however the pupils were not asked to predict outcomes from the experiment and
so are not likely to have any notion of what results to expect. A further procedural design problem was that the acid concentration was too low to give a large change in detected light levels.

The pupils did make pertinent observations: 'Sir, what's happening to ours?' the pupils had not added any acid. Neil observed: 'Sir, there's a weird smell - is it the sulphate?' later, Lyndsey said 'it smells like that perming stuff' The observations by the pupils provided potential intervention points for the teacher, but these were not taken up because the teacher was involved with other pupils.

'What kind of graph will we draw?' asked another pupil. The teacher suggested a bar chart and gave the title of the graph. Neil commented 'this title's so long its reaching to the next star!'.

During this lesson some of the pupils were high-spirited. There was some silly behaviour with pipettes and very little focused pupil activity from the session. Neil was eventually removed from the lesson. The teacher had to intervene a lot to keep the students on task. Craig, Neil and Nick were very unproductive whereas Kevin the fourth member of the group and Nick's brother, was trying to get on with his work.

The demands on the teacher were high in this lesson. He gave a lot of information to the pupils and there was very little asking the pupils for their ideas or contributions to the exercise.
The fourth lesson

This was the first meeting of the group following a half-term holiday. During the first part of the lesson before lunch, the pupils completed poster display work in preparation for the impending visit by OFSTED. It was noted by the researcher that the pupils seemed quite enthusiastic about this poster work in contrast to some of their responses to the preceding practical data-logging activities. The pupils followed a written method supplied at the white board by the teacher and copied it neatly for their posters. Despite the apparent interest of the group only about one third of the class were engaged with the task, the majority engaged in 'side-talk' and other apparently off-task behaviours.

After the lunch break the teacher involved the pupils in an activity which he had not previously tried. The idea was to devise a method for investigating the density of liquids. The principle behind the teacher's idea was to use a position sensor linked to a float to record the 'height' of the float in various concentrations of salt solution; this could allow comparison of relative float height in the solutions and provide an indirect measure of their relative density. Although the idea was outlined to pupils in broad terms, at face value the pupils' task was to design a float, using plasticene, which could be floated in a salt solution contained in a measuring cylinder. The teacher emphasised to the pupils the importance of being able to achieve this reproducibly: 'try to get it to float at the 10cm mark every time'.

The pupils used a trial and error approach to find a mass of Plasticene with air trapped inside which would float. Pupils were engaged in the task quite
enthusiastically and seemed to enjoy the challenge of trying to succeed in the task. But, many of the pupils failed at this task. The teacher then offered plastic teat pipettes as ‘floats’ that could be cut to size and floated in the measuring cylinder.

Some pupils were distracted into a game of noughts and crosses. Craig invited the researcher to have a go!, ‘I'm bored now’ he stated.

There was no data-logging at all in this lesson, the first of the new half term. The teacher explained that equipment and technician problems meant that it was not possible to use ICT in the lesson.

Many of the pupils were keen to try to make a float - this was like play, but none of the potential science was brought out of the activity by the teacher; for example the forces involved in floating and sinking. Nor was the direction of the activity was not well explained to the pupils in this lesson.

Lesson five

This was the second lesson in which pupils were encouraged to make floats with the ambition of using a data-logging approach to measure density of salt solutions. The teacher had modified the approach so that this time corks were to be weighted with Plasticene to get them to float.

The teacher’s introduction gave the activity high status: “This can be written up as a professional method with the school logo ....”. The pupils reacted positively to this proposal and appear to be more involved in the task. They had arrived at the lesson very keen to get going; they seemed to like this exploratory activity. It is possible that it is easy for the pupils to understand the purpose of the task. Perhaps
in data-logging, the purpose is less obvious to the pupils; for the researcher it was less clear as to exactly what the advantages might be of the teacher's chosen 'data-logging' approach over a traditional method for density measurement using a hydrometer.

Lesson six

This was a very differently organised lesson. The school was being inspected by OFSTED during this week, and an Inspector was expected to visit this lesson. Some pupils were sent to the resource centre; some carried out a data-logging activity on greenhouse gases (the same task which had been used during the lessons describe in Case 1); some were assigned to work with the researcher using Insight OILS software. All the necessary equipment was present, including a PC on a trolley.

The lesson seemed to be planned much more with the pupil group in mind, rather than being task-focused. The teacher had arranged several activities and assigned a group to each. The less motivated pupils from previous weeks were sent to the resource centre. This effectively removed them from the lesson and 'freed' the teacher to work on a data-logging task with a small group of six pupils.

The lesson was well managed with a positive atmosphere. It appeared that the teacher had been able to gather resources and plan for this lesson more purposefully than in some other lessons which had been observed. There were new activities, organised in a circus and all the necessary equipment was there from the start of the lesson. This observation serves to stress the importance of good preparation and organisation in ICT-based science lessons.
One Y9 boy commented at the end of the lesson that the teacher had "*got rid of us because of OFSTED*". He was one of those who had been troublesome in previous weeks and had been assigned to work in the resource centre on this occasion, rather than in the laboratory. The researcher was struck by this remark. It was a useful reminder that pupils can be perceptive and that teachers do need to be sensitive to the implicit 'messages' in their actions.

After this lesson the teacher indicated that he had plans to "*turn it into a science enrichment*" next term. He viewed the data-logging tasks as too difficult for the pupils. Where the ICT equipment was available the pupils managed well. It is possible that the teacher's comment here was recognition that the data-logging activities are difficult for a teacher to manage successfully. There are risks attached to running data-logging tasks in terms of the availability of equipment and the pupils' skills in using it. But there is also the challenge to the teacher concerning how comfortable they feel in managing ICT activities. Enthusiasm for using ICT is one thing; experience of managing it so that the pupils successfully achieve the planned outcomes of the lesson is another.

**An overview of these six science lessons.**

During these six lessons the teacher was open and welcoming on all occasions to the researcher. A number of factors arose during the six observed lessons which shaped the value of the sessions as examples of ICT use in science.

The lessons were held in a room away from most of the other laboratories and preparation rooms. This meant that it was necessary for the teacher to anticipate all
the equipment demands for a lesson. It was impractical to resolve unexpected technical problems because the equipment and support was not readily available.

The teacher adopted a whole-class approach to data-logging activities. There were probably good reasons for this decision in terms of equipment and group organisation, but these were not obvious. Sessions were presented to the students as one-off activities except in some cases where the activity ran into a second week.

There were problems with the session being split by a lunch break, which meant that either equipment had to be put away, the teacher had to ‘sit’ with it over break, or no practical was started until the second session. All three of these options were used at some point during the period covered by these lessons. The preferred option seemed to be to sit with the equipment.

The pupils were a group of mixed ability. Some of the less motivated pupils were quite vocal in their reaction to the situation and the tasks they were being presented with.

Once the practical sessions were running, most pupils tackled the tasks quite well. The task strategies were structured for the pupils with the teacher demonstrating how to set up the equipment and the pupils then assembling their own. Equipment shortages meant that the working groups were of three or four pupils.

A number of different data-logging activities were used, and data gathered using LogIT with Checkit attached. No computers or graph plotting software was used in the first five lessons observed. Thus the pupils were collecting readings, recording
them manually, and when graphs were drawn, they were drawn by hand. No discussion of results or interpretations of findings was observed.

In some lessons, no data-logging was observed, as the pupils were tackling the problem of how to get plasticene or corks to float at given point in a measuring cylinder of water. This was in preparation for a novel approach to using data-logging to 'measure density'. The pupils tackled this challenge enthusiastically. In the second of these sessions, one or two groups began to link their corks to movement sensors but no quality data was collected. At the end of the fifth week the teacher expressed the view that data-logging was too difficult for some of the pupils.

Lesson seven - a contrast

In this lesson there were some pupils using palm-top computers for data-logging. They were interested and enthusiastic about using these machines. The pupils spent quite a lot of time exploring the computers and so needed to be kept on-task by the teacher. The teacher seemed willing to tolerate quite a lot of off-task activity of this kind, where the pupils explored the various features of these small computers.

One group used data-logging methods to re-run the greenhouse gas experiment from lesson six. Another group of pupils were using temperature sensors for a new experiment. One boy Kevin (Y9) spent a lot of time setting up and revealed a persistent approach. He had shown this more focused attitude on several occasions in the past. Another boy's behaviour (Neil) was more variable. He could be very focused but could also be easily side-tracked into off-task activity. After some time on his data-logging task, Neil remarked "A good old pen, paper clock and
thermometer is what I want." Perhaps for the benefit of the researcher. However, some pupils may be bored by data-logging and may prefer traditional approaches. Neil's comment said as a joke, raises questions about the pupils' role in a data-logging activity where the technology does a lot of the measuring work which pupils would do in typical non ICT lessons. The issues here is what role should the pupils adopt in a data-logging activity?

An audio tape recording was made of parts of the lesson that revealed that these apparently relatively disinterested pupils could be engaged in dialogue about experimental data. This is developed under the discussion of interactions below.

These experiences raise many issues relating to successful management of data-logging in science.

6.3.2 Findings from Case 2

Issue 1 task features

Different pupil tasks were used in each lesson or pair of lessons. The focus of the tasks appeared to be on pupils developing a data-logging method rather than on the pursuit of explicit science objectives. Although science objectives could be identified for each of the tasks, these were implicit. The explicit objectives, as communicated to the pupils were more directed towards the development of an activity using data-logging.

This focus resulted in pupils being presented week by week with different and challenging tasks. These tasks were novel and appeared untested by the teacher.
The pupils' role was to 'build and test' a data-logging activity; as indicated above, any science objectives were typically implied rather than stated explicitly.

The teacher's decision to focus on devising and developing a data-logging activity resulted in an open approach with high equipment demands since pupils needed to be able to follow through their ideas for developing the activity. This approach increased the demand on the teacher for materials of various kinds. It also had the effect of increasing the range of pupils' activity and increasing the ambiguity of the task. Consequently the teacher's approach resulted in a lack of clarity of task purpose and direction.

One recurrent problem throughout these lessons was that often, the possible equipment needs of the pupils had not been well anticipated. This may have been a technician problem or a planning issue for the teacher. Here the pupils were struggling to attach string to corks which they wanted to float. The string would absorb water like a wick and so its mass would increase. The use of wire or fishing line would be a better choice as it is also less elastic. The issue here is one of teachers anticipating likely needs and pitfalls in a procedure or at least offering the pupils a range of materials from which they have to select - an approach which might prompt them to consider the relative merits of the materials on offer.

At the end of one lesson, the teacher commented that data-logging "was too difficult for the pupils". However it was the researcher's view that the pupils had not yet actually done any data-logging! Perhaps what they had done is to struggle with an ill-conceived method. The question needs to be asked of what value is added to the experiment by an ICT approach? This episode indicates the need for a
teacher to consider the appropriateness of their planned use of a data-logging method over the alternatives.

**Issue 2 task presentation and organisation**

The activities presented to the pupils by T2 had a developmental focus. They were presented as whole group tasks and introduced a competitive edge to the activity. The tasks were open in design in the sense that the teacher did not have a single solution in mind to the design 'problem'. The open nature of the pupils' activity resulted in high equipment demands which the teacher found hard to meet, partly because of the difficulties posed by the location of the teaching room and the need to plan and order in advance the materials required for the lesson. Moreover, because of the exploratory nature of these tasks, there were no pupil prompt sheets or other paper-based materials to support the pupils.

The teacher was a confident user of ICT; however because of the focus on task development given to these lessons, the opportunity to use data-logging equipment was limited. Much of the pupils' lesson time was spent on activity to do with designing and assembling apparatus rather than on using it to find answers to science questions. This aspect was probably an outcome of the untried tasks. Had the teacher known by experience that the pupils could achieve a workable 'product' from their design activity, then it may have enabled the pupils to move on through the task to carry out a science-based investigation.

**Issue 3 Roles and responsibilities**

In the open-style of the lessons in case 2, within the broad context of the task set by the teacher, the pupils defined their own activity and purpose. Their activity was
largely undirected by the teacher although he carefully monitored and supported them when necessary. In developing their own methods the pupils tended to adopt a trial and error approach to solving the problem pose by the task. This demanded persistence on the part of the pupils and some effort by the teacher to keep them on task and moving forward. The intrinsic interest of some pupils in ICT and the enhanced motivation which has been associated with its use, was not always evident in this case. It seemed here that the prospect of using ICT was not a sufficient motivator to sustain the pupils through the early parts of the task. Possibly the potential use of ICT in these lessons was too removed from the immediate problem which faced the pupils, of developing an ICT 'method'.

**Issue 4 Interactions – pupil interactions**

The teacher worked hard to maintain discipline and to keep the pupils on task. He frequently intervened in pupils' activity to check on progress, help and encourage them. Given the nature of the tasks, it is not surprising that much of the pupil-pupil interaction was focused on managing the task. Only in a minority of the lessons did the pupils' activity result in an experiment with science objectives that could be achieved using the data-logging method. Where this did occur, there was some limited evidence of pupil dialogue involving prediction. However, in many lessons there were off-task interactions or interactions directed at the management of equipment rather than science outcomes.

As describe above, the tasks frequently presented in case 2 were of a problem solving nature, somewhat removed from the practical use by the pupils of data-logging technology. Nevertheless, in these lessons there was a lot of interaction.
between the teacher and the pupils. This was because the support requirements of the pupils was high in their lessons as they struggled to make progress.

Teacher interventions

It was indicated above that some of the pupils in case 2 were disinterested in the data-logging activity. Nevertheless, there were further examples in lesson seven of this case study where the effect of teachers engaging pupils in dialogue about their work was revealed. The following exchange between a teacher and Nick, one of the more difficult pupils in the class shows that careful questioning can help the pupil reveal and articulate his understanding of the data-logging activity and the meaning of his data.

TEACHER: What has happened there?

NICK: I'm gonna zoom back out again, try and find ...

{pause}

NICK: look Sir, little humps.

TEACHER: now, if one of these bottles was cooling down quicker than the other one, what would the graph look like do you think?

NICK: It would be going down, one would be straight and the other would be going down if it was cooling down

TEACHER: OK, what would you expect the difference between them to be like? The difference between the two lines?

NICK: quite heavy, quite big
TEACHER: so, ... if you were drawing on a piece of paper what you think would happen, what graphs would you draw?

NICK: (drawing on paper) the one, number one, the one covered in the plastic stuff, that would be going like that, I'd expect this one to go after a period of time, to go down there like that. After a period of time but this one will eventually but that one will be first.

TEACHER: right, and this is the one that's had the hot water in.

NICK: yeah, they've both had hot water - that's number one the thermal, plastic one; that's number two the one with just the bottle.

TEACHER; OK what's happened, to the gap?

NICK: It will expand and then it will come closer towards the end like

TEACHER: good!, so why don't you keep that piece of paper in front of you...

NICK: alright then

TEACHER: and then you can see whether your prediction...

Despite some of the rather low level of activity observed in some of the case 2 lessons, this short episode of recorded talk reveals the potential of the data-logging approach and the importance of teachers engaging their pupils in thinking about
data. The need for teachers to have a clear sense of purpose for a data-logging activity in order secure its outcome is a significant finding in this case study.
6.4 Case Study 3

6.4.1 General features of Case 3

Case 3 was set in semi-rural High School. This school takes pupils from age 11 (Year 7) through to age 14 (Year 9) from there they move to an Upper School some distance away, to complete their secondary education. The school serves a mixed catchment area in terms of social class.

A recent inspection of the school by OFSTED (1997) described the science department as strong. The department was praised for its use of information technology and the report noted that pupils' skills in the use of computers for control and measurement were good. This school did not have specialist status and was not a technology-rich school. Nevertheless, the science department has a long-standing tradition of using ICT to support its science teaching. This tradition was supported by the active interest of the head of department and other teachers in using new technology. The department had acquired a range of ICT resources over time and had a reputation for embracing new technology in the teaching of the subject.

The Teachers

The opportunity arose to research several cycles of teaching involving the use of ICT to groups of Year nine pupils. These lesson cycles followed the same teaching pathway and involved the same activities in each cycle. However, they were delivered by different members of staff to different groups of pupils. The lessons were observed between January 1998 and April 1998 to fit in with the science department rotation through topics.
The teachers involved in these lessons were Teacher A, an experienced science teacher who was relatively inexperienced in using ICT and had some reluctance about being observed in the classroom. Teacher B, a more experienced individual who held curriculum management responsibility within the school and who was both experienced and confident in use of ICT. This teacher had played a pivotal role in securing and developing ICT resources for the department and in driving its inclusion into the departmental schemes of work. Teacher C was a very experienced teacher, long established in the school, who also had pastoral management responsibilities within the school. Teachers B and C did not express any concern about being observed for this research.

**Science ICT Resources**

All the lessons observed in this case were held in one teaching laboratory. This was equipped with three stand-alone PCs and several older BBC Microcomputers. The PCs were connected to the school network for printing purposes.

**The pupil group**

In this case study, all the pupils groups observed were in Year nine. Each group was seen for two lessons, one week apart. Because of the organisation of the lesson rotation and the opportunity to observe for just two lessons, it was not possible for the researcher to get to know the pupils and to observe them as closely as in Case 1 or case 2. This was not seen to be of particular significance since the research questions focus on the organisational and management aspects of the use of data-logging techniques.
The lessons

In this case setting the focus was on the use of data-logging activities presented as a part of the teaching of ‘technology’ in this High School. The lessons observed involved a circus of three activities. These were a control activity involving pupils in building a module to control movement of a small buggy - a computer control simulation and data-logging tasks. Over the module of lessons, each pupil spent two lessons on each activity. The pupils were organised into working pairs typically of opposite sex; the teacher determined these pupil pairings.

The types of task

For the data-logging activity there were two tasks, each supported by procedural worksheets. In lesson one pupils learned how to operate the LogIT data-logger and PC-based software. They learned how to record and download data into the PC software to obtain a graph. These outcomes were achieved through an activity involving logging light levels around the school. Equipped with a light sensor and using the Logit’s remote logging function, pupils followed a predetermined route around the school recording ambient light levels. On return to the laboratory, the recorded data was downloaded into the PC software and a graph of the ‘journey’ displayed. Pupils then had to relate the events of the journey to the patterns revealed in their graph. No more interpretation than a qualitative matching of peaks and troughs on the graph to stations was required by the task. In this respect the demands of the task were consistent with the National Curriculum required use of ICT at Key Stage 3, except that the pupils were not required to choose the ICT
approach. The task itself was set in a straightforward style for the pupils, who had not used data-logging techniques before.

In the second data-logging lesson, pupils used temperatures sensors to monitor the effects of reacting a small piece of calcium metal with water and, in a separate experiment, the effect of dissolving a quantity of ammonium nitrate in water. This activity afforded the opportunity for pupils to use real-time data-logging. Thus over the two lessons of data-logging activity the pupils experienced both remote and real time data-logging. The worksheets used by the pupils in these tasks are included as Appendix 11.

6.4.2 Findings from Case 3

Issue 1 task features

The two data-logging tasks presented to pupils in Case 3 were defined by the task worksheets. These provided clear instructions on what the pupils had to do. The tasks describe above were intended to familiarise the pupils with remote and real time data-logging methods, and with the operation of the data logger and computer software. The activities were therefore directed towards developing pupils’ ability to manage the data-logging hardware and software. The activities were set within science context, but it appeared to the researcher that any outcomes concerning the substantive science concepts associated with the tasks were of secondary importance to the operational objectives suggested above.

The pupil data-logging tasks were closed. At face value there was little scope for pupils to explore the tasks outside the framework set for the activity by the worksheet. The focus of each task was very much on collection of data; there were
no questions on the pupil worksheets which might prompt attempts at interpretation beyond purely qualitative descriptions of patterns in the graphs. One group of pupils in teacher B’s group did, however, try to manipulate the computer-based graph because they wanted to “make it bigger”.

**Issue 2 task presentation and organisation**

As described above the pupils’ activities in these technology lessons were supported by detailed worksheets which gave instructions on what the pupils should do. Whilst these sheets provided clear instructions, they were focused on the methods rather than on the science concepts associated with the activity. As teacher A pointed out to the pupils “the technology does the work for you”. Science concepts were not made explicit to the pupils; despite this, there were occasions when the teacher intervened in the small group activity to pose questions and encourage the pupils to discuss their observations.

In another cycle of lessons, teacher C adopted a rather different approach. After the pupils settled at the lesson start, he directed their attention to a note on the board from last lesson: “*Introduction on the board which you need to put down in your books*”. Then later, “*notes off board rapidly*”. Later still teacher C announced “*The first sentence contains gaps- what do I use computers for around the school?*”

During this phase, the pupils were silent. They were quieter than in the other group and the teacher indicated to the researcher that they were a more difficult group. The teacher was formal and cool when addressing the group “*Well then, what*
have you used them for?" the teacher asked. The pupils responded in question-and-answer with the teacher.

This was a formal lesson introduction; the teacher then explained to the group the next few weeks' work and allocated them to working pairs and tasks for the cycle of practical activity.

One girl commented “I don't know what I've got to do...” then later to her male partner “I'm not very good with computers and electronics so you'll have to do it all”. They collected an instruction sheet and read aloud together. They looked at the LogIT and worksheet together, then the girl asked the researcher for help.

Working with a different pupil group, the same teacher introduced the lessons in a similarly formal way.

In these lesson introductions the teachers appeared to be very keen to get the groups settled quickly and working on the practical activity.

Issue 3 Roles and responsibilities

Since the activity in Case 3 was typically managed by worksheets, the teachers' roles included monitoring group activity rather than orchestrating whole class activity. Nevertheless teacher B took time to orientate the pupils: “It says it all on the sheet but I'll just run through...”.

This circus approach shifted the emphasis more towards pupils taking responsibility for managing their activity, with the teacher’s input mediated by the worksheet.

The danger apparent in this approach was that with the risk of limited direct
teacher influence, pupils' activity tended to follow a set of predetermined
instructions.

Despite the closed nature of the activities, teacher B found ways of encouraging
pupils' ownership of the task: "you choose when to stop logging" and "stop
logging when you think your experiment has finished".

**Issue 4 Interactions**

There were some interesting anomalies in the graphs produced by the second
experiment where the pupils had stirred or lifted the probes out of the solutions.
The teacher's prompts revealed the pupils' appreciation of the main features of the
graphs. But these responses tended not to happen unless the pupils' attention was
directed to the data by a carefully posed teacher question: "What does it say to
you, that graph?"

However, the pupils did observe some experimental features; the reaction of
calcium with water is very 'visual': "ahh! Cool!!" or in the case of the solution of
ammonium nitrate: "Oh it's cold".

Some pupils occasionally made predictions whilst watching the real time graph
display: "It could go below the line", "It's curving"; "Ben, it might go below
freezing"; "It's starting to go down"; "It's cooling down slowly"; "It's going
down it aint going up ... this is freezing".

But these utterances were not generally developed further unless the teacher
happened to be present when they occurred. When the teacher was present at the
right moment he picked up their ideas and helped the pupils to reflect on them by
redirecting their attention with a follow up question for example: "How will you know when it's finished?" or "What do you expect to happen eventually?"

When these interventions did occur, the pupils revealed an ability to relate the graphical and experimental events, albeit in a qualitative way, as the following exchange illustrates.

Teacher: "Now, why is it [the graph] going up and down?"

Pupil: "because we moved it [the sensor] like that"

[illustrates the movement made]

These temperature graphs lend themselves to further exploration, there is potentially a lot that the pupils could make of this type of data, but this depends on what the teacher's objectives for the lesson are. For example, if the prime purpose of the light level practical was to familiarise the pupils with the operation of the LogIT and the software, then there may be no need to consider the experimental outcomes in any detail. So the question remains as to how the pupils can be encouraged to explore their data more thoroughly. This seems unlikely to happen unless the pupils have a clear idea about the purpose of the experiment and their role in it. This is for the teacher to manage in closed tasks such as these.

In addition to these task-focused matters, the social nature of a lot of the interactions in everyday 'laboratory life' must be acknowledged. For many pupils a lot of time is spent in activity that reflects their other concerns. In one pupil group for example, some of whom did not appear too confident in handling technical
equipment, there were examples of exchanges which hinted that the task played a relatively minor part in the pupils’ concerns:

"come on Becky, let’s go play with the computer”

On other occasions where there were technical problems, these interrupted the activity and could lead to off-task activity. Equally there were other groups of both sexes, where these problems did not lead to distraction and where the pupils’ attention was largely focused on the task. This indicates that data-logging techniques are just as subject to the range of different levels of interest and motivation that one can see in any science lesson.

However data-logging techniques differ from regular science practical in at least one important respect that has a bearing on pupil’s engagement with the task. From a pupils’ perspective, they have much less of an active role to play in a data-logging practical when compared with its traditional alternative. They have only to manipulate a mouse and press a few buttons on the data-logger to get the experiment running and start to collect data. As teacher A said “the technology does the work for you”. This contrasts with their typical experience of lessons where pupils may have to take regular measurements and record them.

Pupils’ experience of most science lessons means that they are not used to using the time bonus afforded by the ICT approach to do other task-related activities. They do not possess a repertoire of strategies that can take advantage of the new opportunities in data-logging tasks. Moreover, their teachers may also be equally unfamiliar with managing these approaches. There is a therefore a tendency for
teachers to 'fill' the time bonus with other purposeful activity lest the pupils are unoccupied or, at worst, occupied with inappropriate activity.

In the majority of real time data-logging lessons observed for this research, in a range of different settings, teachers have organised pupils in the data-gathering phase of an experiment into written reporting of the task. Effectively, the teachers have distracted the pupils' attention away from experimental outcomes.

Pupils may need a written report of their data-logging practical, but there is a risk that using the time bonus for writing up results in pupils thinking less about their experiment rather than more. Experience suggests that pupils are very skilled at writing up from a work sheet or from memory whilst simultaneously engaging in talk about other things with their peers. At best in these situations, they are not fully attending to the detail of the experiment but to the mechanics of writing about it. They can only be describing what they did rather than attending to what is happening in the experiment now.

Whilst the pupils are occupied in this way, they are missing out on opportunities to think about the task, to notice features of emerging data, to check their initial expectations with the outcome. In other words, some features in the data, which might prompt their thinking about it, are not noticed. Of course, the pupils may have the whole picture at the end of the experiment, and all those features may be present, but when faced with the whole picture, only the salient features may catch the pupils' attention. Some of the more subtle features may be missed in the wealth of detail in the graph. Revealing the detail bit by bit 'as it happens' provides a way of focusing attention on emerging data and raises the prospect of the pupil being
more familiar with it. At least the pupil will have seen the graph plotted and be able to look at the whole thing—this offers two ‘bites at the cherry’ rather than one.

To make the most of real-time data-logging exercises, the teacher needs to provide pupils with a task which focuses attention on the data as it is gathered. This may be achieved by asking the pupils to make their own predictions of outcomes before they start the experiment. This could be done as a class activity. Pupils could be asked to describe the ‘behaviour’ of the graph as it appears. They could simply be asked to record measurements at particular points during the course of the experiment. Any of these approaches may encourage the pupils to engage more with the data.
6.5 Case Study 4

6.5.1 General features of Case 4

This case is set in the same High School which was described in Case 3. The focus of this case was on the evaluation of a software program designed to teach pupils to use data-logging software. This program is now known as *Understanding Insight* (Logotron, 1998) and is used to support the development of skills and investigative strategies which can be employed when using the generic data-logging software associated with it, known as *Insight* (Logotron). A report on the development of the *Understanding Insight* program and its general qualities can be found elsewhere (Rogers and Newton 2001, in press). For the purpose of this study, the use of the software with pupils, albeit in a pre-release form, provided a useful opportunity to explore the research issues in a different working medium.

It is necessary to describe the general features of the *Understanding Insight* software in order to understand its mode of use in this case study. The software comprises a suite of self-contained lessons which aim to teach users how to operate the *Insight* data-logging software. Moreover, the lessons are designed to develop these operational skills through a series of tasks which have explicit and implicit strategies for examining and exploring data using the *Insight* software tools. Thus the *Understanding Insight* software seeks to develop pupils’ understanding of approaches to the display, manipulation and investigation of data using the tools available in the generic data-logging software. In addition to these 'skills' lessons, *Understanding Insight* contains 'experiment' modules which teach
users how to set up hardware and software for data-logging activities at the laboratory bench.

It is important to note that *Understanding Insight* is much more than a software 'help system' or a tutorial program. Its design allows a high degree of interactivity between the software and user. The user executes instructions from the *Understanding Insight* software using its associated program *Insight*. The *Understanding Insight* software interrogates the *Insight* program in order to monitor and record users responses to these instructions. Thus the *Understanding Insight* program can monitor user activity and provide corrective feedback or rewards appropriate to the user's responses. One novel feature of *Understanding Insight* is that it employs a range of question and instruction formats, including free-response items. Although the software can, through its monitoring system, evaluate user responses to many question items, the free-response items require the intervention of a teacher to evaluate the user's answer. This is an important design feature since it means that the *Understanding Insight* system is not entirely self-contained but provides opportunities to link with other 'events' outside the computer system.

**The teacher**

In this case study, the 'teacher' was the tutorial software *Understanding Insight*. The 'choice' of lesson content and its mode of delivery to pupils was transacted by the computer software – here ICT was taking over these teacher roles. This is an important distinction for the present study since in this respect, case 4 did not seek
to replicate the other case studies but to provide a complementary case involving the use of ICT.

Pupils worked at the computer and were observed by the researcher and a colleague researcher as they worked. The researchers adopted a strategy of minimum intervention so that the primary source of guidance and instruction for the pupils was the tutorial software itself.

Science ICT resources

The *Understanding Insight* software was made available to the pupils on stand-alone PCs operating Windows software.

The pupil group

Four cycles of activity were observed for this case study. In each cycle groups of volunteer pupils worked in pairs at the computer during lunch times. Typically there were three pairs of pupils on each occasion. Sometimes, due to other lunchtime commitments, pupils were not able to attend these sessions. As volunteers, the pupils were a self-selected group. In discussion with the Head of Department, who had organised the arrangement, it emerged that most of the pupils involved were of average or higher ability. Nevertheless one group of lower ability pupils also volunteered. The pupils were all in Year Nine.

The lessons

As indicated in the introduction to this case study, the lesson content was focused around the tutorial software *Understanding Insight*. The pupils spent approximately thirty to forty-five minutes over the lunch times working with the
software. They followed the first four tutorial lessons which covered a number of
skills in the management of the software and in using it to make measurements of
graphically presented data.

The pupils usually managed to complete two of the software lessons during each
lunch time. In the third week of the cycle, the pupils worked on one of the
experiment modules. This was an activity involving examining data from a simple
evaporation experiment. The pupils worked through the tutorial, although they did
not carry out the experimental procedure, they had covered some of the concepts
in their science lessons.

The types of tasks

The skills taught by the software in the first four *Understanding Insight* lessons
were essentially basic skills in software management and use of software tools.
These skills are listed in Appendix 12. It is important to appreciate that developing
pupils' facility in these basic skill areas was necessary to enable them to progress to
the more challenging 'Experiment Module'. Thus the early lessons could be seen as
a preamble, equipping pupils with skills that they could then deploy in the context
of a science experiment. In this way the emphasis could shift from pupils acquiring
skills to them *applying* them in the experimental context, thus fulfilling a primary
objective of the *Understanding Insight* software.

The pupil tasks involved exploring example data from the evaporation experiment,
and applying their knowledge of the software tools acquired from the earlier skills
lessons. The skills acquired were necessary to fully meet the demands of the
experiment task within the *Understanding Insight* software. It should be noted that
pupils did not actually perform the experiment but looked at the experiment screens and genuine example data as a context in which they could apply their new skills.

Following these practical sessions at the computer, in week four, the pupils were interviewed about their perceptions of the *Understanding Insight* software. This provided the opportunity to probe pupils' understanding of the purpose of the software as well as their personal response to it as a learning tool.

### 6.5.2 Findings from Case 4

#### Issue 1 task features

For the purposes of the present study, the key features of the pupil tasks in this case relate to the fact that the tasks are presented by the computer. The pupils' activity was directed mainly by the software. The tasks are controlled by the software and, within the flexibility imposed by its design; the same tasks are presented to pupils in the same way on each occasion when they are used. This provides more tightly controlled and consistent task attributes.

The software design allows for some flexibility of presentation of content in response to pupils' responses to each part of the lesson. However, this is limited by the software and so is potentially much less variable than in the other cases described in this chapter.

As indicated in the section above, the teaching objectives of the software concern acquisition by pupils of two sets of skills in the use of the data-logging software.

First, the skills and knowledge of how to manage the program and operate its
interface; second, the skills in the strategies available for exploring experimental data. Consequently, the potential value added to pupils' experience by the Understanding Insight software is not only achieved in its direct use but also in the transfer of the skills acquired in this environment to other experimental activity involving the use of generic data-logging software.

It should be noted that the purpose of the present study did not include investigation of the extent of any such skill transfer. However this is an important area for future investigation since the nature and extent of any residual skills or knowledge from the use of Understanding Insight will determine its effectiveness as a means of teaching skills of data exploration and interpretation in practical work involving data-logging methods.

**Issue 2 task presentation and organisation**

In each cycle of activity for this case study, the content presented to the pupils and the computer controlled their route through it, with some flexibility of delivery achieved through the interactive nature of the software design. Because of its self-contained nature, the tasks described above are presented to pupils by the computer software in a consistent format and style. The software management system functions to 'modulate' the presentation of material according to pupils' responses to earlier tasks.

The pupils were organised in pairs at the computer for this case study. Although designed for a single user, the study revealed benefits for pupils to be organised in small groups (pairs or threes) when using the software. Typically when interviewed, the pupils reported that they liked working in pairs: "you get a second
In interviews, some pupils commented that they liked the opportunity to have “more than one go to get an answer - you can realise your own mistake”. They also liked the software “giving the correct value to check”. They found the ‘well done’ prompts to be encouraging. They preferred the experiment module to the skills lessons.

Since some of the questions asked of the pupils by the software require marking by the teacher, it is necessary for teachers to have a good knowledge of the aims and purposes of the software as well as its structure. An explicit design feature of Understanding Insight is that it incorporates an active role for teachers.

**Issue 3 Roles and responsibilities**

In this case study, the teaching role was largely mediated by the Understanding Insight software. In the environment provided by Understanding Insight, the pupils controlled the software and so controlled their own working pace through the tutorial program. They were not dependent on the teacher for instructions or information and many corrective interventions were delivered by the software in response to pupils’ input. Thus pupils using the software had a large measure of autonomy and responsibility for controlling their activity.

Some pupils liked the fact that instructions were given by the software ‘in order’ and thought this created ‘more interest’. These pupils stated that teachers were ‘all vague’ and that worksheets ‘never have enough stuff on them’ so ‘you always
need to ask' [for help]. Other pupils commented that the software 'gives step by step instructions instead of all at once' and observed that 'worksheets don't explain it properly'. They liked the fact that "you could just look to see" [what to do] and though that this was better than listening to a teacher. This feature of the Understanding Insight software was also liked by one pupil because "the computer won't go mad" at you!

Whilst the researchers took these remarks as favourable comments on the software, not all the pupils were without criticism. One pupil suggested that the software was 'dead good for analysing graphs' but 'people who weren't computer friendly would' struggle; however, they thought that computer method produced work that 'looks neat'.

Interview data revealed that some pupils saw the use of data-logging software as reducing their practical experience of making measurements: "you don't get so much experience because you are not reading the results and not doing the measurements yourself." Nevertheless, the same pupil though that "the computer gives better results."

The significance of these pupil insights into their experience of data-logging lies partly in what they reveal about their perceptions of much of their other experience of practical science. It is necessary to be cautious and not to invest too great importance to this small sample. Nevertheless, there are indications here of strategies which science teachers might adopt which could make aspects of lessons more accessible to pupils.

**Issue 4 Interactions:** pupil-pupil interactions
The benefits of pair work at the computer, as perceived by the pupils have been indicated above. Here the pupils drew mutual support and confidence from working at the computer in a small group. Moreover, observations of the pupils at work on the task revealed other benefits.

The pupils negotiated their roles in the activity with each other. For example, there was discussion over which individual would operate the software. In the early part of the lesson cycles, the pupils debated with each other about the functions of various icons and buttons in the data-logging software. On some occasions pupils explained to each other their discovery of such functions: “Ah! That shows how it [the graph] changes…”. On another occasion, the same pupil whilst observing the use of cursors and the bar display feature of Understanding Insight reported to his partner:

“The graph goes down, the bar goes the same. ... When it goes flat, [the bar display] doesn’t change at all. Depending on how steep the slope is depends on how fast it goes up and down [sic]. Ahh yes, by moving [the cursors] across [the line graph] you can tell what the graph looks like.”

In a subsequent session these pupils reminded themselves about managing the software tools:

“How do you get the bar window?” [pupil remembers the ‘display’ menu, then, when using the bar, he describes the shape of the graph: “drops, slowly rising …”].

Clearly statements such as those above relate to pupils’ learning to use the software; they could be classified as utterances of an operational type. The software design however, incorporates features which require pupils to input
responses to questions of several types. These either involved pupils in inputting a
responses to a ‘true/false item, a multiple-choice item or a required measurement.
Other types of question demanded a free-response from the pupils to describe a
feature of the data or the software.

In paired work at the computer there was evidence of the pupils negotiating with
each other about the meanings of questions or to agree a joint response to the item.
One such response about the operation of the zoom function was:

"The first time the zoom button is clicked, part of the graph is magnified. The
second time the graph returns to normal. The same part of the graph is shown
each time unless it is changed by us." The pupils talked together, checking and
reaffirming each other’s ideas.

The uses of question types which prompt discussion about data seem likely to
better secure the pupils’ understanding of it.

**Teacher interventions**

In this case study, the teaching about the use of data-logging software was
mediated through the *Understanding Insight* program. At face value there is
relatively little opportunity for input from a ‘live’ teacher because the program
tutorial is largely self-contained. However, as indicated above, an important design
consideration for the program was to be able to link its use to other practical
activity and to build in a role for the teacher.

A lone pupil could use the software, but it has been argued above that there were
benefits in organising pupils in small groups since this appeared to prompt
discussion about the activity. However, it seems likely that teachers engaging the 
pupils in talk about their activity will encourage them to articulate their 
understanding as was found in some other Case settings described in this chapter.

Within the environment of *Understanding Insight* the role of the teacher in 
marking pupils' free responses to questions posed by the software is a good 
opportunity to develop such group talk. Moreover there are many opportunities 
presented when pupils use the software for teachers to engage pupils in such talk. 
It seems likely that there is an important role for teachers to intervene and engage 
pupils in dialogue even in the highly structured environment presented by the 
*Understanding Insight* program.
6.6 An overview of findings from four case studies

The preceding sections of this chapter have described the context of use of data-logging in each case study. It has sought to tease out from the richness of evidence presented, the salient features of the cases in relation to the research issues identified in Chapter 4.

The four cases described here offer complementary insights into the use of data-logging methods. Case 1 provided a setting with many positive features. The teacher was highly experienced with well developed skills as a classroom practitioner and science teacher; he benefited from his status and the relatively high level of ICT resources available in the school. In Case 2, by contrast the teacher was less experienced, and although set in the same institution, the case reveals the extensive range of factors which can influence positive practice of data-logging techniques. The third case provides a contrast being set in a different and less well resourced school, and revealing what was achieved in a prescribed set of activities in the hands of three different but experienced science teachers. The final case provides a further contrast, almost removing the teacher from the teaching situation since the lesson ‘delivery’ was managed by computer. This is a useful case for the study since the major influence of the teacher on classroom events has been identified by the contrasting experiences of Case 1 and Case 2.

Taken together, the four cases provide a range of approaches to use of data-logging methods in science teaching. They are not replicates but complementary cases which reveal the complexities and subtleties of this aspect of teaching science
with ICT. Their diversity provides a rich source to explore data-logging in everyday science teaching.

The purpose of the following section is to revisit the research issues collectively and to summarise the findings research issue by research issue. In this way it is intended to identify aspects of effective practice using data-logging methods, as evidenced through this study, and areas that may require development.

6.6.1 What are the features of data-logging activities designed by teachers?

The case studies presented here have identified several features of task design which appear to be pertinent to effective use of data-logging techniques. These range from the use of tightly focused teacher directed tasks in Cases 1 and 3, and the software-presented activities of Case 4 to the much less structured activity observed in many of the lessons in Case 2.

An important finding from these case studies is that whether set in a closed teacher-designed format, or in the more open ended experience of Case 2, it is the clarity of the task objectives and how pupils are made aware of these that underpins purposeful, focused pupil activity.

Whether the teacher’s primary explicit objective for the pupils is to develop their skills and knowledge of the use of generic data-logging software, or having gained some experience in these skills, to then apply this knowledge to explore a scientific question, the objective needs to be clearly communicated to the pupils. Moreover, any chosen task needs to possess the structure and scope to achieve these objectives.
It is also necessary that the task is an appropriate one in which to use of a data-logging method. Such ICT-based tasks make some additional contribution to achieving the objectives beyond what might be achievable using conventional, non-ICT techniques.

Tasks that are not clearly defined or are too open-ended in design risk presenting pupils with a potentially overwhelming challenge unless they are well-matched to the pupils' prior experience and knowledge. Such tasks are likely to present pupils with minimum ambiguity of purpose. The skill with which a teacher plans activities that have sufficient scope and challenge, but which are achievable for the pupils appears to be a further requirement to effective use of data-logging methods. As with other aspects of pupils' experience in learning science, it is likely that challenge can be achieved within tasks that build on pupils' previous experience and knowledge. Thus activities, which extend the use of data-logging methods beyond data collection and presentation to its analysis and interpretation, can afford pupils the opportunity to apply and extend their knowledge.

6.6.2 How are activities presented and managed by teachers?

It was apparent in the cases studied that even in apparently technology-rich settings, securing ICT resources posed teachers with a challenge. Data-logging methods present high equipment demands and require well-serviced technical support. This level of support serves to reduce equipment failures and thus the threat to achieving the teacher's activity objectives. Teaching with ICT demands a high degree of teacher competence and confidence so that the teacher can
overcome technical difficulties, which may occur even in the best-serviced situations.

In the cases studied, the teachers typically chose to organise pupils in small working groups. In Case 2 where a whole-class practical approach was attempted, the focus was only rarely on actually using the data-logging equipment. Where this was done, in Case 2 the availability of sets of equipment forced the teacher to organise a 'circus' of activities similar to that used by the teacher in Case 1, incidentally in the same school setting. In case 3, the teacher's mode of organisation was also in a practical activity circus. Such strategies for organising pupils' activity make effective use of what is a limited ICT resource. The organisation of pupils into collaborative working groups, whilst perhaps driven by resource limitations, brings other potential gains in terms of beneficial pupil-pupil interactions as discussed below.

The use of a circus approach to practical teaching is demanding on the teacher. It requires the teacher to be able to service and support pupils in a number of different activities. Typically, teachers do not use whole-class activity introductions in circus-style lessons. More usually teachers adopt an approach where a pupil worksheet supports the detail of the activity. This was seen in Case 3 in the present study. The advantage of this approach is that the pupils are less dependent on the teacher for guidance but this is also its disadvantage. A pupil worksheet is the communication medium between the teacher and the pupils and it renders the communication more remote from pupils than in whole-class teaching approaches. However, it has the important advantage in practical work of encouraging pupil
independence and of 'freeing' the teacher to support pupil groups more responsively.

An important feature of the teachers’ styles of working with pupils emerged from the case studies. In case 1 the teacher set the pupils' activity within a clear science context and made use of stimulus material in order to raise interest. It also provided a focus for the data-logging activity which was presented as an investigative task. This contrasted with case 2 where the emphasis was not obviously one scientific investigation. In case 3 the two practical activities did have clear investigative potential and science links. However, these were not to the fore in the lessons observed. In this case the task focus was more centred on the pupils' acquiring operational skills in using data-logging equipment and software.

6.6.3 What are the roles and responsibilities of teachers and pupils?

As indicated in the preceding discussion, teachers play a critical part in the planning and design of data-logging activities to meet specific learning objectives for their pupils. This role extends into the way in which data-logging activities are presented to pupils. Where tasks are presented in an exploratory or investigative style, this serves to engage the pupils in the activity. However, once the teacher has launched an activity, what roles seem to be of value in the data-logging classroom?

In the first case study, the teacher spent a lot of time at the start of the lessons in giving the pupils detailed instructions and in demonstrating use of data-logging equipment. In case 3 less time was spent in this phase but the tasks were supported by worksheets. In both cases the teachers directed the activity albeit through different means. Case two involved a much less defined input form the teacher in
some lessons, and on those occasions there was such input it did not typically more tightly define the pupils' activity which remained very exploratory and appeared to the researcher to lack direction on occasions. In this case, the teacher worked with the pupils in a supporting role as the pupils developed their own methods. In one sense the pupils defined their own purposes in case 2, this contrasts with the clear influence the teacher in cases 1 and 3, and of the computer tutorial in case 4.

Concerning pupil roles in many lessons the pupils followed the activity brief provided. This was typical of case 1 and case 3 where the brief was closely defined, and also in case 4 where the *Understanding Insight* software pre-determined the lesson content. In all the cases studied the pupils were able to work at their own pace through the tasks. In case two the activity tended to be undirected and pupils adopted a trial and error approach to the activity. This was time consuming and frequently did not lead to any data-logging activity. By contrast in the more tightly defined environments of the other cases pupils did make progress through the tasks.

To summarise, in the cases observed, teachers typically directed pupils' activity directly or indirectly. They supported the pupils during the lesson activity and monitored pupil progress. They also intervened in pupil activity form time to time (the theme of teacher intervention in the case studies is developed in the next section). In case 4 the teacher roles were mediate through the *Understanding Insight* software. Concerning pupil roles, pupils typically followed the instructions they received. However, pupils were able to take responsibility to varying degrees in the cases studied. In case 2, which was very open ended, the pupils did not cope
successfully with the high degree of freedom afforded by the approach adopted by
the teacher. In the more constrained situation observed in the other cases the
structure appeared to support pupils to a more successful conclusion.

6.6.4 What evidence of productive interactions between participants can be
found in the cases?

Teacher interventions are an important feature of this study. In case 1 teacher
interventions were observed to direct pupils attention to features of their data-
logging graph. They provided opportunities for the teacher to engage the pupils in
talk about data; this was also a feature of Case 3 and the teacher-marked questions
posed by the Understanding Insight program in case 4. Such interventions elicited
from the pupils attempts at interpretation of data of comments on results. This
study provides evidence that the quality of talk in pupil groups is enhanced when
the teacher engages a pupil in conversation about their activity. Other interventions
were used by teachers to develop pupils’ use of scientific language. Interventions
provided opportunities to monitor pupils’ progress or to identify significant
features of their activity.

Interventions initiated by the teacher or pupils for one purpose were sometimes
used by the teacher to move the pupils’ activity forward and maintain their
momentum in the task. This latter point was important in case 2 where pupils’
apparent interest of concentration of a task was variable although in some instances
these interventions were directed at matters of pupil discipline and control.

Importantly it is clear from the observations for this study that whilst data-logging
activities can allow for a high degree of pupils autonomy in managing a task, this
level of pupils' responsibility needs to be accompanied by a high degree of teacher intervention for the types of purposes outlined above. The benefits of the use of data-logging methods are secured as a result of careful monitoring and well-timed intervention into pupils' activity by the teacher.

The issues discussed in this section summarised in Figure 6.1
<table>
<thead>
<tr>
<th>Research Issue</th>
<th>Case 1</th>
<th>Case 2</th>
<th>Case 3</th>
<th>Case 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Task features</td>
<td>• One tightly focused task</td>
<td>• Different tasks week by week</td>
<td>• Two tasks</td>
<td>• Many tasks within software</td>
</tr>
<tr>
<td>open-closed</td>
<td>• Closed, teacher-designed</td>
<td>• Novel and untested</td>
<td>• Closed tasks</td>
<td>• Directed by software</td>
</tr>
<tr>
<td>potential</td>
<td>• High potential limited by teacher’s objectives of raising ICT</td>
<td>• Objective to develop and test task. Not a science objective.</td>
<td>• Objective to familiarise pupils with data-logging methods</td>
<td>• Overall software structure allows some flexibility in routes</td>
</tr>
<tr>
<td>value added by ICT objectives</td>
<td>• Y7, y9 pupils are ICT novices</td>
<td>• Range of available resources raises task ambiguity</td>
<td>• Focus on data collection</td>
<td>• Objectives to teach data-logging methods and develop pupils abilities to interrogate experimental data</td>
</tr>
<tr>
<td></td>
<td>• One tightly focused task</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Management of resources</td>
<td>• Activity circus</td>
<td>• Whole class group work</td>
<td>• Activity circus</td>
<td>• Singletons, small groups preferred</td>
</tr>
<tr>
<td>pupils</td>
<td>• Small pupil groups</td>
<td>• High equipment demands</td>
<td></td>
<td>• Presentation is self contained</td>
</tr>
<tr>
<td>task presentation</td>
<td>• Task contextualised</td>
<td>• Open presentation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>teacher confidence with ICT</td>
<td>• Stimulus material used</td>
<td>• Testing method context rather science context</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• High teacher ICT experience</td>
<td>• No prompt sheets or worksheets to support pupils.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Familiar and tested task</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Worksheet-supported</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Roles and responsibilities</td>
<td>• Teacher directs activity</td>
<td>• Teacher monitors activity</td>
<td>• Teacher supports circus</td>
<td>• Pupils control pace through tutorial</td>
</tr>
<tr>
<td>means of pupils' independent working</td>
<td>• Detailed lesson introduction</td>
<td>• Teacher supports pupils</td>
<td>• Pupils follow worksheet</td>
<td>• Pupils offer personal or group response to questions</td>
</tr>
<tr>
<td>teacher roles adopted</td>
<td>• Teacher monitors pupil groups</td>
<td>• Pupils develop own methods</td>
<td></td>
<td>• Interventions come from software</td>
</tr>
<tr>
<td></td>
<td>• Teacher prompts pupils through interventions</td>
<td>• Pupils define own purpose</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Pupils follow activity brief</td>
<td>• Pupils adopt trial and error approach</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Pupils quickly get data</td>
<td>• Undirected activity</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>• Pupils more exploratory once experienced with data-logging methods</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>4. Interactions</td>
<td>• Teacher interventions direct pupils’ attention</td>
<td>• Intrinsic ICT motivation seems insufficient to sustain activity</td>
<td>• Teacher question focuses on data</td>
<td>• Prompts and interventions come from software</td>
</tr>
<tr>
<td>Teacher interventions pupil-pupil</td>
<td>• Teacher sustains motivation of pupils</td>
<td>• Teacher sets problem solving task but pupils’ support requirements high</td>
<td>• Teacher question elicits pupils interpretations of method and of results</td>
<td>• Teacher interventions to mark pupils responses to questions</td>
</tr>
<tr>
<td></td>
<td>• Teacher develops pupils’ science vocabulary</td>
<td>• Teacher intervenes to check pupils’ progress</td>
<td></td>
<td>• Teacher interventions mark salient points for pupils.</td>
</tr>
<tr>
<td></td>
<td>• Teacher takes advantage of intervention opportunity to move activity on.</td>
<td>• Some dialogue involves prediction</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
6.7 Exploring the teachers' perspectives on data-logging.

The purpose of adopting an interpretative research approach to the study was to permit the researcher to explore the nature of the practice of data-logging methods in the chosen sites. The observations of data-logging lessons describe above raised important issues; however, it is inevitable that the data presented through a case study approach is interpretative. The actions of the researcher in choosing what to record involves selection and the stance taken in discussing findings involves interpretation, each of which are shaped by the researcher's own experience.

In order to enhance the validity of the observations and interpretations made during the study, interviews were conducted with the teachers whose classes had been observed for the study. It was anticipated that through use of a semi-structured interview approach, it would be possible to probe teachers' views on issues raised during the observational phase of the study.

The interview schedule used is included as appendix eight. The questions used derive from issues raised in the observational phase of the study together with some follow-up questions. The outcomes of the interviews are the subject of the discussion presented in Chapter Seven.
Chapter 7

Some Teachers' Perspectives on Data-Logging.

Introduction

The earlier parts of this thesis have identified some of the benefits claimed for the use of data-logging methods in practical science. It has been argued from the case study data presented in Chapter 6, that some of these benefits were secured in the routine use of the techniques observed. However, an important finding from this study has been the extent to which the outcomes achieved using the data-logging technique were subject to the influence of many interacting factors. This finding develops and adds to those reported by Rogers and Wild (1996), in particular that an investigative climate was important in achieving the potential benefits of data-logging techniques with pupils. Moreover, it appeared to the researcher that realising any of the potential benefits was contingent on teachers being able to construct a productive 'mix' of these critical factors in the classroom.

In the cases reported for this study, the teachers' skills in promoting a classroom climate suitable for exploiting the attributes of data-logging technology were both varied and variable. Some of the skills (for example in classroom organisation and in the management of pupils' practical work) can be viewed as routine craft skills for science teachers. However, harnessing the benefits of data-logging methods for pupils requires the successful implementation of an innovative teaching tool. The findings from the case studies reveal that this is not necessarily straightforward but
dependent on teachers’ understandings of the opportunities offered by the new technology as well as awareness of the challenges it can pose.

Research into the diffusion of innovations, particularly in educational settings, can provide understandings of the issues involved here. These include features of the innovation itself and attitudes towards its use. This field of research offers insights into how data-logging methods can be more widely implemented in the school curriculum.

7.1 Aspects of the spread of educational innovations

In an authoritative overview of so-called ‘Diffusion Research’, Everett Rogers has described a five-stage ‘innovation-decision’ process (Rogers 1995, page 163) (see Figure 7.1). Scholars of diffusion of innovation have explored innovations in a wide range of situations and settings, some of which are educational. This body of research suggests that innovation is a process involving a series of stages, which take place over time.

An important aspect of Rogers’ analysis of the innovation-decision process is the recognition that an innovation is often changed or ‘reinvented’ to better fit the local context during the implementation process. This can mean that the ‘reinvented’ innovation better matches the needs of the inventor and consequently permits a higher degree of responsiveness to these needs than was possible with the original innovation. However, diffusion scholars have identified a risk of reinvention leading to an innovation losing its identity and this can pose a threat to the effectiveness of an innovation (Rogers 1995, page 175).
In studies of the spread of innovation, it has been argued that attention needs to be paid to the differences between the characteristics of people adopting innovation and the features of the innovation itself. It has been implied above that the drive to seek out innovations and to identify needs can be shaped by the personality of the individual concerned. Moreover, an individual’s perceptions of the attributes of an innovation have been seen by scholars of innovation diffusion as useful predictors of the rate of adoption of an innovation (Rogers, 1995 page 204). These innovation attributes are listed in Figure 7.2. With the important exception that attribute 3, complexity, which is negatively related to adoption rate, these attributes are positively related to the rate of adoption of innovation.
With particular reference to educational settings, Michael Fullan 1991 has described factors that are associated with adoption of educational innovation. Not surprisingly there is overlap with those attributes of innovations listed from Rogers in Figure 7.2. However, Fullan identifies other features notably including teacher roles and external factors, for example funding support and central legislation, as influential in successful innovation. These factors can be viewed as external to the immediate needs of teachers since decisions about these matters may be beyond their control.
### Attributes of innovations influencing adoption

1. **Relative advantage** - the extent to which an innovation is perceived to be advantageous over the idea it replaces.

2. **Compatibility** - the degree to which the innovation is perceived to be consistent with the values, experiences and needs of the users.

3. **Complexity** - the extent to which the innovation is perceived as being difficult to understand and to use.

4. **Trialability** - the extent to which the innovation may be experimented with on a limited basis to reduce uncertainty and to gain familiarity with the innovation in a particular context of use.

5. **Observability** - the extent to which the outcomes of the innovation are visible to others.

Returning to the characteristics of the innovation itself, Fullan (1991 pages 68-80) identifies several interacting factors which shape implementation of educational innovation. These factors are the characteristics of the change itself, 'local' characteristics including the teachers and managers immediately involved and
external factors such as the influence of outside agencies. Concerning the characteristics of the change itself, these are listed in Figure 7.3

**Figure 7.3**

**Characteristics of change affecting Implementation of Innovation**

- Needs identification
- Goal clarity
- Complexity
- Practicality of the innovation.

(Fullan, 1991 page 68)

There is overlap with the attributes of innovations described in Figure 7.2. For example aspects of relative advantage, compatibility and observability of innovation, described by Rogers (1995), could be considered to relate to Fullan’s concept of needs identification. Similarly, compatibility of innovation with the experience and needs of users might determine the goals served by it.

Some of these aspects of innovation merit closer scrutiny for the present study and are described further below.

*Needs identification* raises the question of the relative importance of the innovation and what priority it should be given amongst other initiatives. In the case of data-logging, need is driven by the requirements of the National Curriculum and external accountability is driven by the schools inspection process. However, once
in place use of data-logging methods may lead to additional needs becoming apparent, for example, through the value added by the data-logging to the teaching learning experience.

*Goal Clarity* influences the means by which goals are achieved. In practical terms it means being able to say what teachers might do differently to achieve the goals. Policies and programmes are frequently stated in general terms, but a lack of clarity about goals and unspecified means of achieving them are major problems in the successful implementation of educational innovations (Fullan 1991, page 70). This highlights the need to be able to operationalise the general goal to implement data-logging into specific school contexts and lesson goals. Fullan cautions however, against over-simplification of goals and means since this can lead to false clarity. This false clarity can be associated with literal implementation of an innovation without addressing the changes in beliefs and practices which lie at the core of effective use of the innovation. For data-logging the risk is that lip service is paid to the use of the new technology without attention to appropriately exploiting its full potential in science teaching.

*Complexity* concerns the extent of change required to implement the innovation. This can involve the degree of difficulty in using the innovation itself, the shifts in beliefs and values that may be associated with it and the need to acquire new strategies and resources to support its use. Fullan cautions that whilst simple changes may be more easily implemented, they may not have much effect. Difficult changes, on the other hand, may ultimately achieve greater benefits because large scale changes have more scope for success (Fullan 1991, page 71). In the context
of data-logging, this might indicate the need for more pressure to adopt data-logging methods in the classroom.

*Quality and Practicality* of the innovation program concerns ensuring that the innovation is suitable for its purpose, in other words that the needs are salient and that the practical changes which the innovation brings fit well into teachers' situations (Fullan, 1991 page 72). The innovation needs to be practical in the sense that it is achievable and teachers need to be offered 'how to do it' advice, so that they can learn by doing. In this way teachers can develop understanding of what they do in their own minds, rather than by imposition. Thus the focus here is on teachers having first hand experience of the innovation leading to personal meaning and appreciation of its practicality.

These findings from research into the spread of innovation are pertinent to the present study for several reasons. They help to identify areas of potential significance and they provide a framework for consideration of issues emerging from the interview data which is presented below.

### 7.2 Exploring science teacher perspectives on use of data-logging methods

The part of the main study reported in this chapter sought to explore a number of issues relating to the use of data-logging in routine science teaching. These issues are listed in Figure 7.4 which relates them to the characteristics of change discussed above.
### Figure 7.4 Issues Explored Through Interviews

<table>
<thead>
<tr>
<th>Issue explored through interviews</th>
<th>Characteristics of Change (Fullan, 1991)</th>
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<tr>
<td></td>
<td>Needs</td>
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<tr>
<td>Teachers' rationales for using data-logging methods in science</td>
<td>✓</td>
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<tr>
<td>Identification of factors which influence the way activities for data-logging are selected.</td>
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<tr>
<td>The influence of the National Curriculum on practice of data-logging.</td>
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<td>The ways in which a data-logging activity might be integrated into a lesson sequence.</td>
<td>✓</td>
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<td>The skills needed to be developed by pupils and teachers using data-logging.</td>
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<tr>
<td>Identification of aspects of data-logging the teachers would like to develop next.</td>
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A series of semi-structured interviews was carried out with five science teachers. These teachers worked in four different secondary schools. Three of the teachers were involved in the observational phase of the study reported in this thesis (T1, T2 and one teacher from Case 3). The other two teachers (T4 and T5) had been involved in an earlier phase of the research, but were unable to participate over a longer period in the observational phase of the study. At the time of the interviews, two of these schools (Case 1 and 2, and T4's school) had special status as 'technology schools'. As such, these schools were relatively well provided with ICT resources. Moreover, ICT was a prominent feature of their pupils' experience across the curriculum. The other two schools (Case 3 school and T5's school) did not have specialist status, but had acquired ICT resources for science teaching over time and had established its use in the science curriculum.

Following a series of observations of lessons involving data-logging, the teachers were interviewed to explore their thoughts about and general experience of using the data-logging approach. The duration of the observation phase in each school varied since it was dependent on the teacher's plans and willingness to invite the researcher into the class for the observation. For the cases reported in chapter 6 (teachers 1, 2, and 3) observations took place over an extended period of several weeks; for teachers four and five the interview followed a number of discrete observations.

Each interview was conducted by negotiation, in the teacher's school and tape recorded with their permission. The interviews were then transcribed and the interviewees invited to review the transcript and to correct or amend it as they
wished. No substantive amendments were requested to the transcripts by the interviewees. The interview transcripts are included as appendices 9a to 9e.

7.3 Findings from teacher interviews

The findings from the teacher interviews are presented and discussed below under each of the interview themes. It is possible to map aspects of these findings across the four factors affecting educational innovation; namely, needs identification, goal clarity, complexity and practicality of the innovation (see figure 7.4). However, for the purpose of this discussion a focus is retained on the themes explored in the interviews.

7.3.1 On teachers' rationales for using data-logging methods

The teachers interviewed for this study saw data-logging as meeting a need to provide pupils with opportunities to use present-day technology. This was thought to be educationally desirable both in terms of pupils' future needs and also from the viewpoint of appealing to the inherent general interest some pupils show for computer technology.

"... it's modern technology and that pupils should be confronted with up to date stuff." (T3)

"it is how industry is working: the idea of remote logging or logging some industrial process." (T4)
"I think there is something about when you do anything with technology, there is more realism to it - the students take it more seriously. It matters what data they capture, it becomes far more relevant or meaningful than just take a few numbers down as the thermometer changes." (T4)

"It’s fun! I’ve got to include that because the kids do find it fun. To get over scientific ideas in a different way and in a way, certainly these days, that they can relate to." (T2)

These comments from teachers can be viewed as expressions of some of the needs served by the data-logging approach to practical work in science, in particular some comments reflect teachers’ wishes to acknowledge the affective dimensions of pupils’ experience of practical science.

The greater value attached to the use of ICT by some teachers may reflect the ways in which it is used in some classrooms. Although for some pupils use of ICT may be seen as novel, underlying the teacher’s comments was the feeling that pupils could have greater control over what they did in a data-logging activity, for example:

"[The computer method]... adds quite a nice dimension, at a more personal level - of them having control over something, in a more explored way using data-logging, rather than having a prescribed ‘cook-book type’ experiment to do." (T3)
The notion of pupils having to tackle demanding tasks also emerged as a reason for data-logging.

\[\text{If they can see it on a computer screen it's 'true'. To do something a little different, ... to stretch the kids a bit further.} \] (T2)

"There is an element of doing things that are different; to stretch the kids a bit further. You know it's OK, we've just done the temperature experiment with the melting ice and you can do that with a thermometer: usually we do that with the thermometer. But if they've got the added incentive of using the data-loggers, keeping everything going at once, it stretches them - they're doing more than just monitoring a thermometer." (T2)

"Data-logging provides an opportunity to test them at the highest level because of the trickiness of what they have got to set up." (T4)

The increased demand of data-logging activities arises in part from the sophistication of the experimental set up. Developments in hardware have made it more user-friendly; nevertheless, pupils (and teachers) using data-logging approaches have an additional 'tier' of computer equipment to manage. This investment of additional effort can reap rewards at later stages of the activity, particularly in relation to the quality of data collected and the relative ease of software-facilitated data analysis (Newton 1998). Thinking about opportunities to develop pupils' data analysis skills through data-logging software can also enhance
the clarity of the goals teachers may set for such tasks. However, as argued here, there are obstacles to be surmounted before these higher order goals can be secured.

A second facet of the increased demand posed by some data-logging activities relates to the degree of responsibility pupils take in managing their work. Potentially, pupils have greater opportunities to exert control over the management of their activity. For example, the rapidity of the data collection process can mean that pupils can complete more experimental cycles and so the potential for exploratory styles of work which can enhance pupil control is presented. So, demand can be higher in data-logging activities because they lend themselves to more open-ended approaches to practical work.

A key word here is 'potential': whether pupils experience the increased demand is dependent on how the teacher wishes the class to work. The way in which an activity is conceived by the teacher in terms of its degree of openness and the experience of the pupils are just two of many factors which will determine the demand of a task.

Some of the teachers involved in the present study indicated that the use of data-logging had changed the ways in which they could teach science. For these teachers, who were ICT enthusiasts, the possibility of using data-logging to develop new teaching activities emerged:

"It allows me to do experiments and get data that I couldn't easily get in other ways." (T5);
and:

"... I've always seen data-logging as hopefully giving you the
opportunity to delve into those areas that you couldn't actually do
normally ... where the student or teacher is not there to take
readings, the data-logger can do it for you." (T1)

"It opens new opportunities to explore things that we couldn't do
before. For example we've started logging from balances. So I
have started to think about what I can measure with a balance. So
we have started using mass potometers, which weren't there before.
Perhaps we are trying things with pH and oxygen that we didn't do
before because there was no easy way of doing that in biology."
(T4)

This reveals a shift in thinking about using computers in practical science, which
turns technology on its head. Implementation of innovation often begins with users
assimilating new approaches within existing schemes by adopting ideas from others
(Rogers 1995). However, the teacher here is thinking about what new things can
be done with data-logging methods. The novel teaching tool is being used to
invent new teaching activities. So data-logging seems to offer new opportunities in
terms of activities which some pupils find motivating, new experiments and new
'angles' on established activities.

In terms of needs identification, it is possible that the absence of reference to the
National Curriculum need to use data-logging by these teachers occurs because the
National Curriculum Order is in place de facto. For these teachers data-logging seems to offer new opportunities in terms of activities which some pupils find motivating; new experiments and new 'angles' on established activities. Here is a good example of an innovation generating new needs as it is implemented.

The examples in the interviews of teachers adapting the data-logging method to develop new practical science activities can be construed as of the innovation being 'reinvented' in the hands of teachers. Such re-inventions represent users being well advanced in the innovation-decision process, as described above, and may represent development of new learning goals to which data-logging is well suited. Finding examples of new uses in the interview data is not surprising, since the interviewees were selected precisely because of their experience of using data-logging techniques. Nevertheless, the examples reveal the potential of the new technology for facilitating development of innovative science teaching approaches.

7.3.2 On factors which influenced teachers' choice of data-logging activity

The positive tones of these comments reflect the teachers' ambitions for using data-logging methods in their science teaching. However, the same teachers were realistic about the difficulties they faced using new technologies in science teaching. For example here a teacher acknowledges the need to plan a data-logging activity to minimise problems with the technology - an implicit expectation that they may occur and recognition of the potential negative impact on pupils and teachers of equipment failures:
"We don't want a mix of quite a difficult practical and quite a difficult data-logging set up all in one. Because we're going to have breakdowns and failures, we've got to eliminate as many of those as possible to keep it quite tight. Therefore I think we start with something quite basic." (T4)

Technical difficulties were regularly cited by the teachers as obstacles to successful use of data-logging. Technical problems can present novices with problems in data-logging activities; but it is also the occurrence of these problems in the classroom, which seems to exacerbate the impact of such difficulties for teachers. As one teacher put it:

"I suspect that other staff may feel uncomfortable if things go wrong - whether they will be able to deal with it ... with large sets [of students] and all the problems inherent in that. So there's not the same problem with Year 12 [post-16 students], with class management issues some staff are uneasy about the use of large amounts of technology." (T4)

This comment serves to emphasise the fact that classroom management involves a complex set of interactions which can be further complicated for the teacher by the addition of unfamiliar technology. In Fullan's (1991) terms, complexity refers to the difficulty and extent of change required by individuals for whom using data-logging is new. These changes include the acquisition of skills in operating new technology, but in addition, understanding of the new opportunities which data-logging offers is also desirable.
The additional burden posed can make data-logging lessons more risky for the teacher than conventional activities. There is a tension here in that whilst data-logging methods offer potential advantages for pupils, for the teacher relatively inexperienced in the ICT approach, the organisational and management skills needed to successfully run such an activity are greater. This issue was an overarching feature of case study 2, where management issues appeared to be to the fore.

Whilst the additional burden and increased pupil management risks may diminish with teachers' growing familiarity with the technology, this threat may explain some of the apparent reluctance of some to adopt the new approaches. One strategy for addressing this issue could be investment in more in-service training for teachers. There have been courses to support development of teachers' skills in these areas through initiatives funded by Government and other sources, for example the New Opportunities Fund (TTA/DfEE 1998). However, teachers need to perceive the benefits in personal and professional terms of investing in such training opportunities. Furthermore, the equipment and resources need to be in place for teachers, having been trained, to develop data-logging approaches in their teaching.

7.3.3 On the influence of the requirements of the National Curriculum

It was noteworthy in the interviews that the rationales expressed by teachers for using data-logging methods did not explicitly include the pressures from the then National Curriculum to incorporate use of ICT in practical science. It could be that
these pressures were considered by the teachers to be implicit, but when the matter was raised in the interviews, the influence of the National Curriculum was sometimes seen to have been negative.

For example here a teacher identified the assessment structure of the National Curriculum Science Order as a factor constraining the development of data interpretation skills:

"There's still not enough evaluation of the data, because the emphasis in courses is still on acquiring the data. In terms of science investigations, there's a big emphasis on the planning and acquiring the data and I know there is a need to evaluate more and interpret the data more, which is quite high level skill; but to do that you need to practice it more and forget about the other bits. And I think the teachers are still (me included) are more worried about getting it all done rather than spending a lot of time on the evaluation. Perhaps we should be spending more time ... if the evaluation and interpretation was given greater weighting, then perhaps we would do it better." (T1)

Further:

"The National Curriculum is packed and especially in the situation where ... you are not sure of what resources you are likely to be dealing with, data-logging causes an extra problem; especially if you don't know if it's going to work. Here, if I've got a chance to slip it in I always do because I'm interested in it. From talking to
some of the teachers they say 'we cannot rely on it' if you're there
and you've got 26 kids who don't know how to use it then it's too
much work to get round the whole of the group and get everybody au
fait with it and then get them to learn from it. ... the National
Curriculum is too packed to allow you to come in with it unless
you've got good backing, good technical support.” (T2).

A teacher from Case 3 linked the use of data-logging with the broader
requirements of the IT Order, yet saw the value added to pupils' science
experience to be of more significance:

“The IT National Curriculum speaks for itself and yes, you can
comply with that and do what you have to do to comply with that. I
think in a sense, in some ways that is less significant than using it to
help you achieve some of the targets set in the science National
Curriculum. Obviously there's overlap, but to actually help-. I mean
data-logging, what is it good for? It is good for recording remotely,
it allows you then to go and sense things that perhaps you couldn't
just in the hour lesson of a class.” (T3)

For teacher T4 working in an Upper School, the direct curriculum influence was
not the National Curriculum itself but the GCSE examination syllabus:

“We look at our syllabus, and the syllabus has probably sorted for
us, what we need to deliver and they will have looked at the national
curriculum.” (T4).
7.3.4 On the integration of data-logging activities into lesson sequences

The UK National Curriculum requirement to use ICT in practical work presents teachers with the planning issue of identifying suitable activities for using data-logging. One purpose of planning at the departmental level is to map the curriculum content and learning opportunities which is required and to which all the pupils are entitled. The notion of pupils' entitlement is enshrined in the requirements of the science National Curriculum Orders. Teachers have to be pragmatic in their response to these planning needs, so that their local situation can be accommodated within the required curriculum framework. It is not a straightforward task to plan an ICT activity to be presented by all a department's teachers, when they possess varying levels of skill, competence and enthusiasm for ICT. Indeed this is one focus for training to raise UK teachers' skills in classroom use of ICT (TTA 1998).

Yet the need to plan data-logging tasks into the work schemes can be seen as driving development in this area:

"it has got to be written into the schemes of work - without a doubt. We still have not got it written in to our schemes of work fully, because that forces the issue. They've got to do it whether they like it or not! ... I know X and Y will do it here, but I also know a lot of people won't touch it with a barge pole unless there's that expectation."(T1)

Writing data-logging activities into schemes of work invests them with status and gets teachers to take notice. It is questionable whether even extensive provision of
examples of ICT-based activities in curriculum documents, or other sources of general advice carry sufficient weight to drive their implementation in the classroom. However planning at department level may better achieve this goal since it can be matched to planning for progression in ICT skills development for pupils:

"...It's got to be done in a very structured way so that it is built in and develops the skill through time."(T1)

The choice of contexts in which to adopt a data-logging approach was seen as being important for several reasons. The importance of teachers making critical judgements about the purpose of an activity and the potential value added to it through data-logging emerged. One highly experienced teacher made the following point:

"I think it should be an integral part of the topic, just like it's another teaching and learning style. Within a topic sometimes data-logging is not of any use. It shouldn't be there for the sake of it, it should be there to complement and extend the science as we see it. There may be topics where data-logging doesn't come into its own..."(T5)

This point was echoed in another school, where the point was made that chosen data-logging activities:
"...need to fit in with the course we're doing - so they've got to be relevant. They have got to make the experiment easier for the students, they've got to let the students get more out of the investigations" (T5)

These statements may indicate the importance of planning to clarify the goals of an activity and to make them explicit. However, the need not to be too ambitious when selecting a task was also emphasised in a third setting:

"...we've got to think of something that is 'plug in and go' basically. Something that is quite simple as a practical." (T4)

The need for simplicity can be driven by availability of resources, but there are also other factors in play here. As discussed earlier, reducing the technical complexity of a task increases its accessibility for users and minimises the impact on matters of classroom organisation and control. It seems likely that simple data-logging approaches are more likely to win teachers' support.

7.3.5 On the skills required by pupils to use data-logging technology

Laboratory based practical work is a prominent feature of science education. One purpose often claimed for this type of work is that it develops pupils' manipulative skills. Within the context of data-logging work, there is a set of skills required to assemble and link together the components of the data-logging system with the other laboratory apparatus. We can view knowledge of these practical skills as being of an 'operational' type to distinguish them from skills of application of the
data-logging approach to serve a particular science purpose. Operational skills include ability to manage a Windows interface and to use data-logging software.

A number of these pupil-skills were of concern to the teachers interviewed for this study. Some of the teachers identified the need for pupils to be trained in assembling apparatus and operating data-logging software, for example:

"... it makes a lot of demands on their practical ability. I don't know if we are losing that skill, but it seems to me that students need as many opportunities as possible to practise those skills. Data-logging provides an opportunity to test them at the highest level because of the trickiness of what they have got to set up. I find that really useful. They've been able to read a set of instructions and go from that to physically set it up, and follow a set of guidelines. It seems to be a tricky skill for students and data-logging tests that. I do introduce it as a worksheet, prescriptive set of guidelines and it is amazing how students cannot follow that and will tend to turn to you before they will turn to the sheet. There is a whole host of IT skills on the actual downloading of the DL-plus on to the computer, and it tests their understanding of Windows, how to use drop down menus etc".[t4]

However, another teacher did not want the pupils to see data-logging methods as something special. His focus was more on the usefulness to science of the software tools and the need for pupils to overcome any initial reluctance they might exhibit to using computer technology:
"I don't want there be any special skills linked to data-logging. As I said earlier, I like to think that we are just using this machinery in order to get science data. If there is a skill, it is more a skill of not being frightened by the computer - now that is less than it used to be. Two or three years ago, you'd get an awful lot of students who would say 'oh god it's a computer, I can't possibly do anything with it'. That is less and less the case, thank goodness. The other skill which I think they probably need is being able to multitask themselves. That is while the machine is collecting data, they can be doing something else valuable. Very often they don't, they just sit and watch the machine, instead of getting on with something else. So I tend to go around and encourage them to do other things like writing up, getting that side of things done. So, in terms of setting up the hardware, plugging things in and so on, I don't usually get the students to worry about that, because I don't think it matters so much - not in Year 10 anyway. If they do this for more extended project work later on, or in the sixth form, then they'll learn how to set up the equipment for themselves". [T5]

The teacher in case 2 felt that the pupils only needed enthusiasm to get to grips with learning to use data-logging methods:

"All the pupils need is enthusiasm, which most of them here have. A little bit of computer knowledge, they don't need a great deal,
because what I have found with the girls, you know the first girls we had, the bright ones help each other." [T2].

It might be expected that with increasing penetration of ICT use in education (and in the home) that pupils' confidence in operating machines will develop and that this will present opportunities for them to help their peers. Nevertheless, T1 in the same school felt that it was essential for teachers to plan curriculum experiences that help pupils to acquire the necessary ICT skills and investigative strategies over time:

"Well, you've got to have it built in to schemes of work - that's what I'm saying. And it's got to be done in a very structured way so that it is built in and develops the skill through time. It's still very 'hit and miss' at the moment." [T1]

At another level of sophistication, some of the interviewees described the need for pupils to acquire certain skills in application of data-logging methods to solving science problems. For the experienced science teacher in case 1, this meant recognising the need to train pupils to look critically at experimental outcomes and to look for meaning in data:

"The students don't always see the relevance of the data and the fact that it's real data coming in all the time. You've got to train them to look at that data. You can't expect them to... they need training in everything don't they? I remember ATL, teachers had great problems in understanding what we meant by control variables, independent variables, never heard of them before"
because we'd never been brought up on them! Doing training sessions, 'what is a control variable, what is a categoric variable...' it's just about there now for most of us I think, but what a hard work it was at the time! Now if we need all that training when something comes along, I'm sure the kids need that same sort of thing. [T1]

In the same school, T2 from case study 2, also recognised the need to help pupils look for meaning in data:

"... some of the post-16 stuff is quite advanced and they use high level skills. Getting to think is one of the hardest things to do.

[Interviewer: What might those higher level skills include?]

Interpreting the data - certainly with my post sixteen [students] they've got to sit there and think 'well OK, we know what is happening here, we know why it's happening, and we know because we've got this particular bit of information that this is working, or not working...'. Evaluating things when they go wrong. [T2]

A similar theme on training pupils to notice salient features of data arose in interview with the teacher from the case three school:

"yes I think there are a number who will need training (perhaps all pupils) to be more analytical about what they see in front of them and not dismiss any part of a set of results. Try and explain every part, whether they think it might be an error or whether they think something else might be going on." [T3].
This success of this type of activity seems to be dependent both on the level of pupils' skills in using data-logging methods and on the design of suitable lesson structures and activities which enable them to deploy these skills (Newton, 1998).

7.3.6 On the skills required by teachers to use data-logging technology

The implications of having to 'trouble-shoot' problems in the teaching situation pose potential problems for science teachers. Teachers using data-logging need to develop the confidence to know when a system is malfunctioning and to be able to deal with it effectively:

"... if a machine goes down, then some staff who are not familiar [with ICT], may not recognise straight away what the problem will be; cannot diagnose it and therefore will end up spending an inordinate amount of time sorting that one problem out, and therefore they are away from the rest of the class and you have got a control problem." (T4).

The above statement raises a contrasting set of influences of the practice of data-logging. Although these teachers articulated a positive case for incorporation of data-logging methods in their teaching, they also identified important influences that can negatively affect its implementation in the classroom. One such influence is the presence in schools of older technology. This was seen as potentially demotivating for pupils, but acquisition of newer equipment requires investment and will take time:
The ability to invest in new equipment for schools will inevitably lag behind the latest technological developments. A teacher in a different school that was using older non-Windows technology for data-logging, highlighted the extent to which some teachers in his department had become de-skilled in the operation of the old technology, because of the prevalence of Windows-driven applications. In this department head’s view:

"Some people are less happy with a BBC computer - they find it more of a difficult thing to use. ...... [teachers] are familiar with Windows now, they’re not familiar with this other system." (T5)

7.3.7 On the 'ideal' use of data-logging technology in school science

The foregoing discussion identified a range of issues concerning use of data-logging methods in science. A major theme of this thesis has been the extent to which teachers’ actions serve to shape the use of data-logging methods; an important backdrop to these actions is the vision which the teacher holds of new technology, since this vision influences the scope of planned pupil activity.

In order to explore aspects of this issue, the teachers in this study were asked to think about their ideal use of data-logging technology.
The teacher from the first case study [T1] expressed a broad view of the potential of ICT for science teaching:

"Oh! I'd love a [course] unit which is purely IT driven. Where the emphasis is - not data-logging - where the emphasis is using the internet, spreadsheets, word-processing to write it up. One unit a year possible where you would use IT from the outset to say to students, 'look this is what you can do with IT to enhance your work in terms of quality, accuracy, research etc'. To me science is not just about facts and knowledge it's about finding it out for yourself." (T1)

This view may reflect the breadth of experience of the teacher and his excitement about the potential of ICT to support pupils' learning. However he went on to hint at the resource implications of whole classes of pupils working using ICT. This point was also reflected in the comments made by T2 in addition to the following comment highlighting the scope of data-logging methods for supporting investigative work in science:

"...data-logging would be ideal for science investigations because you can use all the skills that they need with data-loggers. So yes, to have the time and to have the kit there - that would be great." (T2)

The same teacher offered the following comment on the skill levels required by pupils to make use of data-logging for investigative work:
in the lower school they [pupils] are still getting to terms with things like evaluating and concluding, drawing from what they are seeing, so it's not [used] as much. But I suppose ...it would be nice to see it more!! (T2).

This comment highlights the need for a progression in knowledge and understanding about the use of data-logging to parallel pupils' development of science knowledge.

### 7.3.8 On plans for future developments for using data-logging methods.

The final part of the interview conducted with the teachers explored aspects of their future vision of data-logging methods in science. Bearing in mind the experience and enthusiasm of these teachers for using ICT, it was anticipated that the teachers could have ideas for future uses that exploited some of the more analytical features of the then available data-logging software. As the following comments from the interviewees indicate, their concerns about future use reflect the constraints that shaped their current use of data-logging.

The need for wider use of data-logging technology within T1's own school (where it was already relatively well-embedded in departmental practice) emerged:

> "I know there are courses around but I'd like to see courses where IT is more explicit." [T1]

Working in the same school, T2 expressed a wish to develop the variety of applications in which data-logging could find a place. The revealing point in the
following remark is the concern to ensure that activities that are developed work reliably and practically achievable in the hands of teachers:

"Coming up with ideas - I love coming up with an idea and seeing if I can do it. [T1] has been coming up with the idea of putting things on the internet for everybody to see - I think that is a good idea. A lot of people have got to the stage where they have seen the experiments. One thing I would like to do is get them to work - the amount we've tried where there were good ideas but somebody hasn't put enough thought into them. Some of them you read are not really practical especially in the time constraints you've got.... [t2]

A similar wish to broaden the use of data-logging methods was expressed by T4; in particular, its potential to support investigative work was identified again

"With data-logging I would like to see it more widely spread. I think we all engage a certain amount or have actives with data-logging involved. I think we could do more with different types of sensors and open new experiments up. I think we could .... well SC.1 interests me. People have said 'presume you use this in Sc.1' and we don't. We're asked to produce precision instrumentation etc. in SC.1 and yet we don't use our data-logging for that. Probably that is the nature of the practicals we do, but I have thought yes we could; but we have got so many students here that we haven't got the kit to deliver it to everyone and give everyone a fair shot, if we are going to use data-logging. We can't give that to 450 Year 10 [pupils] all at
once. But perhaps there is some future there if we can think of something suitable, so that students that need that level on their SC.I can get it through the use of data-logging. [t4]

Another interesting feature of this comment is the teacher’s recognition of the value of electronic sensors to investigative work in providing precise measurement. This feature of the data-logging methodology had not previously emerged explicitly in the research reported here. Nevertheless, the overriding constraints expressed here concern the levels of available equipment and the need for suitable activity contexts in which it could be deployed.

The same concerns emerged in the interview with T5, in addition, the complexity of possible activities was identified as posing problems for teachers. A further issue that emerged in the discussion was the need to use data-logging methods because of the value that they add to an activity, rather than because the use of ICT is currently fashionable:

"Now that we have got technology college status, as from September, in our science development plan it says that 10% of our science teaching shall be delivered using ICT. Now I’m not very keen on that because it rather suggests you’ve got to do it for the sake of doing it. I think 10% might be rather high. Certainly you wouldn’t do data-logging to that extent because I don’t think you could manage it - it would start to look like data-logging for the sake of data-logging. But there are other things you could do - like the lesson I had this afternoon which is a different use of ICT. But I
don't want staff to think 'oh I have got to do a data-logging here and
I've got to do one here...' and each one of these is horrendous to set
up. It is better if a piece of data-logging can be done within a single
class time and the benefit is that the students get their information
immediately and can store it on disk themselves, come back next
lesson perhaps and do a print out. Although the limitation of
printers is a problem. [T5]

Again, the practical issues of organising and managing data-logging methods in
classrooms are seen to constrain their use.

One comment from the interview data indicated a teacher's vision of linking
sensing technology with aspects of control technology:

"In an ideal world I would like to be able to link data-logging to
control and say you've logged certain circumstances and then have
parameters which say IF certain circumstances, rise, fall beyond
certain thresholds it will trigger some control response." [T3]

7.4 Summary of findings from interviews

The findings presented in this chapter can be usefully reviewed in relation to the
four research issues which this study addresses.

Issue 1 What are the features of data-logging tasks designed by teachers?

The potential of data-logging tasks to support investigative work emerged in the
interviews presented here. However, although the teachers were aware of this
potential, their wish to adopt this style of working was constrained by the threshold of skill level required. The difficulty and extent of change required by individuals new to using data-logging includes the acquisition of skills in operating new technology for both pupils and teachers. In the absence of the required skill level, reducing the scope of a task seems to aid its simplicity and increase its perceived usefulness. Moreover, this strategy risks shifting the style of the activity towards more teacher-controlled rather than investigative styles of working.

Issue 2 How are data-logging tasks presented, organised and managed?

Although the interviewees expressed positive ambitions for using data-logging methods, they were realistic about the demands and difficulties of implementing new technologies in science teaching. The need for simplicity can be driven by limited availability of resources, but there are also other factors in play here. Reducing the technical complexity of a task increases its accessibility for users and minimises the impact on matters of classroom organisation and control. It is perhaps not surprising therefore that some of the teachers advocated structured approaches to using data-logging, including the use of departmental schemes of work to help to drive its wider use. Structured approaches also permit consideration of pupils’ developing skill levels as they move through secondary education.

An important theme emerging from this study is that the teachers’ experience of technical difficulties weigh in their choice of task activity. Management of data-logging tasks appears to be more complex than might be thought. The potential impact of technical problems on the success of a lesson raises issues of pupil
management of which even these experienced teachers are wary. Taken together, this may lead to teachers using relatively simple and well tried procedures. The potential problem with this approach is that it risks under exploiting the features of data-logging technology and limiting its value to extend and develop pupils’ investigative abilities. It seems likely that simple, structured data-logging tasks are more likely to win teachers’ support despite the more limited rewards from the new technology.

**Issue 3 What are the roles played by pupils and teachers in data-logging tasks?**

The interview data did not reveal a great deal about the roles adopted by teachers and pupils in data-logging tasks. However, the need for operational skills to be well developed did arise and the consequences of this for experience and training for both pupils and teachers is implicit here. Again a dominant theme was the need for teachers to be able to manage the technical complexities of using data-logging in the classroom.

**Issue 4 What evidence of productive interactions between ‘actors’ in data-logging lessons can be found?**

The interview data did not provide evidence of the teachers giving much consideration to this issue. Although the later interview questions focused directly on teacher skills, engagement of pupils or planning for productive intervention did not emerge strongly as a theme. This could reflect teacher’s concerns with other more operational matters, as indicated above. It could be that this type of
pedagogical understanding represents a more advanced stage of progression in the innovation process. Alternatively it could be that more direct questioning through the interview may have more effectively uncovered this type of understanding. Nevertheless, taking the case data and interview data together, and looking at the teaching materials that supported the observed lessons, the researcher's view is that the practical constraints of organising and managing data-logging activities dominated the teachers' concerns.
Chapter 8

Conclusions and recommendations

Introduction

In this final chapter, the conclusions from the study are set out. In order to present this discussion, it is necessary to restate the research purposes that were identified in Chapter Four. The purposes for the present study were arrived at from a consideration of literature in the field and a desire to explore the extent to which the perceived advantages of using data-logging technology were being achieved in routine classroom practice.

The research purposes of this study were to:

- consider the prospects for data-logging methods in real world classrooms;
- identify current practices of data-logging;
- identify factors which constrain use of data-logging methods;
- identify 'assisting factors' which promote effective use of data-logging methods;
- identify approaches that can more fully exploit data-logging technology for pupils.

As described in Chapter Four, Squires and McDougall (1996) have developed a framework for software evaluation that adopts a situated approach. The notion of a situated approach focuses attention on the context of use of software, rather than merely describing its properties. Moreover, the approach sits well with the context of the present study because it requires an interpretative stance to software
evaluation that considers multiple perspectives in the evaluation process. These perspectives involve the various relationships between the three agents in a software mediated learning environment; namely, the perspectives of the teacher, the pupil and the software designer. Taken together, the interactions between these three ‘actors’ provide useful insights into the range of issues to be considered in evaluating the use of educational software and it is this approach that helped in framing the focus of the present study.

The research issues identified in Chapter Four were:

- **Issue 1** What are the features of data-logging activities designed by teachers?
- **Issue 2** How are these activities presented, organised and managed?
- **Issue 3** What are the roles adopted by teachers and pupils in data-logging lessons?
- **Issue 4** What evidence of productive interaction between 'actors' can be found in data-logging lessons?

These research issues have provided a framework for the presentation and discussion of the case studies and interviews presented in this thesis. The four case studies and the interview data presented in this study are complementary and offer insights into the use of data-logging in a range of contexts.

In Case 1 there was an experienced teacher who tightly managed the pupils’ activity. Pupil tasks were clearly focused and teacher-directed but there was scope for an investigative approach so pupils could adopt an exploratory role.
Case 2 involved a less experienced teacher, and the lessons had relatively weakly focused objectives. Although there was some scope for pupils' investigation, the objectives appeared to the researcher to be too ambiguous for the pupils to cope with at their level of experience. In contrast, case 3 offered a pair of highly structured activities intended to give pupils experience of both remote and real time data-logging. The highly structured tasks reduced the scope for pupils' investigative work.

Cases 1-3 offered little scope for activities involving interpretation of data; the science objectives appeared generally to the researcher as less important than the ICT objectives. In Case 4 however, the 'teacher' was the computer. The teaching was controlled by a software management system incorporated into the design of the *Understanding Insight* tutorial software (Logotron, 1998). The software used delivered a structured activity but pupils were in control of managing the software and so can be considered to be more autonomous learners than in the other cases examined. The software taught pupils operational skills but retained a focus on the science context that re-emerged at different points in the lessons through the tutorial questions presented to pupils on the computer screen.

In this fourth case study, the features of the data-logging tasks and their mode of presentation to the pupils was determined by the designer of the software. Although this might be considered to be atypical of everyday classroom data-logging activity, it should be noted that the *Understanding Insight* tutorial is proprietary software that is available to teachers. Its design purpose is that pupils may learn the skills of operating data-logging software and acquire investigative strategies that exploit the features of such programs (Rogers and Newton 2001).
To this extent one can view the intended use of *Understanding Insight* as naturalistic.

Taken together, the four case studies presented here offer different but complementary scenarios in which data-logging was used. The findings from these case studies were discussed in Chapter Six. Additional insights into contemporary use of data-logging in the case study settings and in other similar contexts were provided by the interview data presented in Chapter Seven: again, these findings were discussed earlier. The purpose in this chapter is to draw on the earlier discussion to present conclusions and make recommendations for future practice of data-logging.

**Conclusions and recommendations**

**8.1 On questions of task design**

The argument presented here suggests that, in considering tasks for pupils involving data-logging methods, teachers need to have regard to the following issues:

*Clarity of task objectives*

In the cases presented for this study it appears that where the teacher has clear goals for an activity and where these are communicated to the pupils, this leads to focused and purposeful pupil activity. On the other hand, when goals were insufficiently clear or not communicated to the pupils, then their activity appears to be less sharply focused.
Scope of selected activity

In choosing data-logging activities, it is necessary for the task to have sufficient potential scope for the pupils to be able to achieve the intended objectives. This requires the teacher to have sufficient knowledge and experience of the planned task to be able to anticipate the potential outcomes. For example, tasks intended to develop pupils' skills in using software can justifiably be less open-ended than those intended to develop investigative strategies where pupils will need to consider the merits of alternative approaches. Awareness of these issues may help teachers clarify task goals and select well-suited tasks to help secure these goals.

Value added by ICT to the selected task

It seems necessary (and desirable) that teachers should keep the science learning purpose to the fore when using a data-logging method. This means that, in designing tasks for pupils, activities should be selected which exploit the attributes of the new technology in ways that add value to the science task. This holds the prospect of pupils learning about the usefulness of data-logging methods for scientific measurement, data collection and, at a higher level of understanding, data analysis and interpretation. Despite the maturity of ICT experience and resources in the schools selected for this study, technical difficulties tended to shift the focus of activity more towards the new technology than to the science purpose it was there to serve. One consequence of this shift was that there was an emphasis on the processes involved in gathering data rather than on its analysis and interpretation.
Match between task objectives and pupils' experience.

The teachers in this study seemed to be aware of the scope and potential of data-logging tasks to support investigative work with pupils, as shown in the interview data. However, in their practice, as revealed in the cases observed for this study, their ability to put this investigative style in place was constrained by other factors. Chief amongst these appears to be the knowledge and skill level of the pupils and teachers in using data-logging methods and the levels of ICT resources required.

The teachers' apparent response to these constraints appeared to be to restrict the scope of the data-logging activities. The desire to constrain the limits of the task puts greater control of it in the hands of the teacher, as opposed to the pupils, with the result that the selected activities served investigative approaches less well.

8.2 Task presentation and management.

Complexity and simplicity

A dominant theme that emerged from this study is the complexity of the management of data-logging activities, which face teachers. As indicated above, even in the relatively well-resourced settings that were observed for this study, the demands placed on the teachers by data-logging activities are high. This finding identifies the need for data-logging activities to be well serviced by technical support to reduce the risks of equipment failures. Teachers require confidence and competence in their ability to overcome the problems posed by equipment failures. This is an important finding, confirming earlier findings of Voogt (1996), for while the risks of problems remain high, teachers are understandably reluctant
to design more complex activities for pupils. They seem likely to stick to tried and
tested activities that may under exploit the attributes of computer technology. It is
noteworthy that this issue remains important despite technological advances that
have sought to simplify and improve the reliability of data-logging equipment.

The teachers in the present study favoured small group pupil activities or rotations
through activity 'circuses' as a means of making limited ICT resources available
to the pupils. The use of group work or multiple tasks in the classroom seems to
lead teachers to make use of worksheets to support the pupils rather than
expository episodes, which are associated with whole-class teaching. In terms of
activity management, the structure of worksheets needs to strike a balance
between a prescriptive worksheet (which tells the pupils exactly what to do) and
the need to retain scope for pupils to take responsibility during investigative work
and therefore developing their skills in the strategies of investigation.

As suggested above, the desire for simplicity in tasks often expressed by the
teachers in this study can reduce the complexity of classroom management to a
more manageable level. The more manageable the tasks, the less prone to failure
and the easier it may be to retain a strong focus on the science learning purpose
rather than on the paraphernalia associated with data-logging methods.

A further benefit of reduced complexity is that it seems likely to favour the
adoption of the data-logging innovation. However, it is to be hoped that increasing
experience and expertise in use of data-logging methods will allow for the tried
and tested activities to give way to newer ones that better exploit the attributes of
the method.
8.3 Roles adopted by teachers and pupils

The discussion of task design and management presented above indicates that in the present study, teachers retained a high degree of control over the management of pupil activity. Although this tendency can be justified by the constraining factors indicated earlier, it resulted in highly teacher-directed data-logging lessons. Whether mediated through exposition or worksheets, the teachers’ voices could be ‘heard’ prescribing the pupils’ activity.

The pupils largely followed the teachers’ directions in the observed lessons; there was little evidence of pupil-directed investigative work in the cases. This is not surprising overall, since many of the pupils observed in this study were learning to use data-logging methods. It could be expected that fewer instances of pupil-led activity would be seen in the early secondary school years. One might anticipate that later in their studies pupils would have opportunities to apply this knowledge in other contexts.

8.4 Productive interactions

There was some evidence in the classroom observations of teachers monitoring pupils’ practical activity and this provided useful opportunities for the teachers to intervene. Sometimes these intervention opportunities arose because the teacher was required to resolve a technical problem, which then led to the teacher posing a question or engaging the pupils in some discussion. However, the tape recordings of talk indicate that the quality of the talk can change to become more science-focused when the teacher intervenes. This finding signals that when using data-logging methods, teachers should plan to engage pupils in dialogue about
their data. Teacher interventions are opportunities to elicit pupils' understanding and develop their use of scientific language about data, graphs and meanings.

Planning for intervention did not emerge strongly in the interviews with teachers, yet some of the teachers did intervene on occasions. It is possible that this teacher skill is taken for granted because it is one of the repertoire of everyday strategies used by science teachers in practical work. Nevertheless, the present study indicates that the importance of interventions needs to be brought to teachers' attention as being of particular value in data-logging lessons.

8.5 Implications of this research

A number of features of data-logging practice need to be in place to provide a basis for further development of its use. First:

- availability of adequate and up-to-date hardware and software;
- provision of technical support to ensure that equipment is serviceable;
- teachers skilled in the technical use of the equipment.

These factors are a prerequisite to establish a resource platform from which more developed data-logging practice can emerge. Experience and familiarity with equipment and its classroom use is necessary to foster the next level of professional awareness of data-logging; namely:

- understanding of how data-logging can change classroom management needs;
- understanding of a fuller range of benefits of data-logging approaches; and
• developing teaching approaches, which exploit attributes of the
technology and add value to the science learning experience.

Issues of classroom management appeared in the present study as a major
influence in the decisions taken by teachers about data-logging activities. The
teachers' concerns about pupil management, technical matters with equipment and
the need to fulfil ICT curriculum requirements for example, seemed to outweigh
their concerns about science learning purposes.

It seems likely that developments in teachers' understandings of the potential of
data-logging methods and their skills in translating these into manageable pupil
activities will take time to emerge. However, in the hands of experienced ICT
enthusiasts, these understandings may lead to well developed rationales for using
data-logging in science teaching. It is to be hoped that these more mature
rationales will extend the apparently 'surface-level' curriculum requirements to
use data-logging methods to deeper and new understandings of the potential of the
approach in a range of exploratory science contexts. It is perhaps through
understandings at this deeper level that more of the benefits of data-logging
identified by research are likely to be achieved in the hands of science teachers
working in real classrooms.

It is possible that a mature appreciation of the potential of data-logging as a
teaching tool may encourage science teachers to identify and clarify learning
objectives for practical science that draw on the attributes of the new technology;
but it is likely that this will need to be led by the curriculum through:

• planned curriculum opportunities for use of data-logging; and
• assessment incentives to encourage greater use of data-logging.

Used in this way, the curriculum can drive further development of data-logging reducing dependence on the work of ICT enthusiasts. It may provide opportunities for less skilled ICT users to gain experience, and it can help to ensure that more pupils have the benefit of using it in their learning of science.

Whilst it is possible to be optimistic about the future development of classroom uses of data-logging technology it is also necessary to be aware of threats to this development. Some of these threats have been identified in the body of this thesis but, as resource levels improve and training initiatives address teachers’ skills deficit in ICT, the range of technological applications which teachers are expected to use in their teaching is broadening.

Data-logging technology has a relatively long history in school science yet, as the cases described in this thesis illustrate, despite this history, the spread of the data-logging innovation and its adoption in classrooms has yet to meet the aspirations of software designers or researchers into its potential. It seems that new practices take a long time to become embedded in teachers’ routine practice yet, with the pressures to keep pace with and adopt newer technologies, there is a risk that teachers could be distracted from this endeavour. Giving insufficient thought and time to the task of understanding the potential of new applications and how to deploy them in the classroom threatens their wider adoption in classrooms.

It has been argued, in Chapter Seven, that some scholars of educational innovation advocate large-scale innovations because of the greater scope for success that this brings. Recent developments in use of ICT in education, for example national
skills training initiatives and new requirements for initial teacher education; the National Grid for Learning and programmes to increase ICT resources in schools, exhibit features of large-scale innovations and are to be welcomed. However, there is a risk that changes on this scale may overwhelm individual teachers whose own working contexts may not match the rhetoric of large-scale innovation. As this thesis has sought to show, at the classroom level, it is teacher decisions about suitable tasks, classroom management, styles of working and classroom environment as well as knowledge of the technical attributes of data-logging technology and understanding of how these might contribute to pupils’ learning science that remain important. These issues remain worthy of further study and present an agenda for further research.

8.6 Reflections and suggestions for further work

The earlier discussion has presented the major findings of this study and, as the focus of discussion shifts to consider the prospects for further work in the field, it is useful to return to the broad focus of this thesis and to reflect on the extent to which its initial aims have been achieved.

The introduction to Chapter Four set out three orienting questions for this study, these were:

- To what extent can the claims made for data-logging from research be secured in ‘real-world’ classrooms?

- What features of the current practice of data-logging appear to help secure the benefits?
• What further aspects of practice need to be put into place to secure the benefits?

What emerges from the present study is the overwhelming extent to which any benefits of the data-logging approach are contingent on teachers' actions. Consequently the study has retained a strong focus on the roles of teachers using data logging methods.

Case study one provided evidence that data-logging technology could focus pupils' attention on the processes of data collection and the emergent electronic displays of line graphs. Episodes of teacher intervention appeared to influence the quality of pupils' talk about data displays and careful questioning by the teacher could help reveal pupils' understanding of these displays. Both of these findings reflect benefits of data-logging use reported in the research literature yet, in the present study, examples of such potential benefits were rare. On many occasions, activity was dominated by 'operational' matters chiefly concerned with getting to the point in a data-logging activity of collecting experimental data. Clearly, this operational activity has intrinsic value in developing pupils' skills using ICT. Ultimately, however, the goal must be to use data-logging methods for scientific purposes and these purposes concern the mode of application of data-logging methods to a problem solving activity. In the present study, examples of these 'application benefits' were sparse.

The contrasts between the lessons in case one and case two (supported by aspects of case three) serve to highlight the significance of teachers' actions in planning and presenting activities with sufficient scope and clarity of purpose to exploit
fully the attributes of data-logging methods. In case study four, where the teaching was delivered by software, there were some examples of pupils attending to electronic displays of graphs in ways that were indicative of some potential benefits. However, the present study offers further indications of this potential and the question as to how far these benefits can be achieved in everyday settings requires further study.

Although case sites were selected for the present study precisely because of their maturity of ICT use, operational and organisational issues were dominant to the application of the data-logging approach to serve science learning purposes. The capacity of teachers to command ICT resources, to have well-serviced resources and technical support, and vision of a learning purpose are key foundations for using data-logging methods. Aspects of successful pedagogy for data-logging methods were not extensively represented in the study as a whole and, where there were indications of this, it reflected the coming together of a complex mix of influencing factors - some of which have been uncovered in this study. Given the complexity of influences shaping the positive use of data logging methods, it is perhaps not surprising that there was variation in the extent to which indications of the benefits of data logging were apparent in the different case studies.

Nevertheless, what does emerge strongly from the present study are indications of those aspects of useful teacher activity that can be developed in order to foster a climate in which the beneficial attributes of data-logging technology seem likely to be secured.
Turning to issues of methodology, it is legitimate to question whether the methodological approaches adopted in the present study were sufficiently sensitive to offer the prospect of revealing the potential benefits to science learners of data-logging activity. The use of audio tape recordings of pupil activity, records of lesson observations and teacher interview data in the present study has revealed a great deal. Clearly, there would be advantages in applying the same approaches in a wider range of case study sites and this could improve the extent to which the findings of the present study could be generalised.

There is a growing body of literature on the educational value of talk and argumentation for science learners. Although the present study found some evidence of the potential of data-logging activities as a stimulus to talk, much of the observed activity concerned collecting data from experiments. It is possible that, despite being carried out in relatively mature ICT contexts, the timing of this study was such that appreciation of the value of the activity to fostering talk was not widely appreciated by the teachers. Therefore more studies of pupil talk in data-logging classrooms, especially as the technology becomes more widely adopted, could provide further evidence of its merits and indications of how teachers might organise pupil activity to develop its potential.

A major ambition of data-logging techniques is that software can, in principle, support pupils' higher order interpretative and analytical activity. This study has supported earlier research findings that data-logging can provide a focus for pupils' talk about experimental data. However it is possible that pupils' thinking on these matters could be 'captured' using research instruments other than audio
tape recordings. For example, observation schedules such as those developed in the early part of present study (see Chapter Five) could be used to record frequency of pupils' interpretative talk. The difficulty with this approach is that whether pupils engage in such talk is heavily dependent on the nature of the task they have been set by the teacher, as discussed earlier. It is likely therefore, that it will not be possible to research meaningfully the quality of pupils' talk in data-logging environments until pedagogy has developed further to provide activities of sufficient scope to offer the prospect of more interpretative pupil activity.

Improvements continue to be made in the levels of ICT resources, design of data-logging software and teachers' operational skills in using ICT. In this climate, it will be worthwhile to develop and broaden the present research. Pupils' written records of science activities using data-logging methods could provide an additional evidence base for examining their interpretative activity. Carefully designed worksheets could provide writing frames to elicit pupils' interpretative understandings. This approach to research holds the prospect of extending the evidence base since it might generate individual responses from pupils. It also has the advantage over audio tape recordings of requiring a response (rather than depending on pupils volunteering one) and of being more private than verbal statements made by pupils in group work at the computer.

As discussed in Chapter One, part of the motivation that many pupils express for using ICT stems from their perception of being able to control their own learning. In the context of investigative science it is envisaged that pupils will make judgements about selecting particular approaches and tools to carry out
investigations. One might expect that, in making their decisions, pupils will be able to weigh the relative merits of the available options. In this context, it would be valuable to explore pupils' perceptions of the usefulness of data logging technology. Studies that explore pupils' ideas about the value of data logging methods and how they can add to their practical work, as well as affective domain factors (such as motivation), are important areas for further work.

It is necessary to be clear that the claims made in this thesis are based on the case studies examined, and that the implications discussed here are signalled from these case studies and interview data as well from supporting literature. It is therefore desirable that future work should explore the extent to which the influencing factors raised in this study appear to be of significance in the wider context. It would be valuable to explore some of these issues on a larger scale through survey techniques. Although surveys may not offer the richness of the experiences reported in the present case studies, they offer the prospect of detecting how far some of the issues revealed in this study apply in the wider school population.

Since the fieldwork for the present study was conducted, there have been national initiatives to raise the ICT skill levels of serving teachers and of those in initial teacher education. It would be valuable to explore the impact of these training initiatives over time on teachers' practice of data-logging.

The contribution of this study has been to offer a detailed exploration and examination, through case studies, of the factors that influence the practical application of data-logging methods in 'real world' science classrooms. It has
identified the range of these influencing factors and sought understandings of the ways in which they inter-relate to influence data-logging in practice. These understandings have signalled more clearly, issues that science teachers need to be aware of when designing data-logging activities and when implementing these activities in their teaching. It has been argued that these understandings are necessary if the intrinsic benefits of data-logging technologies and those further benefits that accrue from its mode of application in the classroom are to be enjoyed by pupils.
Contact Summary Form V1.5

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<tbody>
<tr>
<td>Name:</td>
<td></td>
<td>Contact's role:</td>
<td></td>
</tr>
<tr>
<td>Class Name</td>
<td></td>
<td>Year:</td>
<td></td>
</tr>
</tbody>
</table>

1. Main themes & issues arising in this contact:

2. Summary of information gained (or not gained) on target questions:

<table>
<thead>
<tr>
<th>Question</th>
<th>Information</th>
</tr>
</thead>
</table>

3. Other salient, interesting, illuminating or important points:

4. New or remaining target questions for next contact with the site:
APPENDIX 2
Classroom Environment Inventory

Directions

This questionnaire contains statements about practices which could take place in this laboratory class. You will be asked how often each practice actually takes place.

There are no right or wrong answers. Your opinion is what is wanted. Please answer on the separate answer sheet provided. Please DO NOT write on this sheet.

Please think about how well each statement describes what your laboratory class is actually like. Draw a circle around:

1 if the practice actually takes place ALMOST NEVER
2 if the practice actually takes place SELDOM
3 if the practice actually takes place SOMETIMES
4 if the practice actually takes place OFTEN
5 if the practice actually takes place VERY OFTEN

Please be sure to give an answer for all questions. If you change your mind about an answer, cross it out and circle another.

Some statements in this questionnaire are fairly similar to other statements. Please don’t worry about this. Simply give your opinion about all the statements.

Practice example:

Suppose that you were given the statement: “Students choose their partners for laboratory experiments.” You would need to decide whether you thought that students actually choose their partners “Almost Never”, “Seldom”, “Sometimes”, “Often” or “Very Often”. For example, if you selected “Very Often”, you would circle 5 on your answer sheet.

Please remember that you are being asked how often (Almost Never, Seldom, Sometimes, Often or Very Often) that each of the following practices actually takes place in this laboratory class.

<table>
<thead>
<tr>
<th>Statement</th>
<th>Almost Never</th>
<th>Seldom</th>
<th>Sometimes</th>
<th>Often</th>
<th>Very Often</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Students in this laboratory class get along well as a group.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>2. There is an opportunity for students to pursue their own science interests in this laboratory class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3. What we do in our regular science class is unrelated to our laboratory work.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>4. Our laboratory class has clear rules to guide student activities.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>5. The laboratory is crowded when we are doing experiments.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>6. Students have little chance to get to know each other in this laboratory class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>7. In laboratory class, we are required to design experiments to solve a given problem.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>8. The laboratory work is unrelated to the topics we are studying in our science class.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>9. This laboratory class is rather informal and few rules are imposed.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>10. The equipment and materials that students need for laboratory activities are readily available.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>
### APPENDIX 2
#### Classroom Environment Inventory

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.</td>
<td>Members of this laboratory class help one another.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>12.</td>
<td>In our laboratory sessions, different students collect different data for the same problem.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>13.</td>
<td>Our regular science class work is integrated with laboratory activities.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>14.</td>
<td>Students are required to follow certain rules in the laboratory.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>15.</td>
<td>Students are ashamed of the appearance of this laboratory.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>16.</td>
<td>Students in this laboratory class get to know each other well.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>17.</td>
<td>Students are allowed to go beyond the regular laboratory exercise and do some experimenting of their own.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>18.</td>
<td>We use the theory from our regular science class sessions during the laboratory activities.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>19.</td>
<td>There is a recognised way of doing things safely in this laboratory.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>20.</td>
<td>Laboratory equipment is in poor working order.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>21.</td>
<td>Students are able to depend on each other for help during laboratory classes.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>22.</td>
<td>In our laboratory sessions, different students do different experiments.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>23.</td>
<td>The topics covered in regular science class work are quite different from topics dealt within laboratory sessions.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>24.</td>
<td>There are few fixed rules for students to follow in laboratory sessions.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>25.</td>
<td>The laboratory is hot and stuffy.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>26.</td>
<td>It takes a long time to get to know everybody by his/her first name in this laboratory class.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>27.</td>
<td>In our laboratory sessions, the teacher decides the best way to carry out the laboratory experiments.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>28.</td>
<td>What we do in laboratory sessions helps us to understand the theory covered in regular science classes.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>29.</td>
<td>The teacher outlines safety precautions before laboratory sessions commence.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>30.</td>
<td>The laboratory is an attractive place in which to work.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>31.</td>
<td>Students work co-operatively in laboratory sessions.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>32.</td>
<td>Students decide the best way to proceed during laboratory experiments.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>33.</td>
<td>Laboratory work and regular science class work are unrelated.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>34.</td>
<td>This laboratory class is run under clearer rules than other classes.</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>35.</td>
<td>The laboratory has enough room for individual or group work.</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
# APPENDIX 3

## Observation Schedule for Key Stage 3

<table>
<thead>
<tr>
<th>Science 1 at Key stage 3</th>
<th>Activity Category Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Planning experimental procedures</td>
<td>Setting the problem</td>
</tr>
<tr>
<td>1a) asking questions from scientific k/u from own &amp; others' ideas</td>
<td>considering variables</td>
</tr>
<tr>
<td>1b) carrying out trial runs where appropriate</td>
<td></td>
</tr>
<tr>
<td>1c) making predictions where appropriate</td>
<td></td>
</tr>
<tr>
<td>1d) considering key factors in simple contexts</td>
<td></td>
</tr>
<tr>
<td>1e) isolate the effect of changing one factor</td>
<td></td>
</tr>
<tr>
<td>1f) deciding on number &amp; range of observations or measurements</td>
<td></td>
</tr>
<tr>
<td>1g) recognising uncontrolled variables and judging amount of evidence required.</td>
<td></td>
</tr>
<tr>
<td>1h) selecting apparatus equipment or techniques. safety.</td>
<td></td>
</tr>
<tr>
<td>2. Obtaining evidence</td>
<td>Selecting apparatus</td>
</tr>
<tr>
<td>2a) using arrange of apparatus safely &amp; with skill</td>
<td>Handling apparatus</td>
</tr>
<tr>
<td>2b) making observations &amp; measurements to an appropriate degree of precision</td>
<td>Getting data</td>
</tr>
<tr>
<td>2c) making sufficient observations or measurements for reliable evidence</td>
<td></td>
</tr>
<tr>
<td>2d) repeating observations &amp; measurements appropriately</td>
<td></td>
</tr>
<tr>
<td>2e) recording observations &amp; measurements appropriately as the work is carried out</td>
<td>Recording data</td>
</tr>
<tr>
<td>3. Analysing evidence and drawing conclusions</td>
<td>Reporting a) oral;</td>
</tr>
<tr>
<td>3a) to present qualitative and quantitative data clearly</td>
<td>b) written</td>
</tr>
<tr>
<td>3b) to use graphs appropriate to the results obtained</td>
<td>Drawing graphs</td>
</tr>
<tr>
<td>3c) to use lines of best fit where appropriate</td>
<td></td>
</tr>
<tr>
<td>3d) to identify trends or patterns in results</td>
<td>Exploring data</td>
</tr>
<tr>
<td>3e) to use results to draw conclusions</td>
<td>Interpreting data</td>
</tr>
<tr>
<td>3f) to decide whether the results support the original prediction when one has been made</td>
<td>Justifying</td>
</tr>
<tr>
<td>3g) to try to explain conclusions in the light of their knowledge and understanding of science</td>
<td>Applying principles</td>
</tr>
<tr>
<td>4. Considering the strength of evidence</td>
<td>Evaluating evidence</td>
</tr>
<tr>
<td>4a) to consider whether the evidence is sufficient to enable firm conclusions to be drawn.</td>
<td></td>
</tr>
<tr>
<td>4b) to consider anomalies in observations or measurements and explain them where possible</td>
<td></td>
</tr>
<tr>
<td>4c) to consider improvements to the methods that have been used</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other/ uncodable</td>
</tr>
<tr>
<td></td>
<td>Off task</td>
</tr>
</tbody>
</table>

### Observation Record

<table>
<thead>
<tr>
<th>Date</th>
<th>Site:</th>
<th>Class</th>
</tr>
</thead>
</table>

### Scan segment 2 minute intervals

<table>
<thead>
<tr>
<th>Student Sub-Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<th>9</th>
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</tr>
</tbody>
</table>

304
### APPENDIX 4a

**Observation Schedule for Key Stage 3**

<table>
<thead>
<tr>
<th>Date</th>
<th>Site:</th>
<th>Class Year 7 8 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context:</td>
<td>Everyday □</td>
<td>Science □</td>
</tr>
<tr>
<td>Problem:</td>
<td>Defined □</td>
<td>Not Defined □</td>
</tr>
<tr>
<td>Methods:</td>
<td>Defined □</td>
<td>Not Defined □</td>
</tr>
<tr>
<td>Solution:</td>
<td>One □</td>
<td>Many □</td>
</tr>
<tr>
<td>Exploratory style</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Variables given</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Investigation</td>
<td>Type 1 □</td>
<td>Categoric IV</td>
</tr>
<tr>
<td>Type 2 □</td>
<td>Continuous IV</td>
<td></td>
</tr>
<tr>
<td>Type 3 □</td>
<td>&gt;1 Categoric IVs</td>
<td></td>
</tr>
<tr>
<td>Type 4 □</td>
<td>&gt;1 Continuous IVs</td>
<td></td>
</tr>
<tr>
<td>Teacher introduction</td>
<td>□</td>
<td></td>
</tr>
<tr>
<td>Worksheet</td>
<td>□</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Activity Coding Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting the problem 1</td>
</tr>
<tr>
<td>Considering variables 2</td>
</tr>
<tr>
<td>Handling apparatus 3</td>
</tr>
<tr>
<td>Ratifying data 4</td>
</tr>
<tr>
<td>Reporting a) oral; b) written 5</td>
</tr>
<tr>
<td>Obtaining graphs 6</td>
</tr>
<tr>
<td>Exploring data 7</td>
</tr>
<tr>
<td>Justifying 8</td>
</tr>
<tr>
<td>Applying principles A</td>
</tr>
<tr>
<td>Evaluating evidence E</td>
</tr>
<tr>
<td>- Anomalies identified N</td>
</tr>
<tr>
<td>- Improving design I</td>
</tr>
<tr>
<td>Other/ uncodable U</td>
</tr>
<tr>
<td>Off task X</td>
</tr>
</tbody>
</table>

### Observation Record

Scan segment 1 minute per group. Observations records at 30 second intervals

<table>
<thead>
<tr>
<th>Group</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
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<tbody>
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</tbody>
</table>
APPENDIX 4b

An overview of contextual information recorded during lesson observations.

| Context refers to the wording in which the activity is embedded. |
| Exploratory style The most open approach which reflects whether students are involved in defining a task and developing approaches to solutions. |

**Openness of investigation** is indicated by whether or not the problem & methods are defined for the students; and whether there are alternative possible solutions.

<table>
<thead>
<tr>
<th>Date</th>
<th>Site:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class</td>
<td>Year 7 8 9 10 11</td>
</tr>
<tr>
<td>Context:</td>
<td>Everyday □ Science □</td>
</tr>
<tr>
<td>Problem:</td>
<td>Defined □ Not Defined □</td>
</tr>
<tr>
<td>Methods:</td>
<td>Defined □ Not Defined □</td>
</tr>
<tr>
<td>Solution:</td>
<td>One □ or Many. □</td>
</tr>
<tr>
<td>Exploratory style □</td>
<td></td>
</tr>
<tr>
<td>Variables given □</td>
<td></td>
</tr>
<tr>
<td>Investigation Type</td>
<td>Categoric IV</td>
</tr>
<tr>
<td>Type 1 □</td>
<td>Continuous IV</td>
</tr>
<tr>
<td>Type 2 □</td>
<td></td>
</tr>
<tr>
<td>Type 3 □</td>
<td>&gt;1 Categoric IVs</td>
</tr>
<tr>
<td>Type 4 □</td>
<td>&gt;1 Continuous IVs</td>
</tr>
<tr>
<td>Teacher introduction □</td>
<td></td>
</tr>
<tr>
<td>Worksheet □</td>
<td></td>
</tr>
</tbody>
</table>

The **Investigation type** is determined by the variable structure. They are of increasing complexity.

| Variables given. In closed activities, variables are defined for the students. |
| Teacher introduction sets the scene for the activity |

**Notes:**
1. Openness is based on the degree of autonomy the students have in the investigation, as described in the OPENS project (Simon and Jones 1992)
2. Investigation type is classified according to variable structure and increasing complexity as described in Gott and Duggan (1995).
APPENDIX 4c
Operational Definitions of Coding Categories for an IT-Based Practical Investigation

1. the problem arises from students own ideas & predictions; rather than being set by the teacher.

2. students identify variables and consider their manipulation.

3. all categories oh selecting, assembling and adjusting apparatus & hardware.

4. students interacting with data on a screen.

5. students describing data qualitatively or quantitatively in written or verbal form.

6. students interacting with graphs presented on screen.

7. students working with data, identifying trends & patterns.

8. students matching findings to predictions or claims.

<table>
<thead>
<tr>
<th>Activity Coding Category</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting the problem</td>
<td>1</td>
</tr>
<tr>
<td>Considering variables</td>
<td>2</td>
</tr>
<tr>
<td>Handling apparatus</td>
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<td>Ratifying data</td>
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<td>Off task</td>
<td>X</td>
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A. students using prior knowledge to explain data

E. students considering the strength of evidence for forming conclusions.
APPENDIX 5

Some Ground Rules

<table>
<thead>
<tr>
<th>Rule</th>
<th>How Important is It?</th>
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<tr>
<td></td>
<td>Least</td>
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<tr>
<td>Listen to what other people say</td>
<td>1  2  3  4  5</td>
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<tr>
<td>Don't be nasty to each other</td>
<td>1  2  3  4  5</td>
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<tr>
<td>No talking when someone else is talking</td>
<td>1  2  3  4  5</td>
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<tr>
<td>Be kind to each other and give support</td>
<td>1  2  3  4  5</td>
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<tr>
<td>If people don’t want to say anything they don’t have to</td>
<td>1  2  3  4  5</td>
</tr>
<tr>
<td>Don’t laugh at what other people say</td>
<td>1  2  3  4  5</td>
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<tr>
<td>Think before you ask a question</td>
<td>1  2  3  4  5</td>
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Any more ...?
Some Ground Rules for Working in a Group

Listen to what other people say
Don’t be nasty to each other
No talking when someone else is talking
Say what you think
Give reasons for what you think
Be kind to each other and give support
Don’t laugh at what other people say
Think before you ask a question
Involve every member of the group
Share information and ideas with others in the group
Be fair when making decisions
Try to use your own ideas
Reach decisions without an argument
Agree on what to do in the group
Help each other, co-operate
Don’t mess about with stuff you’re not supposed to
If people don’t want to say anything they don’t have to
APPENDIX 7a

TRCTC01
25/4/97
Y7;2F.

First lesson.

(MEMO: general reminder to the group about the use of the palm tops revised from last week.)

TEACHER: What we're going to do as a starting point, if you read the booklet, is to see what happens if one's got some carbon dioxide in and one hasn't got carbon dioxide in. And our sun ... don't do that please Otis (indecipherable) ... our sun is going to be a lightbulb. Now the lightbulb is going to get very hot so don't what ever you do touch it; but the big problem is thinking about the distance because if one is slightly further away from our sun OK it will obviously not heat up so much. So when you've got the two bottles, they've got to be as close as possible OK. That's up to you to work it through, I'm now not going to tell you what to do, I'm just going to help you and get you going and then I want you obviously to talk about things.

So, two bottles, we need a little bit of water in each, just so that it comes up to where the dents go in, not very much in each. One of them is going to contain carbon dioxide and one of them is going to contain ordinary air. How do make carbon dioxide? Well that's simple (pause) Alkaseltzer tablet. So, when you're ready and you have got everything ready (pause) you get the water in both because obviously we're trying to control the experiment. Get ... the sensors go into the top here, you may need a little bit of blutack just to seal the top, seal the top. You want the sensor just about half way down you don't want it right at the bottom because its the end of the sensor which measures the temperature so you want that in the middle of the bottle.

When you've got it ready and you know everything is perfectly ready, you need to break up one of the tablets in about four bits and with the water, both need to have the water in, simply to one of them add the Alkaseltzer tablet, now that'll fizz away that produces carbon dioxide gas, OK? Let it finish fizzing when its finished fizzing, it will be full of carbon dioxide gas OK? When that happens, put the bung in, don't hang around, the other one
should already be ready anyway, put the bung in make sure it’s bunged up, make sure the lamps are on and start logging, and see what happens.

Look closely at the graphs as they go up, look at the numbers, talk about it ... which is which? (Quizzical). I’ll tell you now, some people get easily confused. What happens after about 10 minutes, what happens if you put the bulb closer or move it further away, you can try it then leave it for another 10 minutes ... see what you think; the bulb mustn’t touch the plastic bottles though ‘cos it will melt them. It can be quite close, about two inches to start off with, but if it’s too close it will melt them, too far away and you won’t get the temperature rise. But the important thing is if they’re not the same distance away it won’t give you very accurate results, so think about that as well.

Does everybody understand you’ve got to have water in both only carbon dioxide in one and air in the other OK? Does anybody need any help before we start?

OTIS: My lamp won’t stay there.

TEACHER: Right well what we’ll do is try and clamp that , I’ll get another clamp then Otis OK and we’ll clam that. But please be careful with water near any electrics, other than that you’ll be OK. You’ll need to arrange the bottles as close together as that. Mr Newton will be looking at you; don’t ask him try not to ask him, come and ask me if you’re absolutely desperate. But what we want you to do is to talk about what you see OK/ Off you go then.

(General noise)

Bungs are up here, Alkaseltzer is up here, blutack is up here.

(MEMO: group were very quiet and attentive during this intro. The previous week they had a brief intro. into the use of the palmtop machine. This was only briefly recapped for this lesson.)

VICKY: What do we do?

EMMA: I think we need water first. Sir, this one’s got a hole in the bottom of it.

TEACHER: OK we’ll get another.

EMMA (indecipherable) makes more sense than keeping warm ... sir, you gave us the wrong page, we thought it was that page.

TEACHER: Sorry!
MEMO: seems that the students were working from the wrong page in the method book: there is an experiment called keeping warm which models huddling behaviour in animals.

EMMA: got to be the same distance away.

VICKY: mmm, gonna be a bit hard to do (indecipherable).

EMMA: where's the sensor. Alkaseltzer, that's got to be broken into...

TEACHER: (MEMO: general comment to another subgroup) its no good putting the Alkaseltzer in till everything is in position and ready.

EMMA: is everythink (SIC) in position?

VICKY: yeah I'll get these to give to (indecipherable)

EMMA: so we need to start that again don't we?

... (teacher brought over to work area by a student)

TCHR: ... a new graph you mean, not a clean graph. So menu, sorry, stop OK yeah? Go to start, continue, there you go, so you're ready now. Do you see what I mean?

VICKY: shall we put the Alkaseltzer in now?

TCHR: yeah but you don't start logging until you've got it full of gas and you've got the bulb on OK? So let's stop logging ... go to start, continue, yes OK?

VICKY: so we press enter when we're ready?

TCHR: start logging, press enter when you're ready, But get the gas in, don't start till all the tablet has dissolved and then ... what about the other rubber bung? but yeah this has got to be in the middle so you'll need some blutack to make sure that that one's in the middle as well

EMMA: that one over there?

TCHR: yeah, that's OK. The question is are they equidistant - equal distance away from there. OK yeah? Just wait till its ... you don't want the pressure to build up in there, you just want the air to come out ... and what's going to replace the air?

EMMA: }

VICKY:} (together) carbon dioxide.
TCHR: there's gonna be carbon dioxide in there, and then put this in, What's the blutack for?

EMMA: }

VICKY:} {together} to keep it (the sensor) in place

TCHR: and also what else?

EMMA:. So no carbon dioxide gets out

TCHR: well done! no carbon dioxide gets out. OK and then you need to switch that on obviously, get logging straight away.

(indecipherable)

(indecipherable)

{MEMO: students setting up the kit, whispering to each other utterances (indecipherable).}

...

EMMA: Its working

VICKY: number 2 is a bit higher (EMMA mm's agreement)

(indecipherable) is the carbon dioxide.

EMMA: so there's only a tiny tiny gap isn't there (MEMO: referring to the graph display on the palm top computer.)

VICKY: mmm, the carbon dioxide. Number one's slowly stopping, stopping around the same place.

EMMA: Number 2 is building up isn't it?

VICKY: well its stopped, its going down a bit.

EMMA: its balancing around the forty point isn't it? (MEMO: the student is perhaps having problems here with reading a decimal scale. The computer display shows the two line graphs and a digital read out of the temperature values being recorded by the sensors.)

... {long gap without utterances, logging}

VICKY: it's gone up now, the air's gone up.

(indecipherable)

EMMA: there may be a possibility of going up to twenty degrees centigrade. Number 2 that one isn't going up much, just hovering
VICKY: (indecipherable) carbon dioxide (MEMO: talking over one another, cannot distinguish the detail of what was said, but some numbers quoted indicating decimal problems "point sixty"

EMMA: one's hovering around four all the time.

(Quiet laughter)

VICKY: (how's it) going?

EMMA: well the temperature doesn't appear to (indecipherable), ... that's about 2 inches away, that's about 4.

VICKY: well that's gotta be equal

EMMA: well no, they're not no

VICKY: that's probably why the (indecipherable) (MEMO: some (indecipherable) explanation offered here)

EMMA: (indecipherable) (agreement from VICKY) they have to be moved up closer.

(Long pause)

VICKY: (indecipherable) what were the results like?

EMMA: dunno I've never done it before (MEMO: unclear what they're talking about here). (indecipherable) such a big gap I think (indecipherable). Number one's definitely higher.

(Long pause)

VICKY: that's touched twenty.

(Long pause, pages of method booklet turning)

VICKY: the air is still going higher.

(Long pause)

TCHR: what are you seeing girls; anything happening?

VICKY: not really

TCHR: why do you think its not happening - very much? Any ideas? Is it getting hotter at all?

VICKY: a bit its just hovering

TCHR: so what's causing it, what's making it rise in temperature, where is the energy coming from?

VICKY: there (pointing to bulb)
TCHR: OK, so if the energy's not going in what are you gonna do to try and get it hotter?

VICKY: move it closer.

EMMA: that's (indecipherable) its gone from forty to sixty (MEMO: decimal problem again here)

VICKY: shall I move this one up?

EMMA: so its closer to that

VICKY: yeah

(sounds of apparatus being moved about, lots of background noise)

VICKY: where's one gone? (referring to trace 1 of graph)

EMMA: I don't know where its gone

(MEMO: a boy joins the group, OTIS I think)

OTIS: Nothing's happening?

EMMA: (to OTIS) what happened to yours?

OTIS: one of the wires weren't working.

TCHR: right Otis, come on. Right what's happening now?

VICKY: they've gone..

EMMA: they've broken away, its gone from 20 to 22

TCHR: still not close enough probably (pause)

TCHR: which is the one with the carbon dioxide? That one there.

EMMA: number 2

TCHR: that's number 2. Did they both start off at the same?

EMMA: no, number 2 was a bit ahead

TCHR: ahead slightly, what do you mean by ahead?

VICKY: it was slightly hotter

TCHR: by how much? Did you..

EMMA: about ten degrees

TCHR: when you say ten degrees do you mean

EMMA: the second number

TCHR: right that's point one degree, yeah, because these are
MEMO: interruption from exploding bottle & students’
exclamation!! Laughter.)

TCHR: OK so these are 22 degrees now, that’s the decimal point
and then its points, tenths then the final column is one hundredth
of a degree. OK? So the difference at the moment is 1.5 degrees,
one and a half degrees approximately. OK. Now the only problem
I’ve got is that they are slightly different heights, but see what
happens. What you’ve got to get used to this week is finding out
how close they’ve got to be as well; all right?

EMMA: Gosh what’s happened here? What’s happening to it?
(indecipherable)

VICKY: (indecipherable)

VICKY: its still going, coming up to about...
(pause)

EMMA: its been going one thousand one hundred seconds

VICKY: how long’s that in minutes?

EMMA: about 15
(indecipherable)
(indecipherable)

VICKY: we’ve got a different lamp to one of theirs (MEMO:
referring to teacher’s interaction with another subgroup)
(indecipherable)

VICKY: ... about 20

EMMA: that’s going up to 23 now

VICKY: yeah.

(Long pause, pages turning.)

TCHR: how are you doing girls, is it going up quicker now?

VICKY: yeah

TCHR: its still not going up lots is it, even though we’re fairly
close (MEMO: referring to position of lamps in relation to
bottles).

EMMA: we moved that one up because it was a bit far down
(indecipherable).
TCHR: right, right we need to organise these a bit (adjusting bottles) because how close it is, is quite important isn’t it? Its not going up very much still is it? Hmm.

Pause.

TCHR: do you know what the numbers stand for on the top of the bulb? The forty?

EMMA: is that how many Watts there is in the bulb?

TCHR: well, not in the bulb but is being produced by the bulb, what do you think, what’s the term, what does Watts measure?

Answer (indecipherable)

TCHR: Its the power of the bulb all right? How much power is produced by the bulb, how much energy per second its producing. So if this is a 40 watt bulb it means its giving out 40 Joules of energy per second. Now if we had a 100 Watt bulb which would be a lot brighter, that would be giving out 100 joules of energy per second, right?. So if we replace the 40 watt bulb by a 100 watt bulb, what would happen to the temperature?

VICKY: it would be higher.

TCHR: go up higher, right. Why?

EMMA: because its got more energy.

TCHR: because its produced more energy and that will hopefully heat up. Its like having a sunny day or not a sunny day. On a sunny day more of the sun’s energy can get in and if you’re in a greenhouse it can get very hot, doesn’t it? On a dull day like today, you don’t get so much of the sun’s energy through so its not so hot. OK does that make sense? So perhaps next week we’ll make sure you have got a 100W bulb instead of a 40W bulb because I think that’s having an effect.

Now one’s going up more than the other isn’t it.

EMMA: the carbon dioxide one.

TCHR. The carbon dioxide one is going up more than the other. Now what’s the difference roughly

EMMA: about 3 Celsius

TCHR: about 3 Celsius, good. Did they both start off at the same? How much was between them at the start?
EMMA: it was about a degree

TCHR: about a degree what about 1 Celsius, so the difference is hopefully getting bigger, if you leave it a bit longer..

(pause)

(indecipherable)

(indecipherable)

EMMA: 27 degrees centigrade

VICKY: carrying on longer

(indecipherable)

(indecipherable)

(MEMO: student reading from the worksheet)

TCHR: now I want you to stop in a minute. The people on the computers, what I want you to do is to stop logging now. Go to the menu button, move along to graph and go to zoom. And then go to auto zoom at the bottom.

EMMA: what did it go up to?

(Pause, giggles)

EMMA: it stayed around the same place didn’t it.

VICKY Hmm?

EMMA: it didn’t go up much.

TCHR: I want you to stop now

(MEMO: end of recording)
APPENDIX 7b

Trctc02

2/05/97

y7; 2+1F

Second lesson.

(MEMO: collecting of equipment and setting up ready for teachers introduction)

EMMA: That's about as even as we could get it last time wasn't it?

VICKY: we've got a 100W (bulb) this time

It's not flashing (MEMO: referring to palm top and LogIT)

EMMA: I think we've got a dead logger.

NICOLA: Is it working?

EMMA: Try getting another logger

VICKY: (to T) It's not working

T: switch the power on, you need to put the power lead into it

VICKY: oh yeah!

T: are you going to explain to - its Nicola isn't it? - what you did last week just quickly? OK? Great.

VICKY: so what we did was see if, what was it? Carbon dioxide is a greenhouse gas we see if its a danger to whatever.

EMMA: see if the sun does any response see if one gets hotter, so we have to put sensors in there & see which one gets hotter.

(Indecipherable)

(MEMO: general noise of setting up, much indecipherable talk)

EMMA: what we did was put some water in there, same amount yeah?

Then put an alkaseltzer tablet in. We waited till it dissolved, put the bung in put the sensor in, hold it up with a bit of blutack and then the alkaseltzer fizz gives out carbon dioxide you see; that's how we got it.

?: I'll go and get some blutack
EMMA: don’t put that one in yet because that’s going to be the alkaseltzer bottle.

NICOLA: shall we start breaking it (alkaseltzer) up

VICKY: we’re not allowed to put it in yet ...

NICOLA: why not?

VICKY: ? doesn’t last long.

EMMA: into quarters (MEMO: general talk about breaking up the tablet. Teacher returns to the lesson.)

TEACHER: right, anybody got problems with the computers? You haven’t. Right, now this week a hundred Watt bulbs in each of the lamps. You’ve all got the same 100W bulbs, that will give you quite a lot of energy. What did we find out about the bulbs last week, what’s important about the bulbs?

STUDENT : they’ve got to be equally away from the bottles

TEACHER : right they’ve got to be an equal distance away from both bottles. That’s quite crucial because you want the same amount of energy going in to each bottle and if one’s closer that the other, you won’t. What about how close has it got to be did we come up with any ideas about that last week? What do people think? What did we find out if we didn’t have it close enough?

OTIS: it stayed the same

TEACHER : what stayed the same?

OTIS: the graph, the temperature

TEACHER: the temperature stayed the same it didn’t go up did it. So you need it quite close to actually get a reasonable temperature rise. But you mustn’t let the bulb touch it. Why not?

STUDENT: it will melt the bottle

TEACHER: it will melt the plastic, so you mustn’t let it ouch it but you can get it quite close. So don’t have it too far away because the whole point is to see something happen OK and what we want you to do is when you see something happen is to talk about it. Because obviously, Mr Newton is wants to listen, don’t be frightened, he isn’t spying on you in that respect, but he wants to hear what you think is happening is it going up too quickly is
it going up slowly, OK. What words would you use to describe the graph, think about words, not special words but talk about "oh its going up" or something, quickly slowly things like that.

Now we're going to let you go ahead in a minute we've got a basic set up, let me draw it. We've got two bottles, these pens are rubbish, try it in red, Labour colours, new government colours, that's better. And we're gonna have carbon dioxide in one and we've got air in the other, OK. And the idea is to see if one goes up quicker than the other OK.

Can anybody think what different combinations we could possibly have to try and do a few more experiments because that's one experiment we want to do several experiments. What else could we have here (indicates drawing of bottle) to get different graphs, what other combinations could we have, we've got three sensors, what else could we possibly have .. to check our results? Any ideas (pause)

What could we do instead of having carbon dioxide and air, what else could we do?

OTIS: have two carbon dioxides

TEACHER: right excellent, we could have an air and two carbon dioxides, what would that tell us? Well think about it, I'm not going to tell you. What happens if you have two carbon dioxides and think when you're watching it, before hand, try and say what you think you're gonna see try and think about what you're gonna predict will happen. Try and change what you think in your brain to words so that Mr Newton can either hear it himself or something else and discuss it amongst yourselves. You might disagree with one another, that's fine, but think about it and say. So we'll start off quickly with carbon dioxide and air again, that's another possibility, any other possibilities? He's got his brain in tune, any other possibilities?

STUDENT: two airs

TEACHER: two airs! Of course you could right. In other words do two airs go up the same? So there's another combination. Can you think of anything else we could try?

STEPHEN: carbon dioxide and air in one bottle and just carbon dioxide in the other
TEACHER: in other words, not so much carbon dioxide you mean?

STEPHEN: yeah

TEACHER: right. Now yes that's good now can you work out how to get less carbon dioxide perhaps?

STUDENT: less tablet

TEACHER: put less tabulation yes that's excellent. We're using at the moment a whole tablet the ideas there is to produce a lot of carbon dioxide but if we use less tablet, say a quarter of a tablet there should be less carbon dioxide. So you might want to try, once you've done these (indicates to board drawings) less carbon dioxide. C02 stands for carbon dioxide, one carbon and two oxygens. So you could try instead of a whole tablet of alkaseltzer, you could use half a tablet or a quarter of a tablet. You decide what we want you to do is think about that and try and predict before it starts what you think is going to happen. Will the graphs change in any way?

There is one more interesting one which I've just thought of. Can any one think of another possibility of what we could put in the bottles?

STEPHEN: could you put a quarter of a carbon dioxide in one bottle and a whole carbon dioxide in the other?

TEACHER: yeah. That’s what we’re saying, you can have any combinations you like, yeah. You can do whatever you like, I'm quite happy with that. Yeah. The one thing you mustn't do as a safety hazard is you must not put the bung in before the carbon dioxide tablet has fully dissolved. Because if there is the pressure will build up and we'll get a big pop so please don’t put the bung in until the carbon dioxide tablet has dissolved. As soon as it has dissolved, though, put the bung in and start recording OK. Now so we've got air, what else, 'cos I want you to think of lots and lots of different things you could put in there. What else could you put in there?

Pause

Just as a matter of interest to try

Long pause.
No? OK I’ll give you a hint. There are a couple of things which could be quite interesting. What happens if you put water in one and air in the other? That’s one possibility, or we have got one more gas in here. What’s the other gas we’ve got around?

Pause

what other gas have we got in the laboratory?

Pause

what other gas have we got in the laboratory?

STUDENT: butane

TEACHER: no, not butane

STUDENT: propane

TEACHER: no, not propane. Good names come on there’s one more. You’ve all used gas in the laboratory, what have you used it for?

Pause

What else can you use it for. You’ve all done it. What’s one of the first lessons you do in year 7, with gas? What sort of gas? Where does it come from?

STUDENT: natural gas

TEACHER: natural gas, where does it come from, where does it come from in the laboratory, where door we get it?

Pause

what are those things stuck on the table and what comes out of them?

Students: gas taps

TEACHER: and what comes out of them

STUDENTS: gas

TEACHER: gas, natural gas. I think Friday morning’s not the best...

so we could, if you wanted to try and we’ve got time, but only at the end. If you’ve got time and you’ve tried different combinations like that, come and see me with your bottle, and what I’ll do is I’ll fill it one of them with natural gas. Got to be a
bit careful because its flammable, but it won't burn without matches and we haven't got matches around. So I'll get a Bunsen, put the Bunsen in, turn it on for a little while, fill up your bottle, you take it back quickly put the bung in and you've got now methane or natural gas in there instead of carbon dioxide. We can also investigate not only carbon dioxide and air combinations, but we can try methane. OK. The main thing is whatever you do we've got to talk about what you think will happen and then when its happening think about what is happening, is what you predict the same?

Now any questions before we let you go?

OTIS: I think these batteries (in computer) are going.

TEACHER: OK Otis we'll sort that out, anybody else? Right, be careful because the bulbs get very hot. Off you go.

EMMA: these are only little bits, (referring to alkaseltzer??) this dissolves.

NICOLA: I put all of it in?

EMMA: Yep

NICOLA: look at that fizz (laughter)

EMMA: its like a sodastream

VICKY: check the light's working

NICOLA: yep, straight away you switch it on and I'm blinded

(indecipherable)

(MEMO: teacher leaves)

(MEMO: students shade the lamp)
VICKY: tell me when to start recording

NICOLA: probably now

VICKY: no response from logger? We’ll have to start it again

NICOLA: (the bulb) needs to be closer

VICKY: its all right actually

{MEMO: students shade lamp with card folder}

VICKY: it’s getting hot, lamp is bright

EMMA: its been a minute

NICOLA: already?

Pause

NICOLA: what’s it ‘sposed to do?

Which one’s number 2

EMMA: that one’s the hottest there the carbon dioxide

(indecipherable)

whispers (giggles)

EMMA: acids and alkalis once

(MEMO: side talk, whispers (indecipherable))

VICKY: we should get the light a little covering: feel the heat of that

EMMA: need like a little shield

EMMA: where’s my folder?

Pause

T (MEMO: interrupts, giving out worksheet to the group) here are some questions which might help you think about what’s going to happen.(reading from sheet) ‘what is going to happen to the
bottles when you switch the light on?' now you've got some ideas about that from what happened last week, OK. Do you want one each?

(MEMO: background noise of students shuffling papers, preparing to use the worksheet)

EMMA: no we've got another one about the results (MEMO: shuffling & sorting of papers)

(MEMO: RT. returns to laboratory)

TEACHER: (to whole group) Don't forget you don't need to keep it going for too long; ten minutes you can stop and zoom in on the data. Stop it and zoom on the data if you need..

girls: side talk (indecipherable)

VICKY: what shall we do first; 'about the results?'

pause

VICKY: 'I think this is because...'

silence as students use sheet

(MEMO: VICKY: seeks help & guidance about how to manage the worksheets from T.

T: offers advice on comparing predictions with actual data.

VICKY: where do you put CO₂?

EMMA: You cheat

VICKY: is easier than writing carbon dioxide (giggles)

EMMA: long word

VICKY: I can't spell it! (Giggles)

VICKY: I think we may have to start again
don't get so stressed

NICOLA: calm down

(indecipherable)

VICKY: I predict CO₂, carbon dioxide.

NICOLA:

EMMA: together yeah, yeah
off task talk? (MEMO: may indicate that the group is more relaxed or more natural on this second occasion)

EMMA: the air is still higher isn’t it

EMMA: by 100 seconds that one’s took over

there both the same now its took over (MEMO: (indecipherable) unclear what this exchange is about)

VICKY: its the carbon dioxide that makes the difference

TEACHER (joins group) are we doing all right girls, have we zoomed in yet at all.

EMMA: no

TEACHER do you want me to show you

EMMA: yes please

TEACHER are you still recording at the moment/

? Yeah

TEACHER when you’ve stopped recording, I’ll show you

NICOLA: (whispers) how do you stop recording?

(indecipherable)

VICKY: do you want me to tell you how to zoom in?

Press menu

EMMA: shall we go to ‘our group idea’ now (referring to worksheet)

EMMA: (reading) what will happen to the bottles when we switch on the light?

what’ll happen is they’ll heat up

NICOLA: we’ll put the bottles will heat up

VICKY: (reading) ‘I think this because’ ... the bulb gives off heat

EMMA: the bulb generates heat

VICKY: what have you put?
NICOLA: same as you

VICKY: put the bulb gives off heat

EMMA: I've put 'the bulb generates heat'

EMMA: I'll just put what I want to put ... a scientific word

VICKY: OK

VICKY: (reading from worksheet) If carbon dioxide is a greenhouse gas, can we predict what will happen in the bottle?

EMMA: I predict the carbon dioxide is going to be hotter

VICKY: I predict that the CO₂ bottle will be hotter

NICOLA: I put its heating carbon dioxide

VICKY: I done it before anyway what did you put

NICOLA: air 'cos you had to ..' (indecipherable) What's that one? What's that one called?

VICKY: air

VICKY: reading 'how will we know that it is carbon dioxide that makes the difference?'

EMMA:

VICKY: together: by predicting the temperatures (MEMO: seems to be a circular argument here which would be followed up in a teacher interaction with the group)

VICKY: to see if there was a difference you could see by the difference in temperature.

NICOLA: I've got the same, by the difference in temperature

EMMA: ain't that weird we've all got the same on everything.

VICKY: so let's go to results (referring to the worksheet)

EMMA: Gosh, look at the size of them boxes (referring to space on the worksheet)

VICKY: Hmm!

NICOLA: (reading) 'what was the starting temperature of the gases in the experiment and control bottles?'

VICKY: number one's going down
NICOLA: (reading) our group’s answer...

EMMA: are you cold?

(indecipherable) ?off task

EMMA: 'you know what? Its the first day f a Labour government and have we noticed it? Noooo!

NICOLA: ?? I've still got my 1996 calendar up

EMMA: are we stopping it now

VICKY: OK, press enter

EMMA: go to (indecipherable)(indecipherable)

EMMA: zoom

(indecipherable) giggles

VICKY: about 19 isn’t it

EMMA: excuse me?

NICOLA: is she completely crazy?

VICKY: about 19

EMMA: It says here ‘what was the starting temperature of the gases in the experimental and control bottles?’

NICOLA: off task comment

VICKY: air temperature was 19 and carbon dioxide was about 24

(indecipherable) talk about temperature scales?

VICKY: (reading) use the zoom control to find the temperatures after 10 minutes

NICOLA: (off task talk)

VICKY: I can’t do it, you do it (referring to use of the zoom control I think.

NICOLA: (singing off task)

?talk about spellings of temperature

EMMA: what was it, 28.5?

VICKY: yeah
EMMA: I put temperate

NICOLA: (noises)

VICKY: the air temperature wasn’t
...

(indecipherable)

TEACHER (to group) just one thing I forgot to add at the
beginning; when you’ve got, heated something up; when you’ve
heated something up, what could we do without turning the computer
off? What else could we turn off?

OTIS: the light

TEACHER we could turn the light off and see as it cools down. So
what we could do on one of them is get it hot, see what happens as
it goes up and once its hot don’t turn the computer off, turn off
the lamp and for a few more minutes, watch what happens. Does one
cool down more quickly than the other?

VICKY: just cross it out

TEACHER you’re OK girls?

VICKY: yeah

TEACHER good

EMMA: you’ve got your own tippex

(MEMO: mixture of on task and off task talk towards the later
part of the task)
...

VICKY: you’ll never guess what, i’ve done both of them wrong.

(MEMO: uses tippex to correct errors on worksheet)

EMMA: you touch the pencil case and I’ll kill you!
...

(MEMO: examples of off task talk as the students watch & wait)

whispers (indecipherable)
...
EMMA: God it's freezing in here..

... 

(MEMO: more off task talk)

EMMA: turn the light off we're not using it

(giggles)

EMMA: my pen's bust

(long off task period)

EMMA: shall we do it with two alkaseltzers?

VICKY: we haven't finished these (referring to the worksheet questions)

EMMA: reading 'what was the highest temperature recorded in each bottle? Use the graph to help you'

?this

EMMA: do you get that, I don't

NICOLA: umm carbon dioxide was 33, was 33.2; air was

EMMA: what was the highest temperature?

.. was the temperature change steady? (reading)

(MEMO: off task initiated by Nicola)

VICKY: we'll have one bottle with one (alkaseltzer) and one with two.

(MEMO: Nicola and Emma continue off task talk about buses)

VICKY: there you go.. there's 2 tablets in each (pack)

Sounds of equipment being manipulated.

VICKY: I'll put two in you put one in

EMMA: you break up one and I'll break up one then we'll all have a tablet each.

VICKY: how about two and a half in one and one and a half in the other?

EMMA: No
VICKY: here's my little bits
EMMA: which one's 2
(MEMO: sounds of apparatus being set up)
EMMA: its going to fizz isn't it
VICKY: how do you get a new graph
EMMA: I've put two in that one
VICKY: no you haven't, you've only put the one
EMMA: where shall we put the other one?
NICOLA: have you shaken them
VICKY: you don't need to do you
EMMA: you do
VICKY: (to T) d'you have to save it then
T: you could save the data
VICKY: are you ready
NICOLA: come on no one's helping me
TEACHER you've got about five minutes left
giggles
EMMA: that's when you dropped it in (MEMO: I don't know to what this remark refers)
NICOLA: right then there's them done...
TEACHER right can you think about finishing in a couple of minutes.

Much off task talk

VICKY: Emma its quite a good enrichment this is
EMMA: yeah its my favourite enrichment
TEACHER OK can we start clearing away then, I'll take the computers. Put things back in the green trays.
STOP
APPENDIX 7c

TRCTC03

9/05/97

Y8; 3M

(MEMO: recording starts with teacher organising non-datalogging
groups and sending them off to use internet or CD-ROM)

RICKY: (referring to software display options) Where's logger?
RICKY: is that it? Start logging
RICKY: is logit on?
PAUL: (indecipherable)
GEORGE: when will we be able (indecipherable) sir?
PAUL: might as well now
RICKY: there's still now response from LogIT
GEORGE: turn it on now, yes its on.
RICKY: still now response from LogIT
PAUL: play with the other one (pause) quick
RICKY: no response, I'd get a different on if I was you
GEORGE: let's ask Sir
LN: all right?
GEORGE: yes sir
LN: no response from logit, is it switched on?
STUDENTS: yeah
LN: checked the connections... press the green button, OK now try
again.

(No response)

hmm we need to check the connections now, make sure everything is
plugged in firmly. This probably means we've got a funny lead,
lets try and unscramble our spaghetti (referring to tangle of
cables). Its possible the logit is not functioning.
LN: No response?
RICKY: no response
LN: try a different logit
(indecipherable)
RICKY: switch it on,
LN: what else could be the problem?
PAUL: the plug?
LN: OK try unplugging the logit from the computer to make sure you’ve got a good connection.
RICKY: its the menu button, you want
(pause)
PAUL: it might be this wire here that’s rotten
RICKY: mayday? Take this wire out
GEORGE: plug it in..
PAUL: I’ll get another one of these
PAUL: lets try plugging it in again,
LN: are you OK?
RICKY: yeah
LN: so what was the problem do you think?
(pause)(pause)(pause)
student: ah yes!
LN: OK, now if you touch these two sensors together at the ends you can see how close the....
GEORGE: Sir, there’s one temperature, two temperatures..
RICKY: (handling the computer) cancel, start logging
PAUL: that’s as hot as it will get, its carrying on
RICKY: carrying on? How do you stop it?
RICKY: I know lets save that, what shall we save it as?
RICKY: just call this graph

GEORGE: I want to stick this (temperature probe) in the mouth

RICKY: yeah? We’ll measure it from there: Uh oH

GEORGE: OK what do we now

RICKY: start logging, shove it in your mouth

GEORGE: no

RICKY: put it into there...

RICKY: its gone slightly higher? Or just darker (refers to line on display ?thickness)

LN: OK, why don’t you, whilst you’re waiting, see what other options you’ve got? Look at the menus, things you can do to the graph

PAUL: now look, shall we do a bar chart?

LN: (referring to bar chart) is that kind of graph any use to you do you think? For what you’re likely to do today?

PAUL: no, ‘cos it doesn’t show you what the what temperature it is,

RICKY: no (agreeing?)

LN: what sort of graph would you call that? What kind of graph is it?

PAUL: Bar

LN: a bar graph, OK

RICKY: temperature’s falling, shall we put some water on it to get it hot??

.. set it up George, set it up now,... while you get data logging

GEORGE: need some water then

PAUL: Oh my life!!

Laughter

PAUL: look at that

RICKY: Sir!
Laughter

LN: and how did you manage that!

PAUL: he held it ....

LN: what did you do

RICKY: he just grabbed it in his hand

LN: you held the ends did you, in your hands? What’s happened to the display?

(pause)

(MEMO: teacher returns....)

RICKY: oh! Its going back up and down

LN: anyway you can start a new graph..

TEACHER: OK lets just explain what your target & task is to do. Now what we’re trying to do is a simple experiment to look - just move the bulb away from the bottles for a minute a simple experiment to find out if there is such a thing as the greenhouse effect. Now hopefully from your research you should have found out the gas in the air which is giving cause to this effect, anybody like to tell me the gas?

RICKY: carbon dioxide

TEACHER: Carbon dioxide, good. So what we’re gonna do is have two bottles, one with CO₂ in it and one with ordinary air in it OK? And what we’re gonna try and do is find out if the one with carbon dioxide in it, warms up more than the one with air in it. Now our Sun is gonna be the lamp. The lightbulb is gonna give us the Sun’s energy, that’s gonna be our model of the sun. Now you need to get it quite close to the bottles OK, if its more than a few centimetres away, more than a few centi..., it won’t get hot enough quick enough. So please think about the distance, that’s crucial; how quick it heats up will depend on how far the bulb is away. And obviously the bulb’s got to be the same distance away from both otherwise one will get more energy than the other, so setting up your experiment is quite crucial. Now how do we get carbon dioxide in one of them and not the other?

RICKY: you breathe into one of them.
TEACHER: NO! That's a good idea though, you could try that Ricky at some time perhaps, but that's not what we're gonna do today. But at some stage you could try that, I'm quite happy that you try that and see if there's an effect. But today we're gonna use fizzy tablets or alkaseltzers. Now when alkaseltzers fizz, they produce carbon dioxide. So we're gonna have two bottles, you're gonna put a little bit of water in each, up to the first sort of mark, so just enough water for it to fizz. Now one of them we're not gonna do anything to except out the water in, we're not gonna put a tablet in. That's gonna be our air, what do they call that when you have something beside something else when you do an experiment, can you remember? Its a c. C. Con.

RICKY: control

TEACHER: control, good. Its called a control because you need to find out if its the carbon dioxide which is causing the temperature to go up down or whatever. So one is going to have water in and air and you're not gonna do anything else to that one. And you'll have a bung in the top and a temperature sensor will go through the bung but you'll need to have a little bit of blutak around the outside because the end of the temperature sensor, both of them, needs to be in the middle of the bottle, not down the bottom because that would be in the water, we don't want it in the water; we want to be measuring the air or gas temperature. So you've got to put some blutack round there to make sure its in the middle. Now the second one, that's the air one, we do exactly the same, but you take a tablet and don't do this until you're ready, take a tablet of Alkaseltzer and break it into two and you just pop it in, in the water. Let it fizz completely, don't go shove the bung in straight away 'cos if you go and put the bung in straight away it will pop because the gas pressure will build up and it'll go pop and we had that happen with one of the other groups. Let it stop fizzing and as soon as it stops fizzing, put the bung in, put the temperature sensor so its in the same place, about half way down and make sure there's some blutak around the top. Now obviously you don't want the carbon dioxide coming out, the idea of the blutack as well is to stop the carbon dioxide coming out. And as soon as you've got the two in place, and ready close together with the light on start the computer logging. And you need to press the menu button find where it says start press the enter button - right well you're logging already
at the moment - don’t start logging until you’ve got the two gases in and watch what happens.

Now Mr Newton is gonna be observing you, what you’re doing and he’s interested in what you see happening on the graph and he wants you to think about and say out aloud - don’t shout or anything like that - but discuss between yourselves what’s happening: is it going up quickly, slowly whatever OK? So that’s quite crucial.

Now, after about 10 minutes, 10 or 15 minutes, one thing we’re quite interested in is switch the light off, don’t switch the computer off, switch the light off after about 15 minutes, if the temperature is not going up very quickly, you can always make the temperate go up a little bit quicker by putting the bulb closer, try that. So today’s playing around day really, getting used to the equipment. The second time, session in here we’ll want you to do some experiments a bit more carefully and that. So if things go wrong today, it doesn’t matter; it really doesn’t matter. And you can try different things out but we want to make sure that you can use the computers and you know what you’re doing with the computers and how to set this up. But as I said, after 15 minutes, don’t turn the computer off turn the light off and see what happens, turn the light off.

Now that’s all I’m gonna say at this stage, that’s all I want you to do to make sure you can try and get it. Now after another ten minutes or so, I’ll show you how to zoom the results because the change in temperature is not gonna be very big, is not gonna be very big but what we can do with the computer is magnify the results, all right? What we call zoom the results so that we can see the difference between the graphs. And I’ll show you how to use the facility on there to zoom the results once we’ve stopped.

So it’s setting it up; air in one with a little bit of water. Carbon dioxide in the other remembering not to put the bung in until its stopped fizzing but then do it quickly, get the computer logging the data, collecting it. After about 10 or 15 minutes you can try the effect of moving the bulb backwards or towards it a bit closer see what the effect is. Then switching off the lightbulb, see what happens. Then after another ten minutes, switching that off and I’ll show you how to zoom the results. There’s a button on the menu and you go to zoom.
But try and talk about what’s happening as you go along, if you want help I’ll come along and help but don’t bother Mr Newton too much unless I’m absolutely sort of ... because he wants to obviously keep an eye on you rather than get involved in the experiments. Any questions?

The only thing I ask you to be very careful with is this; these have got water in the computer and the light bulb have got electricity; don’t get the water and that near the computer. Keep the computers and those (bulbs) away from the bottles. Because the last thing I want is a bottle of water being knocked over one of these palmtops. You’ve got about £600 worth of equipment OK, so please, please move the computers and the LogIT out of the way while you’re doing the setting because I don’t want the comput...

The idea is to clamp, clamp the bottles round the neck. Use the clamps that you’ve got and clamp the bottles round the neck so they’re quite in place OK. Don’t just have them sitting there ‘cos if they’re sitting there, they’re quite light they’ll knock over very easily. Everyone OK, Off you go then.

Teacher: (to boys) there’s a tablet I’ve just opened so use that one first time OK.

RICKY: (indecipherable)
(pause)
(pause)

PAUL: which one’s that

RICKY: its the air

GEORGE: do we; how do we put the tablet in there?

PAUL: how (indecipherable) did we know which one’s the air

GEORGE: this could be air

RICKY: have you got any blutack

GEORGE: did you get any blutack

PAUL: you’ve got to put the bung in yet: there’s the bung
(pause)

there’s the blutack
RICKY: get ready, get set

PAUL: (indecipherable)

GEORGE: lets get this ready quick

GEORGE: its starting to stop fizzing

PAUL: I've got this undone.

(Pause)

PAUL: tell what's up (indecipherable)

GEORGE: get it a bit moved back

RICKY: stick it in I'm about to press start now ..

GEORGE: whoops a daisy

(Pause)

RICKY: start logging

GEORGE: wait a minute, we haven't, turned on the bulb yet, Wait a minute we need something first

Start data logging

RICKY: wait a minute

PAUL: its going up now, up

GEORGE: number one's going

PAUL: 2's going up

GEORGE: which one's 2 and which one's 1?

RICKY: One's the air, two's the carbon. Look that's number one m, the air number two's the carbon.

LN: what do you think is going to happen?

RICKY: the carbon dioxide is going go up and the air is going to go down.

PAUL: because the greenhouse

LN: the carbon dioxide is going to rise the air is going to fall, That's Ricky's prediction what's yours

PAUL: I just think the same really
LN: do you
PAUL: yeah
LN: why
PAUL: carbon dioxide will just stay the same all the way through but the air will just drop because it's just like pure
LN: OK, what do you think George?
GEORGE: I think the carbon dioxide will heat faster than (indecipherable)
LN: will?
GEORGE: heat faster
LN: heat faster, so are they both going to get hot or cold or...
PAUL: I dunno
RICKY: the carbon dioxide is gonna get hotter (LN: hotter) before the air will get hotter
LN: so the air is going to get hotter?
RICKY: the air will get hotter eventually but the carbon dioxide will get hotter first.
LN: I see, well you'll have to see if that's what happens.
RICKY: looks like 12 not 1 and 2 (MEMO: refers to number labels of line graph on display)
RICKY: carbon dioxide's (indecipherable)
GEORGE: is it (indecipherable)
PAUL: they're both measured
GEORGE: what's the temperature?
RICKY: they're both no no no
PAUL: which one's Y (MEMO: this refers to the digital display of temperatures and time scale (y axis); student apparently not clear about the relationship between the graph and these numerical displays)
RICKY: One two, I reckon, yeah, because look at the temperatures; one, one, Y is 22.77 and 2 is 22.7, so number 2 is rising and number one is just staying

PAUL: number one's rising,

RICKY: they're both rising

PAUL: none of them has overtaken yet

RICKY: it looks like its gonna overtake

PAUL: it looks like its going to, it might

RICKY: it has! They're not the same, oh my life! Two's taken over, two's 23.4

PAUL: its taken over quite a bit, only just taken over though

(Pause)

PAUL: carbon dioxide's hotter

GEORGE: one problem we have the leads are (indecipherable) they both different

RICKY: think about it George, that aint fair because you got the lamp pointing towards the carbon dioxide

GEORGE: no

RICKY: you got it pointing towards the air

GEORGE: mm true

RICKY: look at that!

PAUL: its rising

RICKY: number 2 is extremely risen its nearly 24, one is 22

PAUL: this is rising, it is rising though, number one's still rising, two's gone up to 24, number one's still at 22

(indecipherable)?? Change things

RICKY: move that lamp in a bit more

PAUL: no, switch one off and only do oxygen as well

GEORGE: its exactly in the middle (the lamp)

PAUL: compare now
RICKY: that's good, now we should have more rise in temperature or drop in temperature

PAUL: no, rise George said

GEORGE: that plastic melting I'm taking it (the lamp) back because it seems to be melting at the moment

RICKY: yeah but look at theirs over there, George look at theirs over there, so put ours right up

GEORGE: the plastic's going to melt

RICKY: right up close George, as close as it will go

GEORGE: temperature should have shot up

PAUL: it has!
RICKY: it has!

PAUL: 27 its 27

RICKY: George, right up to the metal thingy

GEORGE: not touching the bottle

RICKY: now we should have a dramatic rise in temperature; oh look, George, the temperature's rising

GEORGE: (indecipherable) a bit too much I guess

PAUL: the temperature's just gone flying

RICKY: the temperature's flying

GEORGE: what is it now

RICKY: its 30, 32
PAUL: 32

RICKY: 33

PAUL: number 2's rising ah look at that, the temperature's shooting up

RICKY: 34, 32
RICKY: 35, 32
RICKY: 36
GEORGE: take it back a bit because the plastic is starting to melt on the bottles

RICKY: no its not

GEORGE: its not hot, not hot

RICKY: well then move it in then

TEACHER: what ever you do don't let it touch it because it will melt, you're getting a bit close their

(MEMO: looking at graph)

that ones going up a lot quicker?

RICKY: yeah that ones 39

TEACHER what made it go quicker?

RICKY: when the er Sun's closer

TEACHER: right, which is one and which is 2 then; which is which

PAUL: one is air two is the carbon dioxide,

TEACHER: right, so at the moment carbon dioxide seems to be going up a lot quicker

PAUL: yeah

TEACHER: and do you know what this is down the bottom? (MEMO: refers to Y axis)

RICKY: how long it takes

TEACHER: right, and what does the little s stand for?

RICKY: seconds

TEACHER: seconds good, OK. So you've seen what happens when it gets to the end, the computer re-scales it automatically, that's very useful. Now you can see clearly here (MEMO: referring to digital display) that there is a difference of about how many degrees, roughly

PAUL: two

TEACHER: about two degrees different but the graph doesn't appear to show that very much at the moment does it? Now that's why we need the zoom facility at the end; we can't zoom it till we stop
it. Now what I want you to do is after awhile stop heating and then talk about what happens as it cools OK by switching the light off.

(Pause)

RICKY: the carbon dioxide is heating up a lot quicker than the air; as the sun is quite close

GEORGE: its very close

RICKY: the carbon dioxide is heating up a lot quicker than the air, because carbon dioxide is a dangerous gas and dangerous gases heat up a lot quicker than air.

(MEMO: this exchange was made 'deliberately by the students to the microphone, perhaps as a result of the teacher encouraging the students to talk about their work for the benefit of my research.)

RICKY: note for the record: that when we turn off the light, the temperatures in both A the carbon dioxide and (laughter) B the air will dramatically drop. Note finished.

(indecipherable) (MEMO: off-task exchange)

PAUL: they’re more or less staying the same now

RICKY: yeah but you can see the dramatic rise

PAUL: the air’s just staying the same

(indecipherable)

GEORGE: I think they’re stabilised

RICKY: stabilised, we don’t want it to be stabilised we want it to be (indecipherable)

GEORGE: its higher really??

RICKY: (MEMO: to microphone) Note that in the carbon dioxide there is been slight evaporation with the water. Note finished.

Number two is going slightly higher

PAUL: you could fine number one catching up I think (indecipherable)

RICKY: they’re both nearly the same its only like a , just about a degree higher, point four five of a degree.
LN: you know that you’ve had to adjust your lamp? Will that affect the way your graph looks, do you think?

RICKY: yeah

LN: how might it change the way the graph looks

RICKY: er, when it moves closer the graph goes higher but when it moves away it start to stabilise.

LN: so might that confuse you when you look at the graph to compare the two bottles?

RICKY: yeah, it might actually!

LN: it doesn’t matter because you are exploring this week and finding out

LN: can you see any point on the graph where you think that might be where you’ve moved the bulb?

RICKY: there

LN: what’s happened there

PAUL: its gone up
RICKY: its rising; I mean its like I’ve noticed some evaporation in the bottle

LN: OK great

(Pause)

RICKY: But I’ve just thought of something here: the air still has carbon dioxide in it don’t it?

PAUL: yeah that’s what I said before

GEORGE: but that’s normal gas, so if you add more carbon dioxide .. (indecipherable)

RICKY: I think it will stand to go up a bit, George

GEORGE: no

RICKY: I’ll do it

(MEMO: moves bulb closer to bottles)

(indecipherable)

GEORGE: oh how can we have a fair test?
RICKY: temperatures start to rise again

PAUL: oh look, going faster (indecipherable) It doesn't seem to be rising that much on the air.

(indecipherable)

(indecipherable)

RICKY: any change on the graph

PAUL: no not really

GEORGE: not yet

PAUL: yeah, its going up

RICKY: how much?

GEORGE: eight minutes, (Pause) seven

RICKY: I mean is the graph going up

PAUL: eight hundred (MEMO: unclear about this could be referring to the time scale)

RICKY: its nearly going up to 70

PAUL: the rise only goes up to 60, that's going up to 100

(MEMO: this subject of this exchange is unclear, again could be referring the scales)

(Pause)

RICKY: any change?

PAUL: what's 60 times 10?

RICKY: six hundred

GEORGE: what's 12 times 12, 144.

RICKY: this is not a maths lesson!

(Pause)

PAUL: switch it off

RICKY: its increased by 2 degrees, but its still not going any higher.

(Pause)
(Pause) laughter

{MEMO: students adjusting the bulb position}

RICKY: the temperature's rising

PAUL: quite a bit actually

RICKY: tell me when it goes up to 100 or 75

PAUL: well it's on 50

PAUL: 47

PAUL: well they're roughly the same, but

RICKY: it's not rising but it's staying the same

PAUL: I think that that is more carbon dioxide, now it's slightly higher

RICKY: of my life

TEACHER (MEMO: returning to class) now anybody want some help? Anybody not zoomed the results yet

TEACHER: have you zoomed?

RICKY: no

TEACHER: go to zoom, the best one to use is autozoom, that means the computer will automatically zoom this scale, it won't zoom this scale but this scale here. If you do that; there you go. That's scale 1 but you can see 2's gone missing hasn't it, so if you use the 1 and 2 button it will bring them back in. So 1 will bring one on take it off, on off; but two's not zoomed so we need to go back and zoom that as well. We've only zoomed one. Now we can put one on as well, now we've got zoom on one and two and you can see the temperature scale is going just below 25 to 45 from the maximum to the minimum value. So we've just taken the bit we're interested in, OK. But you can see we can take one off put the other one back on, OK and then you can look at them closely to see what happens. What's happening here, why was this happening?

GEORGE: we moved the bulb a bit closer

TEACHER so the bulb, moving it closer, has quite a big effect doesn't it?
RICKY: um the Earth orbits the sun, getting closer to the sun, at different points, so moving the bulb forward and closer gives us a bit of an idea of the hole in the ozone layer and the greenhouse effect.

TEACHER: right, now as George said, you tell them George about the difference between the ozone layer and the greenhouse effect because they're two very different things aren't they? You found that out last week.

GEORGE: yes sir.

TEACHER: do you want to try and explain to Ricky and... sorry what was your name?

PAUL: Paul

TEACHER: Paul, what's the difference is, Go on have a go

GEORGE: Ozone layer is due to the heating of the earth, you know, caused by too much carbon dioxide so it heats up the ozone layer and damages the ozone layer. And greenhouse effect is the effect which causes the ozone layer. So its too much carbon dioxide. And sunlight comes in and cannot escape so its heated up and causing the ozone layer to be destroyed.

RICKY: try zooming again try different zooms

GEORGE: do have a drop there

RICKY: they're dropping.

PAUL: It was at 47 now its dropped to 46

PAUL: it keeps dropping

RICKY: dropping

PAUL: god its gone back up it was dropping to 46

RICKY: I'm causing the greenhouse effect...

(MEMO: tape ends, some missed talk before new tape inserted)

PAUL: (indecipherable) then they're both the same (MEMO: students adjusting position of lamp in relation to bottles.

(Pause)

PAUL: God, you've got the light on that now
RICKY: I was trying to cause the greenhouse effect; it don't seem to be working.

GEORGE: what's the prediction?

PAUL: I think it'll be that and that will be higher.

GEORGE: one didn't drop then, but two did.

RICKY: two dropped dramatically.

PAUL: that was the that drop that I saw the last 40 seconds down to 56.

GEORGE: do you have a very big drop?

(Pause)

GEORGE: That's cheating.

RICKY: that's going off the scale that is.

(MEMO: here the students are fiddling with position of lamps and bottles, changing the display of the graph)

LN: (MEMO: interrupts to try & get them back on task) is that zoomed.

RICKY: yeah.

LN: can you un-zoom it?

RICKY: oh the bottle's changed shape; the bottles seems to have gone like this.

(Pause)

GEORGE: in a minute the (indecipherable) drop.

PAUL: they're dropping because the lamp's so near.

RICKY: yeah I know.

PAUL: carbon dioxide seems to be dropping.

GEORGE: its dropping faster, did pick up though.

PAUL: look at the 1.

GEORGE: 1 dropped off scale.

PAUL: 1 dropped twice.
GEORGE: 2 took some time to pick up

? is there any one increasing

GEORGE: oh that’s interesting

RICKY: its extremely interesting; one seems to be rising, the other seems to be dropping

PAUL: 2’s just dropped; 2’s just gone like that

RICKY: (MEMO: ?draws in the air with finger)

RICKY: look if I turn the bulb off now, come round here, you can see the shape of the bottle

PAUL: look at that huge drop there

(Pause)

PAUL: you should turn the bulb off now

RICKY: no leave it on, its not been 15 minutes yet

PAUL: it has, just over

RICKY: doesn’t matter we’ll go up to twenty

PAUL: we’ll go a bit extra anyway

(Pause)

PAUL: they’ve both dropped you know

RICKY: yeah but I think you’ll find that its gonna rise in a minute

GEORGE: wait a minute

(Pause)

RICKY: I don’t think the heat in the bottles...

PAUL: 1’s overtaking

RICKY: eh eh I’ve just though, the heat, the heat is bound to change the shape of something but its not gonna change the shape of the earth is it? When the thingy gets too hot its not gonna change the shape of the earth is it?

(Pause)

GEORGE: logging
GEORGE: what happened to LogIT

RICKY: I’ll get logit back on

(Pause)

RICKY: I think we’ve developed a problem

GEORGE: we’re having a problem, number 2 is missing

its dropped quickly, crash!!

PAUL: go to zoom and put it on again. Menu, zoom, ... where’s one? Oh dear, Rick number 2 ’s just gone like this and number 1’s gone like this (MEMO: drawing with finger in air)

RICKY: number 1’s that one and that’s only just started to evaporate, Number 2..

PAUL: number one’s, according to this, number ones gone up a bit

RICKY: but number 1’s only starting to evaporate, this ones been evaporating for God knows how long

GEORGE: stop it completely and we won’t stick it back on. Lets observe the drop

TEACHER do you want to try breathing in to it anybody? Ricky?

(Pause)

giggles

GEORGE: two increased faster though

PAUL: two increased faster but it dropped (Pause) quite heavily

GEORGE: I’ll save the changes (Pause) interesting temperature (indecipherable)

(MEMO: sounds of Ricky panting breathing into bottle)

GEORGE: OK should I save the changes?

PAUL: oh no George, ’cos we haven’t finished yet, Ricky’s having another go

GEORGE: LogIT just completed the second time.. oh recording stopped we’ll have to restart it

PAUL: shall I empty this one?
RICKY: yeah, its just to test my little theory. (Pause) George, get ready to start logging

PAUL: yeah you’ve got one

GEORGE: so let’s go (MEMO: switches on lamp)

RICKY: logging

GEORGE: should only be one, lets start again from beginning

RICKY: lets see if this one increase it

LN: can I ask you about your new experiment? What are you trying to find out

RICKY: carbon dioxide is let out, I think its carbon dioxide, out of the back of cars

PAUL: carbon monoxide

RICKY: and what this experiment ... is just to see... when we breather out carbon dioxides let out, so I just try breathing into the bottle to let carbon dioxide in and just see if that has any different effect to the one that we just did with Alkaseltzer.

LN: right, so how will you know if its had any different effect?

RICKY: right if you save the old graph with the Alkaseltzer and we save this graph and if there’s any different rise in temperature plotting on the graph then we know that there’s a different effect.

LN: OK, does the computer let you look at two different graphs at once?

RICKY: yeah

LN: I'm not sure whether it does, you might need to print them out. How will you know whether the carbon dioxide in that bottle that you’ve breathed into is having the... which one of the other graphs will you compare it with?

RICKY: unzoomed we can bring up the graph we just, when we did the carbon dioxide with the Alkaseltzer and just bring that up on zoom and that will be the air, so we can see if that has... check the difference
LN: why didn’t use a bottle with air in as well, was there a reason?

RICKY: no just try and see if the carbon dioxide had an effect

LN: has anything interesting happened George?

GEORGE: Um in the bottle shut off, number 2 seemed to go down quicker than number 1.

LN: and are you logging this experiment?

GEORGE: need a control

LN: you’ve tried lots of different things this morning, adjusting the bottles; have you learned anything about how you are going to set up the next experiment when you do this again, in order to investigate your ideas?

PAUL: haven’t (indecipherable)

RICKY: Um we know the sun and the earth, the sun is closer to the earth at different points, so say we did this experiment for 20 minute, we could move it close, back close back each for 5 minutes

LN: but that would be investigating the distance wouldn’t it

RICKY: that would be investigating the distance

LN: would that tell you anything about the greenhouse effect?

(Pause)

GEORGE: dropped.. its dropped

RICKY: oh my life

PAUL: (indecipherable)

GEORGE: one hundred and twenty five, enough to boil water

RICKY: I think the bottle’s changing shape again

(Pause) (indecipherable)

GEORGE: there’s an error

(Pause)

GEORGE: increasing by jumping

STOP transcription. {{MEMO: students playing with equipment}}
APPENDIX 7d

*Friday 6 June 1997

*3 Y8 boys: second recording. %Year 8 boys, %Ricky, %George, %Paul

*TEACHER: Those people who were in here before projects remain in here, because this is the second session [of data logging]. That first session was like the other group did, was to get used to using the equipment; how to set it up and things like that. Now I know you may have forgotten a little bit today so we've got to try and get it set up as quickly as we can just to remind you; so those groups that were in here, remain in here OK? We've got one, two three sets so there should be three groups. Now there were then three groups out of the room; there were two in the information centre working on the CD-ROM and one of the groups was working on the internet. Now, as I said before, we'd swap round there so one of the groups, who was in the CD-ROM; who was those two groups? [Students indicate by raising hands] OK then, so we'll have this group here will do the internet today and the other group will do the internet next week. So that group will work in my office on the internet; I'll get you set up in a minute to show you what to do. You'll need your file and bits of paper to obviously write on. The other two groups then will go to the information centre to use the CD-ROM machines, and they know you're coming and there's two machines there that you can select any of the CDROMS. The group that were in there last time, you may want to look at another CD-ROM. So look at one or two of the other CDROMS and that. OK? [Some students arrive late]. You all right Gemma, Vicky, bit late aren't you? So the other people can look at the other CDROMS. There's plenty in there I mean we've actually got a very good stock of CDROMS; I didn't appreciate how very good they were in there, so use the time to look through other CDROMS see if you can find anything about the greenhouse gases there. If you've done enough on the greenhouse gases, the people on the CDROMS, look up .. see if you can find something on the ozone layer and see if you can work out what is the difference between greenhouse effect and the ozone problem. OK so O Z O N E find out a little bit about ozone and see if you can think ... it is very different to the greenhouse effect. A lot of people get confused with the atmosphere and they think greenhouse is due to the
atmosphere and ozone's to do with the atmosphere and they think it is all the same but it's not, it's very, very different OK? So if you get a little bit bored without the greenhouse effect and think you have got enough information from the CDROM, look up the ozone effect; see if you can find something about ozone, what ozone does. OK? Is anybody not sure what they're gonna be doing this week then? People who are gonna be in here are the people who were in here last time, this group's gonna be in my office and the other people are gonna work in the information centre. OK. I'll get some paper if you wanna take some you'll need some paper to write things down on and things like that. Make sure your name's on it and dates on it and things like that. Don't forget that I've got to give you a grade at the end of the course and part of that will be on how your folder is kept so that I understand what's going on and you understand what's going on. Has anybody got any questions? Right, people in here we need to get set up, it's going to take a few minutes so be patient we'll try and get ourselves set up. Right let me get the paper for the people going out then the people going to the IC [information centre] can go. [Pause while teacher organises groups working outside the laboratory.] Right, the people in here, there's three computers here, you have got the bottles, I'll get the three LOGITS out and you need to get things connected up; and there's the Alkaseltzer tablets there. [General noise of things being set up]

*RICKY: Pass us LOGIT

*TEACHER: [to whole class] now your job is to make sure it works. Don't start putting the Alkaseltzer tablets in at the moment, all I want you to do is get the computers working so that you know how to log the data; you can make sure the lamp works, the bottles are in place and that things are set up correctly but don't add the Alkaseltzer tablets at the moment because I want to explain one or two things before we start. OK you need a LOGIT ... who's in this group then? Come on girls you need to come and work here. Whose are these bags? Boys .. can you move them right out of the way over there somewhere.

*PAUL: Is that on? [Don't know to what this statement refers, LOGIT or radio-microphone].

*RICKY: No its not on yet I haven't turned it on.
**GEORGE:** Logging? Stopped? What's stopped? [Setting up computer software].

**TEACHER:** so, I'll be back in five or ten minutes, by that time I want basically everything set up. Don't forget that the temperature sensors need to be about half way down the bottle and round the top you need some blutack, there's a little bit of blutack here, not very much: you don't need very much to be honest, you only need a little bit round the top or some plasticene to help you. OK, I'll be back in five or ten minutes; I'm sure MR Newton will help you if you get absolutely stuck, but don't put the Alkaseltzer tablets in yet.

**RICKY:** I've got the blutack.

**GEORGE:** good.

**RICKY:** you can use that one, I'll stand [refers to number of stools available]....

**RICKY:** we'll just start logging for now [indecipherable] [Ricky fiddles with the radio microphone: lots of loud scratching sounds]....

**GEORGE:** [indecipherable]

**RICKY:** I'll come in the Wednesday [off task talk?]  

**RICKY:** don't we need one of these? ... Naughty boys! ... Put that in er wherever it goes, the computer I think one goes in. I'm not sure.

**GEORGE:** whoops. ... about the same [refers to volume of water placed in each of two bottles]

**RICKY:** smell burning I can from that logger. .... and then I'll plug that in to...

**GEORGE:** its running on battery power

**RICKY:** the LOGIT. [Indecipherable]

**GEORGE:** tell me the answer [reference is unclear] [indecipherable]

**GEORGE:** put it on high, put it on high, ... now that's good [Ricky is handling the computer software zoom facility]

**RICKY:** that's brought you into the graph

**GEORGE:** and zoom that one as well
*RICKY: .. and let's go to menu, zoom, zoom one; I'll zoom both of them look. I'll take..

*GEORGE: I'm gonna try a few things out first

*RICKY: don't forget you've got to put the Alkaseltzer in yet.....now we're doing this, we've got to say what we're thinking, OK about the experiment...

*RICKY: I think that the bottle of carbon dioxide is going to go faster than the air. ... I know it didn't last time..

*GEORGE: the word is 'probably is'... [noise of fiddling with the radio-microphone and sounds of equipment being manipulated]

*PAUL: you fill that with water

*NEWTON: so, you're all set up now are you?

*RICKY: yeah, just waiting for Mr Taylor for the Alkaseltzer.

*PAUL: that's the one for the Alkaseltzer [sound of water filling into bottle]

*RICKY: fill it up carefully..

*PAUL: thanks for that [?][indecipherable whispered exchanges]

*RICKY: great sensors...

*PAUL: see if you can take it off [some material to be removed from the temperature probes]. ... [long pause]

*RICKY: now, what if you want the graph if we need it, leave it, leave it; just leave it. [whispered exchange, possibly some fiddling with the computer]

*PAUL: that's all set up, that's the right height [reference to sensors]

*RICKY: oh, that's interesting .. look at the dates.[indecipherable, off task?][indecipherable whispers]

*RICKY: this would be a good idea wouldn't it: leave the labels off and try and guess which one's which. [Refers to sensor labels on the screen]. To try and guess which one's which will be quite obvious because the carbon dioxide will rise quicker than the air

*PAUL: um, yeah then they'll get closer I suppose
*RICKY:* yeah, exactly so we can just try and guess which one's which instead of you know, er having one and two on

*PAUL:* seems right

*RICKY:* it makes it erm, makes it a lot easier. ... I'm sure that means level. [Reference unclear]

*GEORGE:* which is which?

*TEACHER:* right now, is it working? Is it working? Yeah? They're all working?

*RICKY:* yeah

*TEACHER:* right now, do you want to say anything Mr Newton?

*NEWTON:* No, thanks very much

*TEACHER:* now what we want you to do this week then is, obviously a similar experiment, but we want to look at different things that you could investigate, right. Now don't forget one of the things Mr Newton's looking for is your ideas on what's happening, OK. So try and discuss those ideas as you're going along, right. Make sure that you understand what's going on, use your own words things like that, but please try and discuss what is going on and think about what else could be happening as well. Now the first experiment, I think it's worth trying the first experiment again. ... and that was, one tablet, simply the effect of the gas. At the moment, in one of them we're gonna have carbon dioxide and in one of them we're gonna have air. And everybody remember how to make the carbon dioxide? You put the tablet in, don't forget, you don't put the bung in there until it's stopped fizzing. Anybody know what will happen if you do put the bung in? What Ricky?

*RICKY:* Pressure builds up and it goes bang

*TEACHER:* and it goes pop, all right? So please don't put the bung in until, until it's stopped fizzing, then put the bung in so the carbon dioxide is filled up there. Right, the bulb has got to be what? Somebody like to give me an idea?

*JOANNA:* indecipherable

*TEACHER:* that's right, it's the model of the sun so it's got to be quite close to it. But don't just look at it warming up, OK; after a while what you can do is switch the light off and see what
happens when it cools down for five minutes. So you don’t need too long warming up, but let it cool down as well before you stop logging. I’ll probably need to come round and help you zoom in on the results because you won’t see big changes; and that’s one of the advantages of data-logging is you won’t see big changes, but when the computer has stopped logging we can make sure it will zoom those results in other words magnify the effect that we can see. What other things do you think we could investigate though, once you’ve done that? What other things, anybody like... what else could we change? Any other ideas? For the experiment, anything at all... what else could we change... there’s lots of things we could change. [Long pause] oh dear me I think it’s Friday morning, first lesson back. all right let’s think, we’ve got two bottles. The first experiment we’re gonna put air in one and CO2 in the other; what else could we change then, that was the first experiment. What could you do in a second experiment? To check your results? ... come on, you’ve got two bottles what else could you put in them? Come on, there must be something, what else could you do here, what combinations could you do? Ricky?

*RICKY: two, err, with carbon dioxide in

*TEACHER: you could; what we’re hoping for is that the carbon dioxide one will rise more than the air one; that’s what we’re hoping for: that’s the greenhouse effect. I’m not quite sure if it will, but that is what we’re hoping for. But we could check our results by having two carbon dioxides. What was the other combination we could try then?

*RICKY: [whispers] two air

*TEACHER: we could try also, two air. So if we found that the carbon dioxide one went up higher, is that just by fluke in other words are we, y’know just getting a little bit; maybe the lamp here is in the wrong place or something like that. But what happens if we try two air? Theoretically, the two airs should be exactly the same and the two carbon dioxides should be exactly the same. So once you’ve done that first experiment, try the second experiment, try a different combination OK. You could try less carbon dioxide. How could you produce less carbon dioxide?

*RICKY: just use half a tablet
TEACHER: perhaps try half a tablet instead of a whole tablet so you could try less carbon dioxide, OK. There's one more thing we could try, there is another gas in the laboratory here that we could perhaps put in the bottle instead of carbon dioxide. Does anybody know what that gas is? .. you use it all the time in science; ... 

JOANNA: Oxygen

TEACHER: we don't use it all the time, but that's in air, oxygen's in air.. good, good guess. What else is sitting around you in the laboratory, gas?

RICKY: natural gas.

TEACHER: natural gas which comes out of the gas taps. Anybody know the chemical name for natural gas? It's called methane, methane OK. So if you to get to that stage, and you want to try, instead of carbon dioxide, I can easily fill up one of those bottles for you using methane. And all I've got to do is put Bunsen burner upside down, not light it obviously, turn it upside down, connect it up, turn the gas, on fill it up, and let you go away and we can try methane instead of carbon dioxide gas and that's another possibility, methane. So, that gives you a variety of things that you can try out so one you've down one you've got lots of other things to try out to see if the effect is there or not. But don't forget, once you have collected the results you need to stop logging and zoom. Now if you forget how to zoom I'll come and help you because that's important. But talk about your results as it happens: you don't need more than five or ten minutes. If the temperature doesn't seem to be going up that quickly, just move the bulb a little bit closer because obviously that has quite a big effect. Right, anybody got any questions before we start, OK. Now I shall be popping in and out to look at the internet people and I just need to pop over to the IC at some stage but I'll let you get on but don't forget to talk about what you see, which is the important thing. OK off you go then.

PAUL: I think I'll [indecipherable]

RICKY: have you got an Alkaseltzer?
*TEACHER:* You need it [the sensor] half way down the bottle because you need it in the gas not in the water, OK that's what the plasticene's for. Ricky..

*GEORGE:* Use a half tablet [indecipherable]

*PAUL:* One is the carbon dioxide which is that one,

*GEORGE:* Two, is this two?

*PAUL:* Yeah...

*RICKY:* I'll get ready to go [sound of Alkaseltzer fizzing]

*RICKY:* You know I think that the carbon dioxide will go up quicker than the air because...

*GEORGE:* It will go faster... its faster, it was before

*RICKY:* Last time it was faster so this time it will be faster... let's find out... that's stopped dissolving, that has.

*GEORGE:* Hang on not going in

*RICKY:* I'm gonna start logging in a minute

*GEORGE:* No

*PAUL:* I've got the lamp ready

*RICKY:* You can put that in now

*GEORGE:* We can try it at the normal temperature for a few minutes then we can start the lamp. Try it without.

*RICKY:* We'll try it without the lamp for a couple of minutes and see if it has any effect. If don't have any effect we'll turn the lamp on and see if that has any effect, and then we'll let it cool down for a while....

*GEORGE:* Number two's winning, or is it?

*RICKY:* No they are at the same height, it's just that they're not gonna put it on the line are they? [Refers to the position of the line labels]

*GEORGE:* Look number two

*RICKY:* Oh yeah

*PAUL:* Its only slight..

*RICKY:* As soon as that gets over to there I'll start the lamp
*GEORGE: I'll tell you when, now; fifty seconds started

*RICKY: we started the lamp at fifty seconds. That will have some
dramatic effect.

*PAUL: it hasn't as yet

*RICKY: the temperature for one now reads twenty one forty four
[21.44] the temperature for number two reads twenty two sixty one
[22.61]

*PAUL: 22.61, that's going up quite fast; that's the air

*GEORGE: hmm

*RICKY: strange

*GEORGE: try zoom on it.

*PAUL: that's gone flying up

*RICKY: one's temperature is 22.39 and two's temperature is 23.35

*GEORGE: nice and quick

*RICKY: every fifty seconds we'll say the temperature

*GEORGE: OK

*RICKY: two's going up quick, but it's still just less than a degree
higher. Go on its rising faster than that one is. That's going 70,
73 [decimals] that's going 54, 58, 61, 62. That one's going up in
like threes, that ones

*PAUL: it's just gone [indecipherable]

*RICKY: they're both on 24 nearly, there on 24 each

*PAUL: I think you'll find that one the carbon dioxide will be
catching up

*RICKY: temperature one is 24.27 temperature for two is 25.18

*PAUL: two's gone up a bit more now

*GEORGE: we've been five minutes

*RICKY: I don't think there would be I mean there's not really an
increase now is it?

*PAUL: do you want me to move it closer?

*RICKY: yeah, just a bit don't move too close but closer, cos if
you have it that far, I don't thin it will work.
GEORGE: if you look through there you can see..

RICKY: the temperature is rising but it's not rising that much, I think there will be an increase but not that much, what do you think?

PAUL: I agree with you

RICKY: I mean look, now when we've got the lamp really close, there is hardly any temperature change now; apart from a degree

PAUL: I can't look, how much its gone up

RICKY: two degrees

PAUL: oh just on the two, yeah

RICKY: two degrees!!

PAUL: oh its catching [indecipherable]

RICKY: it might be an increase; it definitely will be an increase, but of how much?

PAUL: is the question; .. its quite far ahead now

RICKY: just over two degrees, nearly three degrees

RICKY: guys,

GEORGE: you found a problem

RICKY: no, we've got a nearly three degrees increase.

GEORGE: the lamp was unfair; we could shut it off, for two minutes

RICKY: no its; we've got an increase now, big increase

GEORGE: but for the wrong one

PAUL: I think that one's doing better anyway

RICKY: yeah, it's doing better number two is higher but number one shows higher [incomprehensible]

PAUL: indecipherable

RICKY: I've never been in that you know; Natalie's been in that about a hundred times [off-task talk] pause

RICKY: its still only, four degrees. It's not rising as much as it did last time is it?

PAUL: its catching up. Ricky, its catching up, the first one
RICKY: it is actually, there's a four degree increase

PAUL: one's catching up

RICKY: I mean, by now we thought it would be up to about 75 degrees

PAUL: aha, it's on 34, the air.

RICKY: last week it did reach that but...

PAUL: it's been a bit strange...

RICKY: maybe it show a bit differently on zoom

GEORGE: let's use the bar chart

RICKY: we're changing graph now, to bars. Four degree increase

GEORGE: number two's

RICKY: nearly five

GEORGE: we either shut down [indecipherable] or try and erase it

GEORGE: it stopped. (Long pause)

RICKY: why did it stop?

RICKY: let's move the lamp again

PAUL: no, that'll, no Ricky ... that's fair, that's fair there

RICKY: OK, let's look [indecipherable]

PAUL: that lamp's bright...

RICKY: I'm turning it off now..

GEORGE: no, don't..

RICKY: I want to watch it cool

GEORGE: shall we watch it cool now?

PAUL: no

GEORGE: Ricky, let number one increase

RICKY: then it would be unfair, so..

GEORGE: &

PAUL: no, but

RICKY: would air really increase more than carbon dioxide? I wouldn't say so.
*PAUL: obviously in this test it must
*RICKY: well, we'll cool it down for a bit and see if that has an effect
*GEORGE: we started at three minutes.
*RICKY: it's Shoving off...
*GEORGE: it won't be a problem with this,
*RICKY: there's no problem; it keeps turning off automatically; no wonder, that's off
*GEORGE: the battery might be all right,
*NEWTON: you got a problem?
*RICKY: yeah, LogIT keeps turning itself off
*NEWTON: it keeps switching off?
*GEORGE: because the battery was weak
*RICKY: the battery was weak so we got to turn the plug on
*NEWTON: so are you powering the LogIT from the mains?
*RICKY: now we are
*NEWTON: now you are, so it should be all right now
*RICKY: yeah, I mean we've noticed that there isn't a big increase than there was last time we did it
*NEWTON: oh really?
*RICKY: I mean the lamp we put in the same place and .. no increase
*NEWTON: have you kept it going for as long?
*RICKY: yeah and then we'll turn the lamp off just to let it cool down and then we'll start it off again
*NEWTON: so where are you now? You've heated up ..
*RICKY: .. then we cooled down
*NEWTON: you've probably got time today, if you're not happy with that set of data, and you had a problem with your LogIT, you've probably got time to do it again. You can do lots of experiments if you want to. But you're in charge, you decide what you want to do.
*GEORGE:* when shall we start? (Indecipherable exchange)  
*GEORGE:* I'll redo the (indecipherable) one  
*RICKY:* I'll wait till the temperature's about the same and then I'll start it up again  
*PAUL:* number one's changing... very near the same as it was  
*GEORGE:* the water; it was unfair at first so the changes are that, temperature readings come after the.. they'll want to be warmed.  
*RICKY:* right; switch it on it's going down but the air is going down quicker long pause  
*PAUL:* carbon dioxide's zoomed this time pause  
*TEACHER:* right, how are your group getting on?  
*RICKY:* fine;  
*TEACHER:* OK  
*RICKY:* we were just letting it cool for a while, and then we'll start it back up again  
*TEACHER:* when you zoom, you'll probably have to zoom each one individually. OK and these one and two buttons will take off or add back the data  
*RICKY:* press one, one will go off  
*TEACHER:* and press one again it will put it back on again  
*RICKY:* yeah  
*TEACHER:* but you have to do each one individually, OK?  
*RICKY:* yeah, we showed that to the Malaysian visitors  
*PAUL:* showed that to the what?  
*RICKY:* Malaysian visitors  
*PAUL:* when was this?  
*RICKY:* last week in projects, that's why I had to see Mr Taylor  
*GEORGE:* I'm gonna put two (Alkaseltzer) in and it is quicker  
*RICKY:* no, just put one in put one in  
*PAUL:* you put two in  
*RICKY:* and I'll put one in, break it into four quarters
*GEORGE*: let's put two

*PAUL*: no, one; just put half and half

*RICKY*: one, because if we put two in then it won't have like, much difference, would it like

*GEORGE*: you know the carbon dioxide thing will be higher so we should (indecipherable) (whispers) pause

*RICKY*: OK? Stopped fizzing pause

*RICKY*: that's not very fair though is it? You've filled one more with water than the other, so it's not fair

*GEORGE*: oh

*PAUL*: it's only slightly more

*GEORGE*: yeah

*RICKY*: it wouldn't be fair because the air's get less to burn up than the carbon dioxide. Carbon dioxide's got more to burn up. So it's not very fair is it?

*RICKY*: look, whatever number one is; where's number one?

*GEORGE*: both are the same temperature

*PAUL*: number one's the air

*RICKY*: number one's rising faster

*TEACHER*: when you want to try the methane gas let me know and I'll try and fill it up for you

*RICKY*: shall we do the methane gas after this one?

*PAUL*: yeah

*GEORGE*: five minutes

*PAUL*: what shall we do? Methane and carbon dioxide?

*RICKY*: yeah that's an idea innit, methane and carbon dioxide, then we'll do methane and oxygen I mean air; then we'll do methane and methane

*PAUL*: air and air, that's if we've got time

*RICKY*: and then carbon dioxide v carbon dioxide

*PAUL*: if we've got time
*RICKY: oh, I've just had another idea. Now, put that one on there for just a bit longer while I put this tablet in that one, because than one had more time to heat up hasn't it; so now .. take that off there. Now lets delete

*GEORGE: no response from LOGIT .. its stopped(whispers)

*RICKY: put it in, now turn logit on; line it up

*RICKY: menu, battery.. needs replacing

*GEORGE: let's take a new logit

*RICKY: battery needs replacing

*PAUL: yeah but we're running off the mains

*RICKY: yeah but it like keeps rubbing off because...

*PAUL: yeah but its running off the mains

*GEORGE: don't save it

*RICKY: yeah, save it as C O 2 (tape change)Long pause

*RICKY: take that, try it on the logit

*PAUL: this one should be OK

*RICKY: hold on, I'm checking the battery first: I'll have to plug it in before we can check the err.

*GEORGE: did you replace the battery?

*RICKY: its on the logit that you should press..

*NEWTON: is there a problem?

*RICKY: yep

*NEWTON: what's wrong?

*RICKY: the batteries for the logit need replacing

*NEWTON: is it telling you..

*RICKY: yeah it says battery needs replacing

*NEWTON: on the palm top..

*RICKY: plug it in and then turn it onto desktop

*NEWTON: is that referring to the logit?
*RICKY:* I dunno but this is..., we've just changed this desktop because that one says it needs replacing then we've got this one and this one says it needs replacing so it could be

*NEWTON:* OK and is that mains lead really plugged in? And that is obviously switched on

*RICKY:* that's on. And that just keeps shutting off

*NEWTON:* the logit is shutting down, have you swapped it for a different logit?

*RICKY:* try a different logit. I'll get our old one. This is the pocket book we've just had and this is the pocket book we replaced it with and I..

*GEORGE:* it's a nine Volt battery

*NEWTON:* is there a battery in it?

*RICKY:* check the battery

*NEWTON:* (to teacher) I think we've got a problem with this logit

*TEACHER:* is it not working?

*RICKY:* it's working but it just keeps shutting down. It says, we tried it on the palm top and it says battery needs replacing on both of them

*TEACHER:* what there it says battery needs replacing

*RICKY:* that says battery needs replacing, but we've tried two different LOGITS

*TEACHER:* well its probably this. Well it says good there. Oh the battery on the logit you mean?

*RICKY:* yeah

*TEACHER:* have you had it working on the mains?

*RICKY:* yeah and it just keeps shutting off on the mains as well

*TEACHER:* just take it back over there, right let's get you another logit, just a sec.

*RICKY:* no response from logit; yeah its logic's battery

*RICKY:* OK then: menu, file CO2 that's ours
TEACHER: I'm just wondering whether it's the power pack as well, I'll just see if I can get a battery for you...

TEACHER: right you don't probably need the power supply on that; try that it's got a new battery in.

RICKY: OK

GEORGE: right, let's see the logit; battery?

RICKY: turning it on now

GEORGE: try again

RICKY:

GEORGE: good!!

RICKY: go to open, no you have to go to open I saved our old one... CO2

RICKY: and let's go to menu, logging, start...

PAUL: you've got to tighten that up

RICKY: no we haven't. I'm gonna get some methane....

RICKY: we should have another 'alka' .. oh yeah I used it didn't I?

RICKY: I need a bung quickly ... gimme this

GEORGE: we'll put two tablets this time. ... try it with two anyway...

TEACHER: again, you need to get that in quick, OK here you go...

RICKY: methane; put the methane on but be careful, don't let the gas escape.

GEORGE: I'll start logging, when that stops

RICKY: is the logit on?

GEORGE: yep

NEWTON: have you got any guesses about what is going to happen? Predictions?

RICKY: methane should heat up quicker,

GEORGE: yeah
*RICKY: because it's a natural gas. OH no, no carbon dioxide will heat up quicker

*NEWTON carbon dioxide's natural too isn't it?

*RICKY: yeah but ash, I dunno!

*NEWTON: OK, a real experiment then!

*RICKY: I think err, no I think the carbon dioxide will heat up quicker because natural gas doesn’t cause pollution. But carbon dioxide does. Natural gas is just for cooking and everything....

*GEORGE: switch the bulb on

*RICKY: bulb is on. ... no response from logit. LookStart, collaborating (sic) sensors enter, start logging....

*GEORGE: number two is methane

*RICKY: number two is actually heated up quicker (mixed off task talk)

*GEORGE: increasing like mad. Are you zooming?

*RICKY: bring two on, take two off, no put two on take one off. No but methane's heating up quicker, I don't know why

*GEORGE: very interesting

*TEACHER: the bulb is quite a long way away; it's up to you. You've got to be quite careful because you have got a little bit of paper there, that might stop a little bit of the radiation going in; yeah? .. is it going up?

*RICKY: that's our graph and we're going up as it..

*TEACHER: oh right, are we zooming already? So we've zoomed it and it's still going. Oh right I didn't realise we could zoom it and collect. How did you do that?

*RICKY: we went to zoom, first of all we went to auto zoom for number one, George zoomed in number two..

*TEACHER: as it was doing it?

*RICKY: as it was doing it and then when, and when we go up, we just press up, we can see

*TEACHER: oh right! Well, I never new that. So number two is going up quicker
*RICKY: yeah, which is the methane

*TEACHER: which is the methane. Excellent, well I've learnt something new today. So you started it as normal then you zoomed in George, as it was happening

*RICKY: I zoomed in number one first, then George zoomed in number two

*TEACHER: just on autozoom?

*GEORGE: yep

*TEACHER: and then you can move up. I never new that, I always thought autozoom had to be used afterwards, you know. So you can't see one at the moment can you. But two's really going up. Are you sure they are equidistant from the bulb and that?

*RICKY: yeah its dead in the centre. Can't believe it now.. we're the geniuses, man.

*GEORGE: we struck lucky

*RICKY: let's go up as well; number one will come in any minute. Number two, something's really....

*RICKY: ah number one's just come in (to view) move over a bit. I'm not going to go up until number ones.. ah methane's, methane's levelling out going up levelling out going up

*GEORGE: because we made a few changes to it indecipherable

*GEORGE: its increasing, little by little but stabilising too.

*PAUL: if you keep one of the (indecipherable)...

*RICKY: number one will come in at about 275, and ...

*PAUL: mum its higher than number one

*RICKY: number one is levelling out. Yeah number one and two are levelling out but they're still rising.

*PAUL: level out then rise again, level out then rise (NOTE this effect could be due to automatic rescaling of the time axis)

*RICKY: no, number one's rising right and levelling out. Press it up because number two's rising again, and across

*GEORGE: hmmm a bit of a difference

*RICKY: well they're both starting to level out now
*GEORGE: hmm
*RICKY: yeah, looks like they’re both starting to level out
*GEORGE: number one’s steamed up more
*PAUL: six degrees...
*RICKY: cannot see number one any more
*PAUL: number two seems to be evening out whilst number one’s...
*GEORGE: we’ll shut off in a few seconds
*RICKY: yeah we’ll shut off
*GEORGE: shut off at four minutes, I’ll tell you when
*RICKY: fur hundred seconds
*GEORGE: he
*TEACHER: we’ve only got about five minutes left. Five minutes left
OK. So get to the stage where you can stop or whatever
*RICKY: that’s gone into the eighties
*GEORGE: OK get ready to shut off
*TEACHER: ... I wouldn’t suggest you start another on
*GEORGE: nnnnow! (Switch flicks off)
*GEORGE: its falling, number two’s falling
*PAUL: number one’s still going up
*RICKY: no
*PAUL: two’s falling harder
*PAUL: look at number two falling,
*GEORGE: its falling harder than number one. ‘Nnneowww’ Plane
crashing. I think its because its a gas
*RICKY: there won’t be that much gas left in there now, I don’t
thing there will be that much gas left.
*GEORGE: nothing to heat it
*RICKY: lets go down again (manipulating software)
*PAUL: look at number two, falling down
*GEORGE: dramatic
PAUL: number one, the carbon dioxide is...

RICKY: they look like they’re gonna hit don’t they, they’re gonna collide

GEORGE: probably, not

RICKY: not they won’t collide, they will cross over at some point

GEORGE: we did this with the Malaysian visitors did we? We zoomed both at the same time?

RICKY: yeah but it didn’t move did it? It looked like something moved today....

RICKY: it’s going down but it’s not going across

GEORGE: ohh close!

RICKY: it’s collided, it’s collided in mid air

PAUL: I reckon number two will fall harder

RICKY: wicked!

GEORGE: this looks like a very cool graph!

RICKY: we’ll call this one methane

GEORGE: it’s very good

RICKY: I’ve lost it

GEORGE: wait a minute

RICKY: we’ve lost it again, it’s back up there it’s across but back up

GEORGE: I know

RICKY: it’s way across

GEORGE: I know, there it is

PAUL: yeah, I knew number two would drop more

GEORGE: what happened? Indecipherable

GEORGE: strange, they both increased! Something must have heated them up

RICKY: there’s nout there to heat them up

GEORGE: I’ll take number two

PAUL: number one’s just shot up as well
*GEORGE:* they shot up at ¾ near 31.2 number two shot up at 37.

*RICKY:* turn the lamp on again, turn the lamp on get ready, now,

*GEORGE:* the lamps going on again

*RICKY:* I want see this terrific rise again, I do

*GEORGE:* it's levelling off

*RICKY:* no

*GEORGE:* increasing

*RICKY:* one's rising, two's levelling off and rising. No something must have touched..

*GEORGE:* indecipherable

*PAUL:* it is correct I checked it

*GEORGE:* number one's rising

*RICKY:* I want the teachers to come and have a look at this one

*GEORGE:* very interesting

*RICKY:* I'll wait till they're both at nearly the same temperature then we'll turn it off again so that they can level down at about the same time, same rate.

*GEORGE:* we'll take it at 70, 700

*RICKY:* 650

*GEORGE:* 700 because it's just increased

*RICKY:* look, look they're nearly level so 660, yeah they are look

*PAUL:* no no

*RICKY:* Now! (Click of lamp switched off). Is it off

*GEORGE:* it's off

*GEORGE:* it's levelling and falling,

*RICKY:* shall I call the teachers over to have a look at this graph?

*GEORGE:* yeah

*PAUL:* don't put it on zoom put it on the normal one

*GEORGE:* yeah,
*RICKY: leave it

*GEORGE: we'll zoom it to see how it goes

*RICKY: No go back to that thingy, go back to autozoom because I want the teachers to have a look at it now we'll just say, I wonder if you want to look, no put it back on. Ah look at that man, wicked. Show teachers that.

*PAUL: George, do both of them

*GEORGE: yeah, I need to zoom number two. ... something increases it suddenly.

*TEACHER: do you want some help from me Ricky?

*RICKY: No, I'm just wondering if you want to look at the graph.

*TEACHER: yeah I'll have a quick look then I must go and get the internet people. Oh right! That's interesting.

*RICKY: now we go, back up and across (manipulate software)...

*TEACHER: right so one is which?

*RICKY: one is the carbon dioxide and two is methane.

*TEACHER: right so two's gone, gone up quicker for some reason

*RICKY: yeah and then dropped

*TEACHER: but they did start off the same?

*RICKY: they did start off the same, both the same temperatures

*TEACHER: they dropped about the same so the methane clearly's gone up. So one would suspect that methane is also a greenhouse gas, yeah? That's good excellent!. Right you're gonna have to start clearing away now.

*RICKY: I'll save this

*NEWTON: Ricky did that surprise you, what did you say you thought would happen at the star?

*RICKY: carbon dioxide would go up a lot quicker.

*NEWTON: you are real scientists aren't you! Well done. What happened to giver you these little blips do you know.

*RICKY: no we just turned it off to let it cool down and then it just shot up and back.
*NEWTON: so you think its when you switch it off that it shoots does it?

*RICKY: yeah and then it drops down really fast

*NEWTON: maybe its a spike produced when you switch it off. Good.

*PAUL: shall we save it

*GEORGE: when we on'd it again it shot up, then it went down. That was an excellent...

*PAUL: shall we switch this off?

*GEORGE: yeah, ... great discoveries from the heart of the earth!

*RICKY: what are these here, are they stands or something..?

*PAUL: Ricky you help empty them out

*RICKY: OK, oh let me get killed by the methane! Let me die ravenously slowly, let me undo it... take it over by the sink. (Sounds of clearing up)

*RICKY: Paul, smell that!
APPENDIX 8
Semi-structured Interview Schedule: Data-logging in Science Education (v2.0)

[Script]

"Thank you for being willing to take part in a follow up interview to my previous visits to some of your data-logging lessons. Can I first of all assure you that you will remain anonymous in any report to which this interview contributes."

"With your agreement, I would like to tape record the interview; I will offer you the opportunity to check any written transcript of the interview and to amend it if you wish." [Switch on recorder]

"The purpose of the interview is to explore your thoughts about some aspects of data-logging activities in science lessons. This will help to put lesson observations into context and provide an opportunity to raise other issues relating to data-logging practice which you consider to be relevant."

1. First, What is your rationale for using data-logging methods in science?

2. What factors influence the way you select activities for data-logging?
   ease of use / training needs / resources / teacher attitudes / pupil attitudes

3. How does the National Curriculum influence your practice of data-logging?
   NC Orders for ICT? / NC Orders for Science? / NC Assessment demands?
   Positives? / Negatives?

4. a) What happens in the lesson before a data-logging lesson?
   b) What happens in the lesson following a data-logging lesson?
   c) When pupils experience more than one lesson with data-logging, is there progression in their experience

5. a) What do you see as the data-logging skills needed to be developed by pupils? [is there a hierarchy of data-logging skills?]
   b) Are they / can they be assessed?

6. Are there also skills needed to be developed by teachers?

7. a) Please describe your view of an ideal provision for data-logging.
   b) How does your reality compare with your ideal?
   c) Is there a working compromise here?

8. What aspects of data-logging would you like to develop next?

[Script] "Thank you very much for helping with this interview and for giving up your time. Can I finally ask you if there is any aspect of your experience of data-logging which has not been covered in this interview?"

Probes:

   Anything more? / Could you go over that again for me? / enquiring glance.
   What is your own personal view on this? / Rephrase to check. / 'mhmhm.' / silence
APPENDIX 9a

*12.5.98
*Interview with T1:

LN: Perhaps we could start if I could ask you please, what you would see as your rationale for wanting to use data-logging in science?

T1: Right, I think my rationale perhaps differs from some people's. I've always seen data-logging ... the prime aim has always been to extend science education in ways we could not normally do. Science is taught in blocks of time, 50 minutes, 1 hour 20 minutes, but science experiments are either longer term, shorter term, and I've always seen data-logging as hopefully giving you the opportunity to delve into those areas that you couldn't actually normally do in terms of like biological experiments - a day a week etc. whether the student or the teacher is not normally there to take readings, the data logger can do it for you. The same in short term experiments, the teacher or the student hasn't got the equipment or skills to take the very short time experiments in some cases, so the data-logger is able to give you better data and more data for those experiments. Also on fieldwork, the portability equipment means you can take it outside. So primarily, to try and extend science education in terms of what you can do and rather than staying all the time with the traditional experiments which are good, but going beyond that. I've always seen it as an extension and not 'instead of' in many cases. BUT, I am fully aware, like with science investigations, that you can only take small steps to get people competent; so to get them used to data-logging you may still have the need for staff to do a traditional experiment but using a data-logger in the first instance. But my personal experience has always been to try and extend the techniques available.

LN: you said when you started to answer, that you saw your ideas as perhaps being rather different in some respects...

T1: yes, because every body I've seen and most of the booklets I've read, the people start with the good old traditional experiments. Now, there are several reasons for that I think. One
is obviously the range of sensors, the temperature sensor replacing the thermometer - there's quite a lot of experiments in that and the temperature sensor is very good because its cheap and affordable and most people when they bought LogIT, it had the temperature sensors as a matter of course with it; so you start with that sort of thing. We were lucky in Leeds when we started data-logging because we gave them movement sensors and we gave them five of each so the ideas was always not to really on one sensor, so the range of sensors helped as well to do new things in new ways. I still marvel, I remember going through 0 levels and being told of the cooling curve for water but I had never measured it accurately and seen it happen, but with a data-logger attached to some water in a freezer compartment, I saw that for the first time, and it was marvellous! You know you plot these graphs, you see them in books so you know what should happen, but you never see it for real. So data-logging provided you with the opportunity to see things happen which, in the past, you couldn't really put a thermometer into a freezer and see that happen. But for me the challenge of data-logging has always been to come up with new ideas, that's the excitement of it as well. For instance using the pressure sensor to measure the rate of reaction, and even the LogIT people hadn't seen the possibility of that and yet it worked brilliantly. For me it's an excellent experiment it is easy to do it gives excellent results; for fast reactions it is much better than a gas syringe and it complements the traditional stuff with gas syringes as well.

LN: and it's sensitive as well - I can think of examples in enzyme experiments as with catalase where the volumes are quite small and you cannot measure them with a gas syringe. You've always been good at generating ideas though haven't you!

TI: That's what the excitement is about, that's what data-logging allows me to do to try out new things. The other experiment which is not new, not an original idea was using three metal rods for thermal conductivity, stuck in the end to measure rising temperature as it got hotter. But up to then I had only seen this dome with the three metal rods stuck in a Bunsen. Mick did this, and I said what about trying a hairdryer as a new source of heat - because of the safety reasons. And it works brilliantly, you haven't got to worry about a Bunsen, you can stick the metal rods down with sellotape on a normal bench without any problems
whatssoever, and you get a temperature gradient in five minutes flat!

LN: that's very nice

Tl: so its extending what you can normally do, and looking at new ways of doing it. There are tons of things I'd like to spend more time on, using the motion sensor to look at viscosity. If you have a motion sensor and put a cog on the end, as it goes round it goes through 0-350 so you get a saw-tooth action [draws this in the air] and the gradient of each saw-tooth is a measure of the rate at which the angle is changing. Now if you drop something wound round it goes too fast but if you drop an object through a viscous liquid, as it moves down, the motion sensor moves round. It should produce - I've never done it - a saw-tooth. Each saw tooth using the data-logging software should be able to give you a gradient which is related to the speed at which that object is falling. You can change the size of the cog to get a different sensitivity.

 Whereas light gates would pick it up it wouldn't give you the speed all the way down, but that is a modern version of the ticker-tape.

LN: but you would need some software, some means of doing some work on that saw-tooth trace wouldn't you.

Tl: you would need to be able to pick up the gradient, which most of the packages can do

LN: I'm interested that you raised this issue of doing something with the data once you've gathered it. You have many examples of methods of getting data and what interests me is what happens in the next phase. I suppose it depends on what your definition of data-logging is, I suppose strictly it is literally that, logging data. But as you said in your preamble, you're doing this for a purpose to enhance the science.

Tl: There's still not enough evaluation of the data, because the emphasis in courses is still on acquiring the data. In terms of science 1 investigations, there's a big emphasis on the planning and acquiring the data and I know there is a need to evaluate more and interpret the data more, which is quite high level skill; but to do that you need to practice it more and forget about the other bits. And I think the teachers are still (me included) are more worried about getting it all done rather than spending a lot of
time on the evaluation. Perhaps we should be spending more time if the evaluation and interpretation was given greater weighting, then perhaps we would do it better.

LN: you’re suggesting that the demands of the syllabus, the NC, are forcing an emphasis on to the design and collection aspects rather than the more interpretative...

Tl: GNVQ is the same, there is evaluation required but there is still quite a big emphasis on the doing and collecting of the data, and the selecting of the technique. I would love to see some sort of package where you could see the data happening in front of you with some questions. Now there have been some good CD-ROM’s - the science 2 materials CD-ROM is excellent because it does interactive experiments so you can choose your material, you are not limited by what we have, it does the experiment for you in a reasonable time and it give you a good set, a correct set, of data. So it give you a bit more time to evaluate it. Now the same goes for data-logging - it is a form of data-logging in some respects, because it gives you the data as it is happening although not in graphical form.

LN: there is a time issue here though, of getting on to the interpretative part of the activity, you have got to get the data to do some work on unless you provide ready-made data...

Tl: I know there is some ready made data that LogIT people have already done, but I’ve never seen a package on a CD-ROM of experiments which are interactive, with data-logging graphs available. There’s plenty of interactive experiments, we’re developing some work with Nuffield at the moment on interactive chemistry; but I’ve never seen a package where the emphasis is on data-logging so that you could look at the data on Insight as an interactive technique and then be able to answer the questions in that respect. It takes away also the problems of ‘does this lead fit’, ‘does this go’ which for a lot of students gets in the way. Although, let’s be honest, it’s got simpler, the equipment has got a lot better with the palm tops in particular there are less connections, less time, you press a button and you are into it. To me that’s very important.

LN: And those sorts of skills are fairly quickly learned

Tl: most of the kids we see don’t have too much of a problem using the software
LN: there are always technical problems with leads etc. that you cannot plan for

T1: yeah, but it is still the interpretation of the data, I don't think there's a big enough emphasis on that part. It's high level skill I think it is harder. Without a doubt. When I did some of the APU research you look at that and you see that trends, purely the language that is used is very difficult.

LN: and having the right kind of contexts that the youngsters understand so that the data a means something ...

T1: I definitely think it should extend science education - it certainly has at times we’ve done things that I could never do before.

LN: We’ve talked a lot about your ideas for developing activities and a little about what is happening in practice. If we could focus a bit more on your routine use of data-logging - what kind of factors weigh in your decisions to use data-logging approaches over others. You have hinted at the NC constraining what you might do but...

T1: It is still reliability. Its do you know how to work the damn thing...

LN: teacher awareness you mean?

T1: Right, and teacher training. I've always said that there are four things you’ve got to have in place for it to work properly. One is that the teachers have got to feel confident and therefore the training has got to come in. You've also got to have the right hardware and software: ease of use. That's why I've always said to DP and LR at times, that to me Insight is good but it's quite complicated, whereas with LogIT software you can get staff working on it quickly with less skill. Insight comes into its own without a doubt once you’re into it and you know what you are doing, particularly for physicists. But as a starting point, with LogIT software you haven’t got to measure the time interval, with Insight you always had to - it may have changed with Insight2. That was always a criticism of Insight - I mean how long was the experiment going to go on for - 20 minutes? You get to 20 minutes and the experiment is about to work, you’ve got to start all over again whereas with LogIT you just keep going. And also how easy is it to use, LogIT was always very straightforward generally. And we
still don’t use probably a quarter of the potential of the software. I bet if you asked teachers who have done some data-logging, what features of the software they had used, you would only have got a quarter of what was available. The third thing is that it has got to be written into the schemes of work - without a doubt. We still have not got it written in to out schemes of work fully, because that forces the issue. They’ve got to do it whether they like it or not! They’ve got to actually do it because otherwise people won’t do it. I’ll do it, I know X and Y will do it here, but I also know a lot of people won’t touch it with a barge pole unless there’s that expectation. Now, what was the other one, there’s a fourth one! Training, written into schemes, hardware, software …

Oh management of the equipment - if you haven’t got the equipment managed properly so that how much have you got?, have you got the batteries?, will the technicians be able to deliver the right stuff on time - things like that. You take any one of those away and you are on a loser to be honest! You’ll get the individuals working on it but you won’t get a whole school doing it.

LN: Do you think there’s anything peculiar about data-logging in that. Of those four conditions you’ve described do you think they might apply to any innovation or any new method?

Tl: Possibly true, yeah!

LN: Are there particular things about IT?

Tl: I don’t know but I’ve always said, if you’ve got any one of those missing, you might as well forget about it on a whole school basis. Any one person can manage that because one person can be trained, but try to extend it to fifteen teachers… I don’t think we’ve got it right and we theoretically know what we’ve got to do. …People will still put the leads away wrong!

LN: What about from the pupils’ point of view? Now youngsters will encounter IT in their primary schools and in their early years of secondary education. So they’re becoming more accustomed to using IT. You’ve talked about data-logging activities being written into a scheme of work, I wonder if you could perhaps describe how you see the pupils IT experience being planned within a sequence of lessons? If you have a data-logging lesson coming up, what might happen in the lesson before that to prepare the pupils?
Tl: Well I think it should be an integral part of the topic, just like it’s another teaching & learning style. Within a topic sometimes data-logging is not of any use. It shouldn’t be there for the sake of it, it should be there to complement and extend the science as we see it. There may be topics where data-logging doesn’t come into its own but CD-ROM’s, internet do, you cannot data-log the periodic table! But you can use the internet very nicely! But whereas the internet and CD-ROM’s provide information of a textual nature, the nice thing about data-logging is that its an interactive thing. It is something happening there and then, for me that’s some of the fascination and now the internet and CD-ROM’s are moving that way. It is the interactivity which data-logging already had which the internet will move to.

LN: This raises another issue which is the skills that pupils require; we’ve talked about teacher’s skills and we shouldn’t underestimate those, but what about the skills for the pupils. What kind of skills do they need to develop I wonder, to make good use of data-logging?

Tl: Along your research lines. It is the fact that the teacher is crucial to ensuring that there is an interaction through carefully constructed activity, and it’s not a ‘free for all’. I think the more we do it the more you learn that. There will always be the group who know what they’re doing and you are happy to leave them to get on with it, that’s true of any experiment. But you still need that structure of questioning to make sure the students are on task and working and seeing the relevance of the data all the time - I mean it’s quite good news for the teacher in many respects!

LN: It’s ironic in a way, one might think that giving the youngsters control and scope to explore but perhaps behind what you’ve been saying is the need for the teacher to have a very watchful eye on that process.

Tl: The students don’t always see the relevance of the data and the fact that it’s real data coming in all the time. You’ve got to train them to look at that data. You can’t expect them to... they need training in everything don’t they? I remember AT1:, teachers had great problems in understanding what we meant by control variables, independent variables, never heard of them before because we’d never been brought up on them! Doing training sessions, ‘what is a control variable, what is a categoric
variable...’ it’s just about there now for most of us I think, but what a hard work it was at the time! Now if we need all that training when something comes along, I’m sure the kids need that same sort of thing. Of understanding what we’re doing and to appreciate that you can do lots more.

LN: So, how will the kids get to that position?

Tl: Well, you’ve got to have it built in to schemes of work - that’s what I’m saying. And it’s got to be done in a very structured way so that it is built in and develops the skill through time. It’s still very ‘hit and miss’ at the moment.

LN: So what would be your ideal...?

Tl: Oh! I’d love a unit which is purely IT driven. Where the emphasis is - not data-logging - where the emphasis is using the internet, spreadsheets, word-processing to write it up. One unit a year possible where you would use IT from the outset to say to students, ‘look this is what you can do with IT to enhance your work in terms of quality, accuracy, research etc. To me science is not just about facts and knowledge it’s about finding it out for yourself. I’d love to see some units purely written where you can get all 26 kids or whatever doing it so they can see the potential. Now once they’ve seen the potential, you can say ‘right now you’ve seen that’. We get a lot of our kids typing everything up, because they’ve got the facility. To get 26 kids data-logging ... the other way is to do it on a circus, like we did!...

LN: Weren’t they enthusiastic!!...

Tl: Yeah! they weren’t bad were they!! Some of them had never used the internet before. But that’s what I’d like to do, but to get everybody to do it is a different ‘kettle of fish’. As a manager now, I haven’t got the time to do it, if I was a teacher in a class I’d do it!

LN: Do you think that we’re still in the situation where IT is driven by enthusiasts?

Tl: the NC has changed things. A lot of people complained about AT1:, but because they were forced to do it their methodology had to change, but it was painful for some of them. I remember a training course, where a person said ‘what have we got to this for’ and I said ‘what’s your view of science’ he said ‘science is a body of facts’! I could not believe what I was hearing. You see
it in primary schools, their science is driven by the teacher using text books still, but what I’m saying is that IT plays a part. Yes it’s driven by enthusiasts and it always be.

LN: So what would you like to see next as far as data-logging is concerned - do you have a vision of how you’d like to see that developing?

Tl: Well. I know there are courses around but I’d like to see courses where IT is more explicit ... like 'Spotlight'. END of tape
APPENDIX 9b

12.5.98
Interview with T2

LN: Perhaps we could start if I could ask you please, what you would describe as your rationale for wanting to use data-logging techniques?

T2: It's fun! I've got to include that because the kids do find it fun. To get over scientific ideas in a different way and in a way, certainly these days, that they can relate to. If they can see it on a computer screen it's 'true'. To do something a little different, there is an element of doing things that are different; to stretch the kids a bit further. You know it's OK, we've just done the temperature experiment with the melting ice and you can do that with a thermometer: usually we do that with the thermometer. But if they've got the added incentive of using the data-loggers, keeping everything going at once, it stretches them - they're doing more than just monitoring a thermometer. And it's something that more than one kid can do. You know, one person has the thermometer so if you've got limited resources, you have one person with the thermometer, three people sitting round - but with a data-logger there's always something for them to be doing, and I like that.

LN: So using IT is quite motivating, I suppose the more they use it the more blasé they'll get about it?

T2: I'm not so sure, today I said 'I need some volunteers, anybody want to set up the data-logging? YES!!' and they're dead keen, they're year sevens and they are dead keen. Some of the older ones are blasé to start with, ...I think yeah, to a certain extent, yeah. I heard one kid complaining that this college wasn't very good because they'd only got Windows 3.1, so yeah then can get a bit blasé.

LN: They are enthusiastic about using IT generally speaking; it's novel, topical...

T2: ...they seem to see it as play. If they're playing with the data-loggers ... because quite often with the data-loggers you say 'right if you're just monitoring, now you can use the record' they just playing and they enjoy that aspect of it.
LN: How do you see it helping their science, have you got any thoughts about that, which you have worked through?

T2: Well I’ve just had somebody [a visitor??] asking very difficult questions of year sevens, so they’re paying attention when they are using the data-loggers. They don’t understand everything, but they do know what they’ve been doing and why they are doing it, which they don’t always grasp when they are doing standard science. But as to whether it ... aids to understanding - perhaps if there’s the interest there they will learn it, as opposed to learning it off by heart. So in that respect yeah.

LN: Let me check, do you mean that because they are interested in using the data-logger, they get interested in what the data-logger is doing. So that the first point of interest is the IT and then there is the lucky pay-off because of them tuning into the science a bit better because of that. Is that what you were suggesting?

T2: ... I think in a way yeah, that would be it. They know that they have got to do the science but the data-logging is a bonus - a little play thing.

LN: Well I know from what I’ve seen of you working that you’re very interested in IT and enthusiastic about using it, but what kinds of factors go through your mind when you choosing an IT activity.

T2: Fun. It’s got to be fun. It has also got to be interesting. There really has got to be a sense that they can do it - I mean we’ve gone through a lot of tests where they haven’t actually achieved anything and that does start to tell [reference to the IT enrichment groups I have observed MT with]. They’ve got to be able to so it or think about what they are doing. A lot of the data-logging club was ‘these haven’t been done before’ to try and get them thinking about it, thinking on a different level. Even with science investigations, you say to them ‘right go away and plan that’ and they don’t always think that they need to think anything other than what they have got in their text books or exercise books. But one of the things we’ve been able to do here is to try and get them to think rather than just take information in.

LN: The pupils are positive you’ve said, do you think they need to be trained in how to use IT or do you feel that the play approach meets that need?
T2: When you say IT do you mean data-logging?

LN: I mean data-logging!

T2: yeah, the first session we have with them we go through, make sure they plug things in properly and then I literally say 'go and have a play'. It's the first thing I do when I've got somebody new to data-logging - go and have a play with them, you won't break them. 'Go and stick it out the window, measure your temperature...T2: Yeah, I think exploring it themselves; these kids aren't shy, they'll come back and tell me 'I don't understand that' or 'I'm not getting a response from the logger'. So you can do it on the spot and you'll get the bright kids down there who can do it ... and the others will be saying they don't quite understand. But yeah I like to see them playing with it - see how much they can actually learn for themselves.

LN: Most of the activities that I've been lucky to observe in your groups have been special activities, haven't they? If we think about the way you use data-logging in your routine science which I've not seen, I wonder how far you feel the NC influences they way in which you use data-logging.

T2: Well I'm very lucky here in that I can use my enrichment period to use the data-logging. The NC is packed and especially in the situation where ... you are not sure of what resources you are likely to be dealing with, data-logging causes an extra problem. Especially if you don't know if it's going to work. Here, if I've got a chance to slip it in I always do because I'm interested in it. From talking to some of the teachers they say 'we cannot rely on it' if you're there and you've got 26 kids who don't know how to use it then its too much work to get round the whole of the group and get everybody au fait with it and then get them to learn from it. And I find that to a certain extent, and the NC is too packed to allow you to come in with it unless you've got good backing, good technical support.

LN: Are there two issues there then? One is that the equipment is reliable and managed by the technicians and it arrives when you order it; is second set that it takes time...

T2: ...it does...

LN: and you're suggesting that with the NC being so packed you haven't got the freedom...
T2: ... to say 'I'm going to do a data-logging lesson' you don't get that freedom, you seem to be nose to the wheel all the time. And if you've got one lesson to say, do the temperature experiment and that goes awry because the data-logging equipment has gone, or because half the class don't know how to use them - its time you cannot afford to waste.

LN: It's too risk?

T2: Yeah - risk sums it up very well, especially when you in a place that expects you to get high results. They expect you to be able to teach the kids and get the results at the same time. Which is no bad thing -it's what I'm paid for, but I wan to make sure I'm getting the right results, and if data-logging is causing me a problem I won't use it.

LN: So, are there in your schemes of work, focused topics where data-logging appears?

T2: No, no

LN: so it's up to the science teacher to decide for themselves whether they want to use it/

T2: definitely, one science teacher recently said to me 'I hate the damn things I'm never going to use them'. Trying to get over that block - take a better man than me!! Probably she used them on teaching practice and they didn't work or they'd not been looked after - that kind of thing.

LN: But you're a confident user...

T2: I am...

LN: enthusiastic about using it, and yet you're cautioning still that even for you, with all your interest and enthusiasm and expertise, you still think twice - is that fair?

T2: Yeah, definitely. It's one of those situations where you have got to be pragmatic, and if you are not going to get the results with data-logging, even if it's fun, then it is not worth the hassle to get it to do what you want, if you can get it done by a standard method.

LN: So how do cope with the demands of the NC which imply science teachers should be using IT for collecting data & presenting information, or the demands of the NC for IT where measurement and data handling seem to ...
T2: ... data-logging, yeah, we've built up a system whereby because we've got so many PCs, the kids can do a lot of that. We have set worksheets that they can go through which we have added to the Spotlight Science, that they can access on the network. They can juggle the figures around, so they can do that interactively on the computer so they don't really need the data-loggers to do that. Yes, I mean in an ideal world, we'd have at least one experiment where they could data-logging that, but the ways things are it would take a lot to get that in; I mean we could set it up but you've got that block again of 'God it's data-logging'. ...if we could get to a stage where you've got, like RW here, if you've got trouble with data-logging or any thing to do with it, he will come into your lesson. If we could set that up so that people who don't feel confident with it, and have a standard lesson where we say 'right, you've got to do this experiment with data-logging to get that aspect of the NC, then yes it is possible, but you need specialists, somebody who is good at it.

LN: So, I just want to check that I have understood you. Is what you are saying that as far as the NC orders for IT are concerned which could be met through science activities; where they are met through science this does not include data-logging, the reason for that is that you can meet those requirements in other ways...

T2: yeah

LN: and as far as the data handling aspects of the NC for science, you can meet those in other ways...

T2: yeah, well what tends to happen there is that because the kids have IT lessons, I found out the other day that the IT teachers will take them through - they'll give them a science experiment and they'll run through that data handling process in their IT lessons.

LN: So, why should it change then?! You are enthusiastic about it and I know you will want to use data-logging when you can; but what about people who are less enthusiastic, or more frightened by it?

T2: Two things there. For me to do it, give me the time. Give me the time and I'll have data-logging in every lesson - I'll find some way of getting it in!!. Which is unrealistic because it is never going to be there. As for the 'fear factor' I think a lot of it is training, a lot is making sure your kit is reliable and there on the day and working, and making sure you have got the
ideas. A lot of people don’t have the time to sift through data-logging ‘for beginners’ and find the ideas, so if you have got an IT person, a co-ordinator, who says ‘right, that fits nicely into our scheme, you are going to do it and we are going to spend an INSET day training you’ then I don’t think you’ll have many people day ‘no, we won’t do it’. But there is this teacher thing where you are standing in front of a class and you don’t understand it, because a lot of people still don’t understand computers, palmtops. To learn a palm top for an adult, I mean the kids learn it in about 12 seconds!! But adults have got all the fears and ‘oh god if I touch that it’s going to blow up!!’ - because they are too expensive. And that’s another factor the expense. If you’ve got a group that are climbing the walls and you have got £600 worth of equipment, which I did with my post 16s, they ... it’s a lot of responsibility on top of all the stuff that you’ve got there already.

LN: It’s interesting you should raise that, we shouldn’t minimise these factors - there is a lot to weigh in the decision about whether or not to use a data-logging approach. What you seem to be saying is that some of those factors are actually nothing to do with the IT in the science, they are more to do with the management of equipment or the pupil group you are working with: is that fair do you think?

T2: And the training, the fear aspect of being there, teaching something you don’t understand.

LN: Since you mentioned training, could we talk a little about what you see as the skills that are needed in order to be able to make data-logging work successfully - perhaps we should talk about skills for teachers and skills for pupils.

T2: All the pupils need is enthusiasm, which most of them here have. A little bit of computer knowledge, they don’t need a great deal, because what I have found with the girls, you know the first girls we had, the bright ones help each other. For teachers, they have got to feel comfortable with them. Until they feel comfortable with them and know they’re going to work ... somebody said to me, one of my post 16s, I brought the data-loggers out and he said ‘oh not those things, they never work, they rubbish’ and I said ‘I’ll give you a pound for every one of these that works’ and he got the best results because his data-logger worked! Actually
they were IT students and they just took to the palm tops; but feeling comfortable, that has got to be the most important factor.

LN: Once the students have got their data, what happens then? The reason I’m asking this question is that people have different definitions of what data-logging is. The NC conjured up a particular view of data-logging which is to do with collecting data. But I wonder if you have any thoughts about why you would want to collect using data-logging in the first place. Perhaps there are some reasons such as motivation and fun which you mentioned earlier on, but are there any other reasons which spring to mind?

T2: It’s easier and it’s neater. But I’m not always sure that it helps. If they’re just getting a table there is something to be said for writing results down, because they are actually doing something. It is not like having a photocopied sheet where they won’t read it. The data, they know what they’ve got to do with it. It’s a bit of a disadvantage sometimes when they’ve got to draw a graph because of time factors, so they can see on the ice one [refers to data-logging temperature of melting ice] the s-shape forming because they’ve done the points.

LN: you mean when they have plotted the graph for themselves...

T2: yeah, they know what they have actually plotted and you have got that process of taking the graph all the way through. So from an understanding point of view, I’m not too sure whether that would help.

LN: So could you take me through in data-logging lessons; suppose you’re doing routine data-logging in NC science, what might happen in the lesson before that, and how would you follow it up? Would you have a mental map in your mind of where this activity was going to go and how you might manage it.

T2: Probably not, ... well it depends because if I’m doing a specific thing maybe, but if I’m doing something to fit into the NC where it has got to fit into a slot then no. If you’re doing a science investigation then you would go through the planning stage and you would take about the data-logging, spending on how experienced this lot [the pupils] are, you go through using them and all that lot; but you just don’t have the time to spend you know, even 15 minutes - it’s like gold dust at times. Usually when you tell them they are going to use data-loggers their eyes
light up anyway, especially with the lower school. Going through the activity, if it is going to be an activity for the NC science it’s got to slot in to one of the ‘Spotlight’ topics for example - it’s got to do ‘23E’. I know that sounds very blinkered but because you have got five topics to get through in four lessons, it is down to time.

LN: Well this is real life and that’s what I want to understand.

T2: You just wouldn’t have the time to go through it. That’s why I like this data-logging enrichment, because it gives me kids that are experienced, and I just go ‘set up the data-loggers’ which they did today. They came in ‘right set them up’ and give them the temperature probe and they just went away - and that’s the advantage of having the enrichment: you’ve got experienced kids, which is nice.

LN: Do you see any progression in the kinds of skills that kids need to use data-logging - you said earlier on that they were simple enough for you to be able to give them to the kids to ‘play’ with and let them discover how they work. But if they are going to use a data-logger for gathering some data and download into a pocket book, do you envisage any kind of progression in the skills the kids need to be able to do those things?

T2: Yeah, we found that when they did start getting to the stage where they could use them competently - taking them up a level. ‘Now do this’ to keep them interested and to keep them going. Today, getting to do little things like taking out files that they don’t want without removing the ones they do want- it helps with their computer skills. Because Cheryl said ‘do I just say “file save as” like you do in Windows’ and I said ‘yeah you do’ and then she said ‘if I get rid of this one can I just bring it back up - “file open” like in Windows’. So she had gone up a level today because she’d done something new. There’s lots of scope for doing that.

LN: Can you relate that also to their science?

T2: More to do with their IT, but some of the post-16 stuff is quite advanced and they use high level skills. Getting to think is one of the hardest things to do.

LN: What might those higher level skills include?
T2: Interpreting the data - certainly with my post 16s. 'It's all right, you're not in GNVQ now, what does it actually mean?' they've got to sit there and think 'well OK, we know what is happening here, we know why it’s happening, and we know because we've got this particular bit of information that this is working, or not working...'. Evaluating things when they go wrong.

LN: You mentioned that within the context of a post 16 group, do you see any of those skills with younger kids.

T2: Do I see any of that with younger kids ... ... with the more experienced ones, yes to a certain degree. But in the lower school they are still getting to terms with things like evaluating and concluding, drawing from what they are seeing, so it’s not as much. But I suppose in a way - a little bit - it would be nice to see it more!!

LN: Well it is hard isn’t it? ..... you’ve talked a lot about how the NC constrains what you do and you have mentioned other things like resources and technical management of equipment; what would be your ideal for using data-logging techniques in science?

T2: We’ve just done Spotlight Science competition, whereby we said ' we want to enter this, we want to go for it' so I’ve spent one period planning it, a double doing it and a single for writing up. That would be the ideal. I mean data-logging would be ideal for science investigations because you can use all the skills that they need with data-loggers. So yes, to have the time and to have the kit there - that would be great. I mean I do about six investigations - I know I’m only supposed to do three - but I like science investigations, so you could do six of those a year and write them into your scheme - with the time it would be great. I’d enter a competition every week!! So that would be the ideal situation. But now I am getting to the stage where I have got the ideal because they know how to use them, my year sevens know how to use them, and my year eights, so I don't have that sort of 'oh god here we go... here's half an hour setting it up'- they can go in and do that. So I can cut out the first period and just do an hour...

LN: well that’s progress isn’t it? But the reality you are in is not quite your ideal is it...

T2: not really...
LN: so what would you say are the biggest blockages for you - you've mentioned the NC being crammed full - the time issue - are there any others you could mention?

T2: Not really, the sky's the limit really, apart form the technical issues. There is another little interesting one energy! Your own personal energy. When you are on the go, it is not like a normal practical where you can set them going and then step back and watch what they are doing. Because of the equipment, because it's a bit more complicated that a thermometer, you are on the go all the time. That is a constraint. You come out of a data-logging lesson knackered! you feel as though you've done something. Perhaps that is one of the things people don't want, they don't want that.

LN: Is that because of technical problems perhaps. In your experience do you do more 'trouble shooting' in data-logging lessons that with traditional lessons?

T2: That's a good question ... yeah I would say so. 'My data­logger's not working' 'right, press the green button'. Yeah you are trouble shooting most of the time. And that's another good point about getting them experienced, because today Tom and Simon were solving their own problems, because they've got the experience. Year sevens are not that confident anyway.

LN: If we think about the future and how you might develop data-logging - you've talked about competitions are there any other ideas you've got of how you would like to develop your own use of data-logging?

T2: Oh, my own use - I'm going to keep my enrichment going. Coming up with ideas - I love coming up with an idea and seeing if I can do it. R has been coming up with the idea of putting things on the internet for everybody to see - I think that is a good idea. A lot of people have got to the stage where they have seen the experiments. One thing I would like to do is get them to work - the amount we've tried where there were good ideas but somebody hasn't put enough thought into them. So of them you read are not really practical especially in the time constraints you've got. But for me I'm going to keep up the enrichment.

LN: Do you feel you have any training needs? You are a very enthusiastic IT user- I know that! But I wonder whether you identify things you need to learn for yourself/
T2: a lot of it you can pick up for yourself especially if you've got the time to do it. I had a session today with the IT co-ordinator to find out about reloading the files. I thought the palm tops were indestructible but I've had two kids lock them up completely. You can't get anything out of them. I knew about exiting applications but I didn't know about 'killing' applications, so that now I can go in and I've reached a certain level where if they have got problems I can sort them out. But there's going to reach a point when [the IT co-ordinator] goes that there will be nobody here that I can go to, so...

LN: ...it'll be you!!

T2: Yeah!! This is your data-logger, get it working! You are not going to have a choice!

END of Tape.
APPENDIX 9c

*24.4.98

*Interview with T3:

LN: Perhaps we could start if I asked you what you saw as your personal rationale for using data-logging techniques?

T3: Um, partly because it's modern technology and that pupils should be confronted with up to date stuff - this is why we really want to move on from some of the stuff that we have in school. I mean, pupils being confronted with old technology is just a bad example of the way we progress, but obviously the undermining feature is the cost of development. So being up to date with modern technology is very important; and also developing manipulative skills. Adds quite a nice dimension, at a more personal level - of them having control over something, in a more explored way using data-logging, rather than having a prescribed 'cook-book type' experiment to do; hopefully. I know some of ours are a bit that way, but that's a management, er managing large classes, its more of a management issue; but I would ... that's one way I would like to see, I would hope to see things go. But we have pupils going round school monitoring light levels which is a bit of a tame task, I mean it does get them out and they do then connect what they've done with what they actually download onto the screen. But I'd like it to be more er, fruitful, more valuable, in terms of just simply walking round collecting light levels. Um I think that the stuff that we've done on temperature again is a little bit tame; this is with year 9 classes, looking to moving to year eight which I'll talk about in a moment, but um; simply because we're really using it as a sensor only and not storing, recording data for a period of time, to later download - so my gut feeling about the whole data-logging scenario is in an ideal world you want them to move away from the lab, if possible, certainly away from the computer - to gather information and then to bring it back and download it. Just to enhance the realisation that they can work remotely from all of this stuff.

LN: OK, When they've brought this data back, do you have any examples of where you're using software to explore data at all?

T3: Very little at the moment. ... They use softlab, now that was bought prior to Insight coming on the market. It was in my view,
the best bit of Windows software for the purpose; it had
flexibility and the number of data-loggers you could connect with
- LogIT would and LogIT is our preferred data-logger. Partly
because it is very neat and it seemed at the time a very simple
'one button one push', well virtually. Ironically as a result of
its simplicity we've gone slightly more complex and bought display
units for them which fit on and then you can actually use them as
sensing devices which display the information straight off.

LN: These are the CheckIT devices

T3: That's right yes. They actually clip on. Unfortunately you
have to dismantle them to use the download facility because it
uses the same 'D' connector at the side.

LN: Some of the newer devices, of course, have a built in display
but this is always the problem with technology - it moves on.

T3: Yeah, it moves on

LN: so I mean, what would you see as some of the key factors which
influence the choices you're able to make about data-logging
activities for the pupils?

T3: I would say now - my gut reaction would have been to say
finances, money; but I think in fact, it is teacher time. That
actually implementing this stuff, for example Insight has come out
- I still need to actually sit down and work a lot more with
Insight. We've got it now but we need to develop curriculum
material for it. That is where the most restraining aspect of this
whole issue is. We've got quite a lot of stuff on control, I mean
that's not directly data-logging, but there's stuff sitting in
there - a thousand quid's worth of equipment that has not really
been got at in any depth and certainly no curriculum material put
together simply because of the constraints of teacher-time. It's
easily said - this thing about teacher time and a lot of teachers
do not have the time. Of course you have to prioritise. I think
unfortunately in our situation we've got two, well three teachers
who teach IT in science predominantly, and are very comfortable
with it (that's John, Ian and myself)are all pretty senior in
terms of management of the school. Ian's head of year and has got
commitments that way, and both John and I are assistant VPs
have just got a mammoth task on. So that impinges; that, as has of
course, OFSTED, as has any amount of sundry paper work.
LN: Do you see any training needs? - I accept what you say about time - that's clearly a big problem Do you feel that there are training needs in the department which would need to be addressed to win teacher's support for using these techniques, or do you feel that that's a battle that has been won?

T3: Umm. I think that that is dismissed slightly because there is expertise with three of us, you always feel that we could pass that knowledge on. But of course you're in a catch 22 situation because not only have we then got to commit ourselves to sitting down and passing that knowledge on in a reliable and sensitive way; but we've also got to develop the curriculum materials as we go along. I'm not saying that others in the department don't have IT expertise, they're fairly comfortable with using the main applications, but as far as data-logging and control go, I think it is just another dimension of learning, but yes they could do with - certainly courses are ideal because they take you ( and I think they should) take you off site somewhere else so you are not going to have people saying "I need you for a cover", "Mrs X would you just..." " Mr Dowdall could you..."! You need to be physically removed to get the benefit out of something like that. The answer is yes.

LN: And in terms of resources, IT resources; do you feel as though you've got sufficient to be able to do the kinds of things you want to do at the moment?

T3: I think we're lucky in that we can lay our hands on potentially enough equipment for a class, maybe. There are ifs and buts to that I mean we were blessed with a donation of medium range PCs from Next last year which will data-log fine; again there's a time issue because they were literally the bare guts of the machine: formatting hard disks had to be done, installing Windows then installing the software. Fortunately we've got a site license for software and likewise I think, we've certainly the intention of buying as site license for Insight - and we're fairly positive about moving towards Insight for any number of reasons. But coming back to the actual equipment - the problem is it's scattered. That if we do want a whole class doing this that the PC side of things, yes, we could probably get a dozen in a lab and that would suit three to a machine-type work. For the actual data-logging stuff that is a slightly different kettle of fish because they're quite expensive, the um, data-loggers that we use; the
LogITs. I mean you’re talking about a couple of hundred quid at a time plus thirty to forty quid maybe, for extra sensors. But again we’ve worked it so that in a modular routine, that’s fine, but that doesn’t really answer the final problem. Yes we would have to buy another half dozen at least LogITs - twelve to fifteen hundred pounds worth. But having said that, we think it is valid exercise, very much so; I think we would resource that within 24 months.

LN: It is a big investment whichever way you look at it. What about the demands of the NC and how they might influence your use of data-logging?

T3: Well, the IT NC speaks for itself, and yes you can comply with that and do what you have to do to comply with that. I think in a sense, in some ways that is less significant than using it to help you achieve some of the targets set in the science NC. Obviously there’s overlap, but to actually help-. I mean data-logging, what is it good for? It is good for recording remotely, it allows you then to go and sense things that perhaps you couldn’t just in the hour lesson of a class. So it would fulfil experiments that would take longer which therefore you’d put aside. You could fulfil that need. You could fulfil certain other needs like sense or data-logging very rapid changes that are too quick to be monitored using our conventional equipment. We perhaps wouldn’t require equipment that would cost very much more, Say oscilloscopes, whatever; can be done with data-logging equipment. So it brings, having bought that data-logging equipment, the flexibility then to monitor things that can’t be seen, very transient or rapid changes, enables children to see these things.

LN: When you’re developing curriculum materials, obviously you have to have an eye on the NC, I wonder how far what you can do is restrained by the resources that you’ve got - sensors that kind of thing...

T3: we’re quite, well, I’m quite optimistic that given a valid activity that there would be some way round getting the equipment to monitor it, between a little bit of changing the activity you could still get the result. Having said that of course, one activity that we have done is record pupils motion using motion sensors. We’ve had to wait quite some time to get the LogIT motion sensor developed, in fact we had the first one - serial number 0001!
LN: Could we talk a little bit about skills in data-logging? what you see as the skills that pupils need to acquire in order to make use of data-logging?

T3: Start with the IT side, the pure computer side, they get a diet in school anyway of using Windows and so familiarity with that is a must, and they get that. They must have ability to control Windows software, and then because they’ve got that ability, decent Windows programmes tend to come naturally - you don’t have to fight too much to get a result if it is a good program. And I think by and large, the two we will be using are OK; it’s not too difficult to get lost in them occasionally, but that’s ... So pupils must have Windows skills. They must be able to physically switch on the computer whether... the amount of actual plugging together of all the bits and pieces, I would say yes that’s important; we leave the leads loose from the serial port and then they just connect the LogIT to that, so a bit of manipulative skill, connecting up the hardware, having some understanding what’s going on, why they’re connecting one wire there and putting a sensor in the front. They seem to adapt to that quite reasonably, but again I think that reinforces, it is an important part of realising, 'yes they’ve gone out to collect data, they need a lead to it back to the PC so that’s why they’re plugging this in the side'. What else did you ask me?

LN: Well I was thinking about the kind of skills that they might need...

T3: right, in terms of them downloading - that’s a little bit 'recipe book' but again there’s stuff in there. What I then see as being very important and again we barley touch on is interpreting graphs, interpreting data. I think that is the most important part and yet its the part that we barely get into. We’re going to address that problem by moving a lot of the year 9 stuff we currently do down into years 7 & 8, and then allow access to analyse the data. But that is what I would certainly like to be looking at far more than we do. Getting some quality data that is worth analysing and not just a series of peaks from light levels around the school and them saying ‘oh that’s when we were outside in...’ you know! That’s as limited as it is at the moment.

LN: If we could I like to develop that a bit and ask you why you think you’re at that point now. What I mean is you’ve talked about the gathering data side of things and your desire to move into
more interpretative activity, what’s stopped you being able to do that? Is it back to the time issue?

T3: Simply back to that. As much as anything it is sitting down and... We’ve got one or two experiments, they data-log the temperature of a couple of chemical reactions, and in fact we do as a teacher demonstration at some other point in the curriculum, cooling to below freezing. There are some interesting points that come out of that and how the thing plateaus and how the temperature sensor detects quite subtle changes that would certainly not be recordable on a thermometer and this prompts pupils to actually question why these little dips occur here and there; and it is things that where I would like to say ‘well you’ve got a graph, what have you seen on it? How do you explain these parts on it, what is going on in these parts. It is taking it to that, but coming back to your question, why aren’t we there yet. We’re there in a limited way but it’s a) getting that refined, producing more material sitting down to do that within the time constraints that we have had. It’s been a slightly, well for one reason or another, it must have been a lower priority than any number of other tasks that we’ve had, because, OK you’ve got a certain amount of time but it is a question of prioritising.

LN: Do you think the kids notice the kind of dips and squiggles on graphs that you alluded to there or would you see a training issue there for the pupils?

T3: Both, yes they do notice them and sometimes dismiss them as being a quirk ‘oh it just does that’ ‘the lead slipped’ ‘it came unplugged for a moment’. But alternatively, and just looking across the room at something I did with a pendulum, that they can, if they do sit down and analyse it, they can get a tremendous amount of information from it. Its a very simple thing to do, a simple thing for them to do ... coming back to your question, yes I think there are a number who will need training (perhaps all pupils) to be more analytical about what they see in front of them and not dismiss any part of a set of results. Try and explain every part, whether they think it might be an error or whether they think something else might be going on.

LN: There’s so much information isn’t there in a data-logged graph. Tuning in to what’s important and what is just noise is hard I think.
T3: The pendulum one is nice and straightforward because it tends to give nice and very reliable results, but you start messing about with temperatures and liquids which have got convection currents in and you have got all sorts of issues, whether perhaps your temperature sensor touched the side of the tube and the glass is at a slightly different temperature. Whatever, then..

LN: you've mentioned where you are now and you have described very eloquently your ambitions to be able to move into more analytical things; you're not going to be able to make that leap all at once are you, in terms of time. So do you see any compromise or 'halfway houses' that you can-

T3: I suspect that what might happen with continued involvement of people like yourself, and Laurence; partly because, I'm not necessarily saying it is an expertise thing, it's almost a prompt, a push, a nudge a bit of encouragement - right, we've got the kids involved in OILS or whatever, yes we ought to get that as a higher priority. So we'll sit perhaps on a Tuesday evening meeting and say well this paper work is just banal, let's go away and play and get something real done! I think what will probably happen is that once the shove has come, that that will precipitate and then things will get done over the following months. But it is actually getting on that road and getting a number of us more than one of us on that road. But it is actually getting the catalyst to precipitate that.

LN: I know exactly what you mean!...

T3: you keep looking ahead and saying 'after reports, after OFSTED', 'after the next thing'! Get those out of the way and we can really get some good stuff done. We're desperate to do it, both John and I. One thing that has happened is that we've spent two years trying to decide which way to go with data-logging and our control work, because of the overlap between the two. There are so many interfaces that will cater for both that because we had already committed ourselves to the LogIT, but then we were also committed to doing part of the design technology control work. Also we're committed to doing this across all three years, so there is quantity of apparatus as well. It was just trying to get the best options fulfilling that. It is possible to use a LogIT to control but I think that was seen as a bit of a nightmare-
LN: it has got to be easy

T3: yeah! It's got to be easy and we wanted something that was as easy as using the BBC and Deltronics controlIT boxes, I know I'm getting off the data-logging side slightly, but it all affected our choice of what data-logger to continue buying. Whether we should buy control boxes that could data-log as well, at extra cost.

LN: One of the things you talked about a few moments ago, was wanting to shift some of the data gathering activities that you use in Year 9 into earlier years, Could you briefly outline for me that the data-logging experience might be throughout years 7, 8 & 9, would they be coming into contact with any data-logging in the earlier years?

T3: Well, at present they do. That equipment that was set up at the front of the room a moment ago, was to monitor reflected light. It was a teacher demonstration and again it was data-logging in its loosest sense; it depends how you define it but I have always interpreted data-logging as really something that at least can be done remotely, brought back. There we were just really using a light sensor as a sensor, attached to the data-logger, to the PC; so really it's more sensing rather than logging. But having said that it produced a graph, produced a series of results rather than just one short-lived result. That was to a year seven, all year sevens will have that. It is not a particularly good example for logging because there you're just shoving different materials underneath to see what light levels are reflected. Whereas logging wants to monitor change, and change over time, not just isolated snapshots of different incidents. Year eight do a little bit on, cooling and boiling, plateau of boiling point. Year nine freezing point and then there's the (technology)module we do. I also do some work on pendulum motion in year 8 or year 9 depending on the timing of things.

LN: So they are getting quite a range of different contexts-

T3: yeah, I still think it's not- you see there's one other experiment I set up but I've only given it to odd groups as extension work. Unfortunately I haven't done it this year because I don't take any top groups, and it is the top groups who tend to progress through the material at a quicker rate and therefore have a need to be extended. One I quite liked was if you refract light
through a prism, you can get the spectrum out of the other side but you can also get infra red and ultra violet and that can be picked up by light sensors. It is quite interesting, their realisation that if they move the light sensor across the spectrum and look at the graph they realise there’s still something coming out below violet and beyond red and the graph doesn’t drop to nothing. So there’s something there!

LN: Wonderful!

T3: Yeah it’s nice it works! Again data-logging- it is more sensing. Its extension work for them.

LN: Thank you very much. Is there anything else you want to mention that we haven’t touched on?

T3: Probably quite a lot! In an ideal world I would like to be able to link data-logging to control and say you’ve logged certain circumstances and then have parameters which say IF certain circumstances, rise, fall beyond certain thresholds it will trigger some control response.
Interview with T5:
20.5.98

LN: If I might ask you, George, what you see as your rationale for using data-logging in your science teaching?

T5: It allows me to do experiments and get data that I couldn’t easily get in other ways. That’s the first one. Then, being a biologist, lots of our data readings are long-term ones, so being able to set something up and do a recording over a long period of time; or get lots of readings very quickly from a shorter term investigation, lots of readings – beyond what a student could do – to give a clearer pattern of any change that is happening. That’s the first area. Then the other bit … being able to record when you are not in school, and allowing the student to spend more time looking at the science behind what they are doing rather than just drawing graphs and collecting data. Once they’ve learned how to collect data with ordinary equipment and draw graphs by hand, then you can get a lot more out of doing some data-logging – get the results very much more quickly.

That’s for the long term analogue recording. The other thing we use it for principally, is for digit recording like light gates for ‘trolley’ investigations. Being a biologist I loathe ticker tape! I’ve never used ticker tape, I never intend to use ticker tape, and thank God they’ve invented light gates! Because with light gates you can do the experiment dozens of times and get your results, whereas with ticker tape you’ve got to spend most of your time counting r***y dots! Those are the main rationales – you get to the science quicker.

LN: If I ask you to think about the kinds of data-logging activities you have got in place, what sorts of factors influence you choices about those things?

T5: They need to fit in with the course we’re doing - so they’ve got to be relevant. They have got to make the experiment easier for the students, they’ve got to let the students get more out of the investigations going back to what I said before. The next step, and I think this does come next, is that we are required to provide the data-logging element of IT training. So once we’ve designated certain experiments which we can do by data-logging, we
can then give report on each individual student saying 'yes, they have used data-logging equipment, yes they know what a computer is... yes, they know what a data-logging is and yes, they're beginning to see the advantages of doing this'. So we look at the course and we say 'yes, that would really give us better information if we did it with data-logging'. Like ticker tape instead of light gates...

LN: it’s a good example... . Those sorts of factors are very much to do with the curriculum demands. Might there be other kinds of factors which are to do with individual teacher’s or pupil’s skills, which might influence what you are able to do/ would you be able to say anything about that theme?

T5: I don’t quite know what you mean...?

LN: Right, well what I’m exploring here is things like the resources you have available, the expertise of members of staff may have, the timing in the year; those kinds of factors might have a bearing on whether you select a particular type of activity.

T5: Yes, well we are selecting activities principally by when something occurs within the Salters Unit we are doing. So for example, if someone is doing the Salters ‘Moving On’ unit, which tends to be early in Year Ten, then when they ask to do trolleys - to investigate motion of trolleys; the technicians will automatically set it up with light gates. Now some members of staff are more confident with it, although most of them now are getting reasonably competent. Some people prefer to use it just as demonstrations, some people are quite happy to get a whole class set up doing it. The main drawback which stops people doing it with a whole class is that the machinery we are using is still BBC [microcomputers]. Some people are less happy with a BBC computer - they find it more of a difficult thing to use. Some people are not so happy using it with the whole class, preferring demonstration.

LN: You give me the impression that this is fairly tightly organised and in place...

T5: yes it is getting that way. You ask for a certain experiment and almost certainly if you ask for that experiment, the technicians will provide it to you with data-logging equipment.

LN: So does that mean that these data-logging activities are written into your schemes of work?
T5: Yes several of them are getting that way and it's increasing.

LN: Presumably...

T5: ...not every teacher may use every one. It could be that ... there are experiments which teachers select to do or not, depending on what track they want take through the module; how they want to teach something.

LN: But you don't, from what you've said, find the fact you are using older computers is a barrier for you [personally].

T5: No because the BBC is a good workhorse machine. We are close to getting something new - we're close to going down the 'Emate' line. I've got one for trial at the moment and we have had a representative from Xemplar in who demonstrated the Emate to the staff on the teacher day. So the BBC is OK - it's the putting the hardware together that is the nuisance. Sometimes going round making sure everybody has save their data, there isn't a printer linked to every machine so sometimes you have to save data and bring it to a central machine to give them a print out. If I'm doing this, let's say I'm doing an experiment on temperature change when plaster of Paris sets. So at the end of the they had to let it run beyond the end of the class ... and when it stopped I just went round with a disk and saved everything then printed it all out to give them copies of the print out next lesson. It does encroach on my other time, which is a nuisance.

LN: Have I understood you to suggest then that those kinds of fiddly thing- of having to go and save data in particular ways, or checking assembly of things - those are the kinds of things that stand in the way of some teachers using a class approach?

T5: Yes whenever I get called in by another teacher who's having a problem, it is usually because they are having a hardware set up problem. Something has been plugged in wrong, or something's not loading up right, or the disk drive is set on 40 when it should be set on 80! Some of them do still with BBCs find that a complication because those who are locked into using PCs or even Macs are not used to this now...

LN: ... and you quickly forget...

T5: yes, absolutely. So yes, that can be a problem but we try and get people over it so they get most things set up ready if they need it.
LN: So by getting to the point where things are well organised before the start of the lesson, you are trying to minimise the risks of problems.

T5: that's right. Student come in hopefully and get on straight away. They can concentrate on the science rather than the computer.

LN: Do the students have any problems do you think, with having the appropriate skills for using data-logging techniques?

T5: Only in that they are not used to using BBCs. It is the same problem. Most students now ... , I had a class this afternoon in the computer suite using 'Publisher' for a science exercise and they get on to those quite happily. But the BBC is more of a mystery now because it is rather like trying to drive a Ford Prefect as opposed to BMW.

LN: [Laughter] well never having drive either ...!!! Perhaps it is the Windows environment that they are familiar with.

T5: They are familiar with Windows now, they’re not familiar with this other system.

LN: Going back to the kind of factors which influence your choice to use data-logging techniques, you mentioned that you assess the IT element of the NC for IT presumably - the data-logging activity. Are you using data-logging for any other kind of NC activities?

T5: I’m not aware of any others.

LN: The reason I am asking is because I have heard concern expressed that if you data-log a science 1 investigation, you run into problems in being able to identify that youngsters have made measurements etc.

T5: Right. I brought this up at an examiners meeting in December and they said quite clearly there that data-logged results would be acceptable, providing that the science was being set up properly. They were quite prepared to accept data-logged materials. So yes we do use data-logging experiments within science 1 investigations. The plaster of Paris one ... it wasn’t a whole investigation. I just used it for analysis. To some extent you could use the data-logging but not use the observation bit of the skill. So that you plan it, you don’t mark them on the observation but you mark them on the analysis and the evaluation.
If you could argue that they haven’t personally taken enough readings because the computer has done it, fine! They can still plan to a high level or analyse to a high level; so just don’t mark on the ‘o’ bit - you can certainly do it that way. So I think you can still use data-logging in science 1 without any trouble.

LN: If we think for a moment about your routine data-logging, not necessarily in the context of an investigation, could you perhaps talk me through how a short series of two or three lessons that included a data-logging activity might run. I’m trying to get at how you might set the activity up, what the kids might do in the experimental phase and how they might follow that up.

T5: well, let me take the example of an assessment on the rate of reaction between plaster of Paris and water - how quickly it sets. It is taken straight out of the Insight materials - so I know it well because I wrote it!! The idea is that it is an exothermic reaction so we were doing the module on construction of materials. So I had introduced the idea of reactions between chemicals and the fact that when chemicals react energy exchanges are involved. Then I demonstrated this energy exchange using data-logging. What I did was to set up the lap top computer with a display monitor, and we had heat of reaction when you neutralise an acid, I actually had two or three acids and two or three alkalis. I could show them very clearly that we got a temperature change. So that was the introduction, at the same time showing them the data-logging kit. Now they had actually seen this before, but if you had got a group which hasn’t done any data-logging before, then at this stage you have got to introduce the equipment so that they know what it is. I also stress at that stage that is not the computer that is important - it’s what is in the beakers that is important. The computer is simply doing their job of collecting information - it is saving them writing it down. So I’ll try and draw them away from the computer and on to the science. So that’s the introduction, they’ll be given then the worksheet which outlines the actual experiment they are going to do. Depending on the group or might do a quick demonstration of the experiment usually stressing things to do with procedure that they need to be careful about. Such as if you’re doing the plaster of Paris experiment you must wrap the temperature probes in cling film or you’ll never get them out of the plaster of Paris. Simple housekeeping things like that. On the actual experimental session,
the technicians will before the lesson, set everything up. Now we’ve got a good group of technicians and they will usually set up the interfaces with the computers ready for us. So that on the front bench we’ve got the beakers, they weigh out plaster of Paris, they get the water, wrap up their probes... and then hopefully they should be able to get on with their experiment following the worksheet. But as students very rarely read worksheets (!) or listen to you, you then go round and tell them again what they are supposed to be doing. On an investigation like that, once they’ve got it running I would encourage them to start writing up the procedure, during a diagram, so that they are now getting something on paper while the thing is running. That as I said, was an investigation where the actual reaction took between 30 to 50 minutes, so in a 50 minute lesson, by the time they have set it up, it is running into the next lesson. If you’ve got another group coming into the room that can be a nuisance, but if you are aware of it you can probably timetable it where it will run it to a break a lunch time, or a time when the room is free or there is a sixth form class coming in, so it doesn’t cause too many problems. But it does mean that when the experiment is finished, I have to go round with disks, save each data to floppy trying to remember who was where, bring all the disks back here to the computer which has got the printer, and print out the results. I then photocopy the results so that each student has a copy of their results and then the next lesson, they have got their photocopied results so they can then do the analysis.

LN: Are there results in a table or graph?

T5: Graph, I usually give them a graph. I can’t see the point of making them draw the graphs - it defeats part of the object of the exercise. Now that’s a fairly long one [experiment]. If they were doing a timing one say, trolleys using light gates. Then they’re doing ‘single shot’ measurements, so again they’d be introduced to the principle of running trolleys thorough light gates. And then the way I’d do it is to give them a particular investigation so they would be looking at velocity or acceleration, usually just those two. If I had a higher level group later on I might look at collisions, crumple zones. I can do a nice investigation where if you set the light gate in exactly the right place you can see the effect of different crumple zones on the front of the trolley, and you can get different graphs showing how quickly they slow down.
But you have got to get the light gate set in exactly the right place so, if you are going to do that it needs some careful setting. But on that, once you've got the trolleys and the light gates set up I tend to say, 'right, this is the sort of information you want to try - try and work it out'. So on that one, it might be a little bit freer, they might get lots of results.

LN: With the plaster of Paris experiment you have just described, one I came to observe actually; there is that long period of time. I guess that might present problems for a teacher new to data-logging or any teacher I guess?

T5: Any teacher. The one thing that when we had all of our staff talking about using the new Emate in classes. The one thing they were concerned about was that if kids had been doing work on these things and then you transfer the work on to another computer for the teacher to look at, who's going to do all this transfer? When is it going to be done? How much time is it going to take? And it is that getting the information together which often falls on the shoulders of the teacher after the lesson - and that can be a real 'downer' because, you know, if you have got a morning to work on it then the students can do their investigation, they could go to the computer suite and they could generate the whole report. But of course most students rush off to their next lesson and don't think about it until they see you again.

LN: So this suggests I guess that when you are planning activities to build into schemes of work you need to be quite thoughtful about where data-logging is going to make a contribution, and where it can be managed in terms of the logistics of the process.

T5: Yes. Now that we have got technology college status, as from September, in our science development plan it says that 10% of our science teaching shall be delivered using ICT. Now I'm not very keen on that because it rather suggests you've got to do it for the sake of doing it. I think 10% might be rather high. Certainly you wouldn't do data-logging to that extent because I don't think you could manage it - it would start to look like data-logging for the sake of data-logging. But there are other things you could do - like the lesson I had this afternoon which is a different use of ICT. But I don't want staff to think 'oh I have got to do a data-logging here and I've got to do one here...' and each one of these is horrendous to set up. It is better if a piece of data-logging
can be done within a single class time and the benefit is that the
students get their information immediately and can store it on
disk themselves, come back next lesson perhaps and do a print out.
Although the limitation of printers is a problem.

[Telephone rings - break in recording]

LN: to raise another issue in this; if we can go back to the
skills the pupils need to use their data-logging; you’ve already
mentioned that together with you technician team you work hard to
get things set up so that the youngsters can come in ready to run
as it were. Do you see any specific skills that the youngsters
need in a data-logging lesson while the activity is in progress,
or perhaps in the follow up lessons - skills which might be
peculiar to data-logging, or are there just generic skills
deployed in an IT context perhaps?

T5: I don’t want their to be any special skills linked to data-
logging. As I said earlier, I like to think that we are just using
this machinery in order to get science data. If there is a skill,
it is more a skill of not being frightened by the computer - now
that is less than it used to be. Two or three years ago, you’d
get an awful lot of students who would sat ‘oh god it’s a
computer, I can’t possibly do anything with it’. That is less and
less the case, thank goodness. The other skill which I think they
probably need is being able to multitask themselves. That is wile
the machine is collecting data, they can be doing something else
valuable. Very often they don’t, they just sit and watch the
machine, instead of getting on with something else. So I tend to
go around and encourage them to do other things like writing up,
getting that side of things done. So, in terms of setting up the
hardware, plugging things in and so on, I don’t usually get the
students to worry about that, because I don’t think it matters so
much - not in Year 10 anyway. If they do this for more extended
project work later on, or in the sixth form, then they’ll learn
how to set up the equipment for themselves. But it is very
complicated in a class of 25 to 30 to say ‘there’s a box of
interfaces, there’s a box of temperature sensors, there’s your
computers - plug them together. They’d take all lesson doing that.
LN: Right, so your justification for having it set up first is to
save time...
T5: it is a complete waste of time to get the students to do it - it's a pointless exercise. If I wanted to teach them technician skills, then I would, but it's not on NC science.

LN: Can I pick up one thing you mentioned. You talked about students needing the ability to multitask, so they could do something else while the machine gathers data. Are there any circumstances where you've wanted the students to be engaged in looking at the data as it was gathering?

T5: Oh yes! If it's something which is happening more quickly, obviously with the trolleys they've got to be involved all the time because that is single shot things. If we're out in the field with a data-logging collecting information, then obviously they are immediately involved. They are going around selecting what data they are going to collect. If it's a relatively short change, perhaps a cooling exercise, then they might be watching it happening. The plaster of Paris was a particularly long one and for 20 minutes they just sat there and there was no temperature change. You had to say 'there's no point watching at the moment, it ain't going to do anything just at the moment'.

LN: Is there a classroom management issue here ... you've got lots of time with youngsters apparently having not much to do ... it's risky.

T5: That's right. I think you need to be aware that the experiment might, once they have set it up, just need to be left on its own. That comes within part of your classroom planning. So you say 'right, once you have got it set up you can leave it, you might give it the occasional stir just to see what is happening, but you can leave it, and start writing. But some students will always take the opportunity to say 'oh I'm watching it' and not do anything else. They are the ones that you've got to keep on saying 'come on there is something else to do here'. Yes that is part of the management, you do need to write it in as you do your lesson planning.

LN: And time is precious...

T5: absolutely, 50 minute lessons go no where.

LN: Do you think there are any skills that teachers need to develop? You have got quite an experienced department and you are
very experienced yourself, but if you were advising beginners, what kinds of skills would you...

T5: ...patience! Certainly you can’t go in with something like this and assume it is going to work because it is a computer. Start off by assuming it isn’t going to work! Try it out; you must, must try the experiment out just to see what the problems are with it. The problems are often not with the computer, they are with the experiment itself. People assume that because you’ve got a computer everything is going to be fine, but is isn’t. It is often the case that some problem is going to crop up. So the skill I suppose is good planning and know your experiment, know that you can do it and that your computers will work. Don’t assume that the technicians will have set everything up perfectly for you. Be familiar with the program you are using and the machinery you are using. Some people are not happy at all with BBCs, I don’t think you’ll ever get the situation where everybody is happy with the machine you are going to use, although we do try. As I say the Emates could be the way everybody seems quite keen on it at the moment and it will link into a data-logger fairly easily. It links into the LogIT system and we hope that it will be easier for people to work with rather than huge machines. The skill is managing the time. Most people have problems because they haven’t really thought out what they are doing.

LN: I guess one can apply those things to any new technique, not necessarily an IT based one.

T5: Yeah! Yeah, there’s nothing special about IT. I’ve seen exactly the same problem with people using videos. You know, you take your video set it up and the kids take no notice. That’s not how you use a video in class. You use a video in class by having a worksheet, being interactive with the video, by pausing it by talking... and anybody who uses a video by setting it up and letting it run is rally not classroom managing properly. But its no different.

End of tape.
*interview with T4:*

LN: What would you see as your rationale for wanting to use data-logging techniques?

T4: Right ... a number really. First of all it adds a new slant to science; it adds a new exciting means of operation that wasn’t there before. It brings a sort of relevance to students in this media age that perhaps we’ve lost by expecting students to just watch a colour change, or be ‘wowed’ by something happening in a test tube. So by offering data-logging we’re more in tune with what students expect for excitement. It adds that ‘wow factor’. Plus the fact that that it offers a greater level of precision that perhaps wasn’t there before. Plus the fact that it opens new opportunities to do practicals that weren’t there before, that either happen too quick or too slow, that we couldn’t really follow them. It offers some (threads?) for example a long term investigation - is that interesting if you say to the students ‘well we’ll come back to that next week’? Does that really maintain their interest? If you are data-logging it though, I’ve found that there is a real interest and excitement and anticipation of what is going to happen. Because you’ve actually got some data that has been generated over time. So there is one or two rationales! I think also of course, it is how industry is working. The idea of remote logging or logging some industrial process is also of relevance. Plus it gives us more freedom to do things with data that wasn’t there before, perhaps.

LN: So there is a range of possibilities with data-logging and you have touched on a lot of them there. What kinds of factors are influencing your choice over what you do?

T4: With data-logging? Right... I think, if you look at GCSE, for a starting point we’ve got to think of something that is ‘plug in and go’ basically. Something that is quite simple as a practical. The practical has got to be quite simple so that the technical problems that will arise will be to do with the data-logging. We don’t want a mix of quite a difficult practical and quite a difficult data-logging set up all in one. Because we’re going to have breakdowns and failures, we’ve got to eliminate as many of those as possible to keep it quite tight. Therefore I think we
start with something quite basic such as some sort of temperature cooling curve, or something. Perhaps put a new slant on it by getting students to make predictions about beaker X versus beaker Y. But that actual practical itself is relatively simple and therefore we can introduce data-logging to that without any difficulty. Starting with temperature sensors that we know are quite robust and we know are easy to handle - they don’t need calibration etc. That therefore comes into the equation on where we start with data-logging. Go back to the question again...

LN: ... thinking about the sorts of influences that will help you to select particular activities or approaches.... You’ve talked about wanting to choose a practical method which is going to succeed with the pupils; that’s about a successful experience of practical work. Using data-logging techniques or equipment which is robust and reliable. Other kinds of things spring to mind?

T4: It opens new opportunities to explore things that we couldn’t do before. For example we’ve started logging from balances. So I have started to think about what I can measure with a balance. So we have started using mass potometers which weren’t there before. Perhaps we are trying things with pH and oxygen that we didn’t do before because there was no easy way of doing that in biology.

LN: Are you finding that you have to choose particular activities because you think about the people who are going to be using them? If you are planning for other people, teachers or pupils, would that influence you?

T4: Yes, definitely. Going back to this point about the temperatures sensor. It is the one we use most because I think most people can get to grips with that and it is easy to use. The other ones can start to become a bit tricky in all sorts of ways. In terms of the robustness of the probes, say pH or oxygen; you have a very sensitive probe which can be easily damaged. Therefore I would think twice before I started giving that to all 450 students in Year 10 to look at. There is some issue here about how often they are used and with whom they are used. So far, we’ve experimented with those at A level, with the more trustworthy students, and we’ve just got to see how that works and how much attrition we get from our kit before we decide to take that further.
LN: Thinking about some of the A level work you invited me to see. You have some quite sophisticated procedures that were working very well, but they need a measure of confidence from the teacher in knowing how to manage those and set them up.

T4: Well, to some extent. But I think we have alleviated that by putting the onus on the student to sort it out. So that enzyme circus you saw was very much to do with ... rather than delivering to the students and saying 'right at the end of the lesson you will have done this...' we give them three or four weeks in which they expected to have something by the end. Therefore you plan for problems, your recognise that the first week round students are going to cock it up, and not get results. They'll recognise where the fault was and therefore they come back to it the next week and realise that they are going to have to do things differently. Therefore it doesn't really matter about the expertise of the teacher because, given the competence of the students we have at this college, they can solve it for themselves. The beauty of that is that although I do have to run round and sort things out, you get students that suddenly realise that their battery has gone down and so they go off to the technician for themselves. So this is really good science because they are just not doing the practical, but they are thinking through the technical problems they have got and solving it for themselves.

LN: Do you see the beginnings of that with pupils in Year 10 and 11?

T4: Yes. That's the thing with Year 12. They have already had the experience in Y10 and Y11 of using temperature sensors and perhaps one or two others, and therefore they start to recognise that the kit can be fragile. But they don't dismiss it and think 'oh god this is going to go wrong - computers!!' and stand back from that. They start to recognise that they have got to be more patient with it and that they will run into problems.

LN: Have you ever come across youngsters who do 'stand back' in the way you were hinting at there?

T4: ...and don't get involved?

LN: ... who are perhaps fearful of using the technology?

T4: Yes -ish. I would always be looking round the classroom to see who wasn't getting involved and to make sure they do get involved.
Because I don't actually believe that they are fearful to the extent that they don't want to use it; I think it is a confidence thing.

LN: I was wondering if data-logging methods are so commonplace that it is something youngsters just take in their stride?

T4: I would like to think so. With some of the kit they are using, I can't see why any of our students here would have a problem using a temperature sensor and a logger. When you start to use a pH sensor which needs to be set to pH 7 each time, then there start to be new problems; but they're not insurmountable. Yes I think they can deal with it.

LN: This is very encouraging isn't it!

T4: However, I do tend to use data-logging with all students, no matter what ability. The extent to which other staff have taken that on is variable. I suspect that's more down to their IT expertise rather than their belief in the students' ability to do it. I suspect that other staff may feel uncomfortable if something goes wrong, whether they will be able to deal with it at GCSE; with large sets [of students] and all the problems inherent with that. So there's not the same situation with Year 12, with class management issues, some staff are uneasy with the use of large amounts of technology.

LN: Because it adds to the management burden?

T4: Yes.

LN: I think I understand what you are saying. If you are working with something new like that, then it makes the issue of managing a group of pupils more difficult. One extra thing to worry about?

T4: Yes, if a machine goes down, then some staff who are not familiar, may not recognise straight away what the problem will be; cannot diagnose it and therefore will end up spending an inordinate amount of time sorting that one problem out, and therefore they are away from the rest of the class and you have got a control problem. Now we have got certain things in place to get over that; we write worksheets that are very prescriptive. So to a lot of students you can say 'OK you've got a problem here, have you read the instructions?'. This throws it back to the students again to sort it out and not getting yourself involved in sorting it out for them. Also we tend to have back up kit, so if a
data logger goes down, we don’t have to try and solve it there and then. We make sure we’ve got spares so you just replace it and say ‘try that one’. So there are all sorts of ways to perhaps try to help that.

LN: That seems to me to depend very heavily on careful thinking about what you are going to do...

T4: Yes, that’s right...

LN: ... anticipating problems.

T4: We have thought this through and because we are using it we have hit a lot of the problems that do occur.

LN: What about the national curriculum - how does that shape what you do?

T4: Gosh! Is this on tape?? We look at our syllabus, and the syllabus has probably sorted for us, what we need to deliver and they will have looked at the national curriculum.

LN: Well, I’m not testing your knowledge ! ! ! What I am thinking about is whether there are demands within your syllabus, say. Which mean that you need to be using data-logging techniques with particular activities or whether the demands might limit what you can do?

T4: Our syllabus does not make any statements at GCSE or A level that they must use this kit. I think in chemistry A level there may be a suggestion that students do things by certain means, but I suspect that they recognise that a lot of schools cannot afford to do it by technological means and therefore I don’t think syllabuses are that prescriptive. So I tend to look at the syllabus and think ‘oh there is an opportunity’ rather than it being dictated to us.

LN: Do you see any opportunities for youngsters to be using data-logging for working on data after they have collected it?

T4: At A level there is a lot of post data-logging analysis where they may look into gradients. They may export their data into Excel and do things with it. Or use the software itself to find out gradients - Datadisc software can do that. At GCSE I think, perhaps because we are biologists, that’s different to a physicist or a chemist, I am more interested in logging the phenomenon as it were. Actually seeing as it happens or retrospectively on the
graph, what is the relationship between variables. There are one or two occasions where we take it further, for example at GCSE we would ask them to make predictions about what they would expect the rate of fall of temperature to be, and to think about surface area to volume ratio. Then compare those predictions with the actual. Probably that's as far as we have gone with it. In a lot of cases it is a case of comparing A versus B and was it quicker or slower, or what happened over time: not using numerical analysis further than that.

LN: It interests me that you are talking about getting the youngsters to predict things, before they get their hands on the data-logging equipment.

T4: Yes, it is a case of trying to engage the students and think about what is going to interest them. And to pose them a problem and to make predictions is, I think, part of a good lesson in which you are trying to make sure students are thinking for themselves and hopefully explore something. By the end of it if they have confirmed what they believe, or may be it is the opposite of what they believed. That's a good techniques, if you can get something to be not so obvious, then it maintains interest.

LN: Do you think there are more opportunities for that kind of thing in the data-logging context than in other contexts.

T4: I don't see why; I don't think there's anything... let me think about that for a second! ....... No, I don't think data-logging is necessary for that. Do you?

LN: No! I think there are things that you can do with data-logging that are quicker. So that there is the potential for more of those cycles of predict / observe / explain. But it is a good teaching approach whenever you are doing practical. I'm not sure there's anything special about data-logging in relation to that.

But I am interested to explore with you your view about the skills that youngsters need to be able to data-log. You hinted at these earlier on - students taking responsibility etc. Does your experience led you to the view that there are specific skills that need to be developed for data-logging that you set about teaching perhaps?
T4: I think it makes a lot of demand on their practical ability. I don't know if we are losing that skill, but it seems to me that students need as many opportunities as possible to practise those skills. Data-logging provides an opportunity to test them at the highest level because of the trickiness of what they have got to set up. I find that really useful. They've been able to read a set of instructions and go from that to physically set it up, and follow a set of guidelines. It seems to be a tricky skill for students and data-logging tests that. I do introduce it as a worksheet, prescriptive set of guidelines and it is amazing how students cannot follow that and will tend to turn to you before they will turn to the sheet. There is a whole host of IT skills on the actual downloading of the DL-plus on to the computer, and it tests their understanding of Windows, how to use drop down menus etc.

LN: So one has got to assume a level of competence in those before your students are going to successfully be able to download data and do any analysis. What about skills for teachers?

T4: What are we asking? Do we need...

LN: are there new skills that teachers need to acquire to be able to data-logging?

T4: Besides the IT expertise? ... ... [pause, thinking]

LN: there is a confidence issue for some... ... maybe not?

T4: I don't know, let me think. ... I think it really tests teachers' ability to manage the classroom doesn't it? But any practical does that.

LN: What I'm wondering is if there is anything to do with the newness of it? Perhaps you have got to a phase here now where things are very smoothly organised and they run well. But if you introduce something new, I wonder if there might be skills of innovation.

T4: That's true. There is also the resourcing of that practical; the planning through of what you are trying to achieve and thinking through the pitfalls. I suppose that applies to any practical though doesn't it? That liaison with your IT technician and your science technician to make sure the kit is in place and that it is going to work. I think it puts higher demands on that side of things than perhaps other practicals.
LN: Might we be trying to achieve something different with the data-logging practical as opposed to a non-IT approach to that practical?

T4: In what sense - the educational outcomes ... what do you mean?

LN: I was pondering on whether, if you think about a temperature based experiment and you decide on an IT or non-IT approach to that, in a way your science goals are likely to be the same. So I wonder if there might be other goals that one might have in an IT approach...

T4: besides the fact that you are using an industry standard way of doing things, that your are putting more demands on their IT skills and practical skills, which we've mentioned. I don't know ... and the wow factor. Well had you something in mind then?

LN: Well, I wonder if there are opportunities to develop experimental skills - things like producing hypotheses, testing them out, exploring data.

T4: Yeah I agree; we mentioned that didn't we? ... I wonder if it tests their ability to work in groups more. I think there is something about when you do anything with technology, there is more realism to it - the students take it more seriously. It matters what data they capture, it becomes far more relevant or meaningful than just take a few numbers down as the thermometer changes. I wonder if because there is that onus to get it right as it were, because it is obvious if they've got it right or not, then it develops a far more co-operative, skill between student to get it to work and to get the practical done. Going back to 'getting it right' I think that's quite an interesting one because there is not the opportunity for the students to say 'what's everybody else getting?' they cannot make their results up and so there is an onus to ... and it is obvious to the teacher what students have done. You can sometimes see errors in the data where they may have pulled the probe out or turned the sensor off; and so perhaps we actually get real results.

LN: Do you think they are interacting more with their data?

T4: Yes, definitely, definitely. It happens with a lot of IT. The data-logging stuff...... there's a real interest 'why's it going down' or 'look at that one compared with that line'. All sorts of things are opened up there. That applies to a lot of IT, whereas for some
reason, if you see it on the computer it has a meaning rather than just your bit of data that you have gathered on a piece of paper.

LN: Is that because the data is presented as a graph...

T4: Yeah, on the DL-plus they can be looking at the graph as it goes along.

LN: Yes because they actually see the graph on that little display...

T4: yeah and there is also the readout on the sensor, so they may have seen it start at 8 degrees C and see it fall to 6 degrees C.

LN: There is an issue in that which interest me which is to do with what kids do while the data-logging equipment is collecting the data. You have suggested that the kids are quite engaged with the data.

T4: I think for a while, but again it is class management. You have got to recognise that once it has started it frees them up. It depends on what you are doing, maybe there are some that require active involvement all the time, that may be setting up the next run or it might be stirring the thing. But you have got to be aware that because you are data-logging it does free the students up. So therefore what I tend to do with the worksheet I have developed is to ask questions that they can do as the experiment I going on. Perhaps asking them to think about that practical a bit more- asking them ‘is this a fair test?’, ‘what controls would be useful?’, ‘what do you expect to happen?’ etc. etc. So it’s engaging them still in that practical but it is keeping them on task while their hands are free.

LN: I take the point about the classroom management issue there. I wonder if you have ever felt a tension between wanting manage their activity in that kind of way and distracting them from the gathering data?

T4: Sorry, so you are saying?

LN: Well I wonder if the pressure perhaps to manage youngsters in a group practical - which is a very complex situation from the teacher’s point of view - might lead the teacher to distract youngsters’ attention away from data gathering into some other activity?
T4: Well I think you draw a happy medium where, if you believe the students are gleaning something from observing what they are doing then that's fine. But as soon as you start to see students larking about then you make sure they are on task, by doing something. I'm all in favour of the first one if that is the case and there is something constructive to be got, some sort of educational outcome from actually watching that data 'as it happens'. But if it's not then I would prefer for them to be pushing on to something else.

LN: So a teacher who is new to using IT in science would need to 'wake up' to the possibility of youngsters having wait times.

T4: Yes I agree, and it is something that has occurred to me is that to start with you think 'right we're introducing data-logging it's going to be a cracking practical' and you suddenly realise that you do free up this time and it is something that you don't take into consideration when you are thinking through your practical, if you are not careful. It is drawing that happy medium isn't it?

LN: Well look, your IT s very well developed here, so what would you like to develop, where would you like to go next?

T4: With data-logging I would like to see it more widely spread. I think we all engage a certain amount or have actives with data-logging involved. I think we could do more with different types of sensors and open new experiments up. I think we could ... well SC.1 interests me. People have said 'presume you use this in Sc.1' and we don't. We're are asked to produce precision instrumentation etc. in SC.1 and yet we don't use our data-logging for that. Probably that is the nature of the practicals we do, but I have thought yes we could; but the we have got so many students here that we haven't got the kit to deliver it to every one and give everyone a fair shot, if we are going to use data-logging. We can't give that to 450 Year 10s all at once. But perhaps there is some future there if we can think of something suitable, so that students that need that level on their SC.1 can get it through the use of data-logging.

[Tape ends]

Other issues raised include the link between data-logging and control processes e.g. fermentation. Which models industrial applications of control technology.
YOUR TASK Most students will have heard of the "greenhouse effect". This investigation sets out to find out if high levels of carbon dioxide gas could cause a "warming up" of the atmosphere.

Your task is to try and find out if carbon dioxide could act as a "greenhouse gas".

WHAT TO DO

Set up the equipment with at least two plastic bottles. One bottle should act as a control and contain normal air whereas the other bottle should contain carbon dioxide. This can be produced by placing an AlkaSeltzer tablet in a small amount of water in the bottom of the bottle.

The two temperature sensors are inserted through rubber bungs or corks once the tablet has dissolved.

Switch on the lamp (which acts as the sun) and place it about 6 to 10 cm from bottles. Select AS IT HAPPENS followed by GRAPH. Record the temperature increase in both bottles over the next 30 minutes.

If the temperature does not appear to rise much bring the lamp slightly closer.

ABOUT YOUR RESULTS

Use the ZOOM option to display your results more clearly.

Does the temperature in the bottle containing carbon dioxide rise more than the bottle containing air? If so by how much?

Are your results reliable?

How could you alter your investigation to ensure that the difference in temperature at the end was due to the two different gases and not because the bulb was closer to one of the bottles?

OTHER IDEAS TO THINK ABOUT AND TRY OUT

How can you make your investigation more reliable so that you can be sure the difference in temperature between CO2 and air at the end of the warming period is due to the two gases?

What effect does different coloured light have on the temperature change? Try using felt tips to colour the plastic bottle or use a sheet of thin coloured plastic to wrap around the bottles.

Do other gases produce a "greenhouse effect"? Try natural gas (methane) but be careful not to have any naked flames near the bottle.
Data Logging

Logging the levels in and around the school

The Experiment

1. You are going to take the Logit around the school to record the level of light in different locations.

2. Check that a light sensor is plugged into socket number one of the LogIT.

3. You will also each need to complete a Route Timetable sheet by writing down the time as you pass each named place.

4. To start logging press the Green button twice (The LED will flash). Do not press the buttons again until you are ready to download.

5. Your journey should last about 5 minutes.

6. To make the test fair hold the LogIT steadily in a fixed position as you walk.

7. Stop logging when you return to the classroom. Press the Green followed by the Red buttons on the LogIT.

8. You will now need to download the information from the LogIT into the computer. (See Downloading)

In your best books

- a) Write the Titles
- b) Put in the graph
- c) Put in your Route Timetable
- d) Write each location on the correct part of your graph.
- e) Analyse your graph to explain how the light levels changed at different locations. Where were the levels highest and lowest? Where did they change gradually and suddenly?

Downloading

9. Connect the LogIT to the computer with the link cable.

10. Press the LogIT Green button once

Use the mouse to click on the following commands

11. Collect

12. Remote

13. Check that “Fetch data set 1” is displayed

14. O.K.

15. Switch off the LogIT (Press Green then Red)
Data Logging

Investigating the temperature changes as chemicals are added to water

Connect the LogIT to the PC with the link cable and set up the apparatus as shown.

Timescale
If the Time scale on the computer display does not end at 4 minutes, mouse click on:
Setup
Timespan
+/-(until 4 mins shows)
OK then Continue

1. Start logging the water temperature as follows
   i) Press the LogIT green button twice
   ii) Mouse - Click on start (Choose continue if asked)

2. When your graph is progressing steadily, Add all the pieces of calcium to 2cm of water in the boiling tube.

3. After 4 minutes Switch off the logit. Press the Logit's green then red buttons

4. Repeat the whole experiment again but use ammonium nitrate instead of Calcium.

5. In your best books put:
   - Title
   - Method
   - Diagram
   - Results (labelled graphs)
   - Conclusion

   Explain how the graphs changed (by how much and what this shows).
   Find out what the words Exothermic and Endothermic mean and include them in your conclusion.
APPENDIX 12

Skills developed by lessons 1-4 of
*Understanding Insight*

Hiding and showing graph lines
Using the 'zoom' feature
Changing the appearance of graph points
Using cursors to take readings
Locking the cursors
Using the bar display to show changes
Measuring changes
Measuring time intervals
Describing the features of graphs
Measuring changeover certain time intervals
Graph talk: some observations and reflections on students' data-logging

Leonard Newton

Observations of students using data-logging indicate that talk can lead them to a better appreciation of data.

With the development of sensors, interfaces and software, new approaches to practical work in science have emerged through the use of data-logging techniques. Despite the growing awareness of these techniques, their benefits for learners have proved difficult to study and have perhaps been less widely appreciated. In this article, I wish to consider briefly some aspects of research that may throw light on the use of IT in practical science teaching. I then describe some observations of relatively inexperienced students making use of data-logging; in particular, I wish to draw attention to aspects of their talk about real-time graphs which may be beneficial. Finally, I will consider the implications of these findings for teachers designing data-logging activities for use with their own students.

Managing IT settings

The ways in which data-logging can influence the teaching and learning of science have been explored in a number of recent studies; for example Barton, 1997. An important feature of this work is the increasing interest in teachers' management of students' learning, rather than in matters of a more technical nature. Issues relating to the design and presentation of activities that exploit the new technologies, the contexts in which they are set, and the ways in which these can encourage students' collaborative activity, are receiving more attention (Mercer, 1994).

Research has also shown that data-logging techniques can save a significant proportion of lesson time because of the relative ease with which experimental data is captured and presented (Rogers and Wild, 1996). The question arises of what use students can make of this time-bonus. Experiments can be readily repeated, generating more data for analysis for example; or students can manipulate the parameters of experiments and re-run them, allowing more investigative styles of working. These decisions are usually under the control of teachers, and students may need some encouragement or training to feel confident in taking on this responsibility. Teachers may also need to be prepared to cede more control to students, to foster a more investigative approach.

Interactions in IT settings

The interactions between participants have an additional dimension in IT-based work. Typical laboratory interactions can still be seen; however, in data-logging activities the computer becomes an additional player. The computer can fulfill various roles in the group setting: as information provider; as a 'respondent' to questions asked of data; as an arbiter of disputes. Students and teachers can interact with the output from the computer and respond to it with
Student data-logging

Newton

questions, commands or changes in their actions. In this sense, the computer is an important influence in shaping the learning context for the students (Kelly and Crawford, 1996).

Users' decisions determine how the various 'roles' of the computer are exploited. Such decisions are likely to be heavily influenced by the participants' prior experience of science lessons. With IT, users require experience of the computer tools to extend their repertoire of data collection and analysis strategies, and to develop some vision of their potential contribution.

Real-time data-logging

Real-time data-logging presents a graph drawn on a screen 'as it happens'. The simultaneous presentation of a graph as the students watch their experiment has the potential to help them relate the graphical image to the observed experimental events.

At face value, some experiments are better suited to data-logging techniques than others. Heating and cooling experiments are popular choices for students' early data-logging experience. However, they do not always afford all the benefits of real-time data-logging because there is often little for students to observe as the experiment progresses, other than the temperature change itself. Nevertheless, in my own research, students using IT in such experiments have been observed to react to computer generated real-time graphs in ways which suggest that the presentation of graphs in this form is of great value.

Case study scenario

Observations of year 7 and 8 students beginning to use data-logging techniques have revealed their use of interesting language to describe graphs. The students observed were of mixed ability, and worked in groups of three on a simple data-logging experiment as part of an enrichment activity to enhance their experience of IT in science. They also had opportunities to use CD-ROM and Internet facilities to gather information on the theme of the greenhouse effect.

It is important to note that the primary objective in these practical lessons was for the pupils to have experience of learning to use the data-logging equipment. In this respect, learning about the greenhouse effect was of less importance, although it provided a connecting theme for the students' work.

Students carried out a simple experiment to record the temperature of gases in plastic drinks bottles, containing air and air enriched with carbon dioxide, which were heated by a 100 W lamp. Students used temperature sensors connected to LogIT data-loggers and Acorn Pocket Book computers running LogIT software, to compare the temperature changes in real-time. At the start of the lesson, the teacher gave a demonstration of how to assemble the equipment and manage the data-logging software. Students were asked to see what happened to the temperatures in the two bottles when the bulb was switched on. The activity of groups of students was observed, and their talk was recorded on audio-tape.

At the end of each session, the students were invited to write an individual response to contribute to a structured diary of their work. As well as noting what they had done as groups and as individuals, the students were asked to identify features of their activity which they had particularly enjoyed or not enjoyed.

Using the 'time bonus'

It has been previously suggested that the time bonus generated by data-logging techniques is not necessarily productively used. There can be an apparent increase in students' off-task activity (Rogers and Wild, 1996). Observations for the present study indicate that some student groups do spend time apparently doing little more than watching the equipment log the data and present the graph. Analysis of the students' lesson diaries revealed that, whilst many particularly liked handling the equipment and doing the experiment, they also disliked passively watching the experiment. These were some of the students' diary comments:

I didn't enjoy just sitting around and just watching the bottles and the palm top.

I did not enjoy watching the lines going up or down or staying the same.

I did not enjoy waiting for the temperature to rise and watching it rise.

These statements suggest that the apparent waiting times could lead to students becoming bored with their experiment. There is a danger of students being 'switched off' and not engaging with the activity or its outcome, or being distracted into some side activity.

For this risk to be avoided, there is a clear need for the students' activity to be carefully structured. One option may be to get students to write up their experiment during the wait time, but this strategy
deprives them of one of the key benefits of real-time data-logging, as suggested above. It is better perhaps for the students to be encouraged to think about their data as they appear on the screen, by providing some prompting strategies or activity.

In order to understand more fully what students are doing as their experiment is running, and to look for examples of talk related to data, tape-recordings of group talk were made and transcribed.

**Graph talk**

Study of the transcripts of talk occurring during the data-logging task reveals a number of interesting features. The kinds of talk which take place relate to the various phases of the students' experimental activity.

First, a large proportion of the recorded talk is of a type that might be termed 'operational talk': talk concerned with students setting up and managing equipment. It is not surprising that this kind of verbal interaction occupied so much of the lesson time. These students were novice IT users. They might be expected to direct much of their attention to equipment issues, since they were becoming familiar with setting it up and using it. In the process they encountered problems of positioning of sensors or of managing software which they needed to solve in order to get the experiment working. Of course, these are important aspects of students' developing skills in Experimental and Investigative Science (National Curriculum, Sci.), and they form a part of any practical activity.

Once the experiment is set up and the data are being logged, a proportion of the students' talk relates to the gathering display of data. During this second phase of the practical work, students have been observed reporting to each other on the data. These exchanges constitute a verbal commentary on the data. In real-time data-logging, the graphical display provides students with the data in a format which seems to encourage qualitative description and comparison. The following recorded exchanges illustrate the point:

Note: The computer display shows the two line graphs and a digital display of the temperature values being recorded by the sensors in the two bottles.

S1: *It's working.*
S2: *Number 2 is a bit higher* [S1 *hmm's agreement*]... [indecipherable] *is the carbon dioxide...*
Student data-logging

S3: Which one's Y? [This refers to the digital display of temperatures and time scale (y axis); the student is apparently not clear about the relationship between the graph and these numerical displays.]

S2: 1, 2. I reckon, yeah, because look at the temperatures; 1, 1. Y is 22.77 and 2 is 22.7, so number 2 is rising and number 1 is just staying.

S3: Number 1's rising.

S2: They're both rising.

S3: None of them has overtaken yet.

S2: It looks like it's gonna overtake.

S3: It looks like it's going to, it might.

S2: It has! They're not the same, oh my life! Number 2's taken over. 2's 23.4.

S3: It's taken over quite a bit, only just taken over though.

Pause

S3: Carbon dioxide's hotter.

In this exchange the students' comparisons of the two data sets have the flavour of a race. The collaboration between the students revealed in these exchanges, and the elements of competition they introduce into their descriptions of the emerging data, seem to focus their attention on the data.

An important skill in Science at key stages 3 and 4 is the ability of students to identify trends and patterns in results. At key stage 3, students need to be able to use results to draw conclusions and make a decision about the results in relation to their predictions. Progression at key stage 4 requires that the relationships between variables be considered; this may demand a more quantitative approach. Encouraging students to consider data qualitatively as a first step is likely to allow them much easier access to the meaning of the data than if they have to grapple with manipulation of quantitative data to construct a graph and then to describe any trends. The higher order skill of quantitative description of the variable relationships may be more successfully accomplished as a result of familiarity with trends in the data.

However, a study of students' performance in graphical tasks, carried out on data collected under the auspices of the Assessment of Performance Unit (Swatton and Taylor, 1994), reported that many students only most readily described the obvious features of graphs. They also appeared to see graphs as 'pictures' of one variable rather than as a representation of a relationship between variables. The authors suggest that the ability to describe relationships between variables is dependent on students understanding what a graph represents and on helping them to acquire the vocabulary required to translate the graphical image into an appropriate verbal form.

In my own studies of students' talk about their real-time graphs, there are examples of students' perceptions of the graph as a single variable image. However, there are two features of the data-logging graph that appear to offer the students the potential to develop a deeper understanding of the variable relationship displayed by the graph. Firstly, the graph is produced as it happens in time. This may serve to emphasise the time variable because it becomes a more prominent feature of the graph than in a 'static' graph produced after the event. Further, a software feature which automatically re-scales the time axis as the experiment progresses, may emphasise the graphical image as having two variable components. These two features may help to direct students' attention more effectively to meaningful parts of the graphs.

A second useful characteristic of the experiment described is that it generates two data sets that are simultaneously displayed by the computer. This encourages the students to make comparisons between the two lines on the graph. It appears to prompt students to look at features of the graphs a little more critically. In short, there is potentially much more for the students to observe and to talk about in the real-time graphical display than in traditional graphs.

Teacher interventions

I have indicated that much of students' talk about their graphs is of a descriptive nature. The ability of students to describe trends in graphs is, of course, an important skill and one which can help pave the way to students successfully articulating the variable relationships shown by graphs.

It is likely that some students may be able to describe patterns in graphs using the kind of everyday language illustrated above, without appreciating the underlying meaning or significance of the graphs themselves. There is no reason to suppose that exposing students to real-time graphs will of itself lead to students' developing this deeper understanding. On the contrary, one might expect that, as with many other skills, students need to be guided in their thinking and taught how to tackle these problems.

A significant feature of the recordings made in the present study reveals that the quality of the students'
talk about their data improves in discussion with the teacher. This is illustrated in the following two edited extracts:

**Extract 1: Exchange between year 7 girls and the teacher**

T: Right what's happening now?
S1: They've gone.
S2: They've broken away, it's gone from 20 to 22.
T: Which is the one with the carbon dioxide? That one there?
S2: Number 2.
T: That's number 2. ... Did they both start off at the same?
S2: No, number 2 was a bit ahead.
T: Ahead slightly, what do you mean by ahead?
S1: It was slightly hotter.
T: By how much? Did you...
S2: About 10 degrees.
T: When you say 10 degrees, do you mean...
S2: The second number.
T: Right, that's point 1 degree, yeah?, because these are...

An interruption occurred at this point.
T: OK, so these are 22 degrees now, that's the decimal point and then its 'points', tenths ... of a degree, OK? So the difference at the moment is 1.5 degrees, one and a half degrees approximately, OK?

**Extract 2: Exchange between a year 8 boy and the teacher**

T: You know that you've had to adjust your lamp? Will that affect the way your graph looks, do you think?
S: Yeah.
T: How might it change the way the graph looks?
S: Er, when it moves closer the graph goes higher but when it moves away it start to stabilise.
T: So, might that confuse you when you look at the graph to compare the two bottles?
S: Yeah, it might actually!
T: Can you see any point on the graph where you think that might be where you've moved the bulb?
S: There.
T: What's happened there?

These exchanges indicate that students can identify important features of their graphs and relate them to their experiments. However, the teacher has a key role in directing the students' attention to these features and in prompting their thinking. By asking open questions that encourage the students to formulate their own responses, teachers can help students think more critically about their data.

**Implications for teaching**

In this article, I have attempted to draw attention to students' perceptions of data-logging experiments and their activity in this kind of practical work as indicated by their talk. It is important to acknowledge that the reflections offered here are based on limited observations of novice students. Nevertheless, some important features of their activity emerge which, I suggest, have implications for teachers planning IT-based lessons.

First, the students who were the subjects for this study exhibited a lot of interest and enthusiasm for doing experiments and using data-logging equipment. However, that enthusiasm was dampened for some by an apparent lack of things to do while the system recorded data. This observation indicates that student activity needs to be planned and prompted for all phases of an experiment, with the prospect of the students becoming more self-reliant as they become more experienced.

Secondly, the appearance of real-time graphs on screens does seem to focus students' interest on the graph and encourage its qualitative description. The language used by students necessarily draws on their existing vocabulary and involves extensive use of metaphor to describe the data. Much of this vocabulary is unscientific, and teachers have a crucial role in helping students to acquire and use more 'acceptable' language to talk about the details of graphs. This needs to involve the teacher by engaging with the students in discussion of their data, and sharing more scientifically acceptable verbal translations of the graphical image. As Dreyfus and Mazouz (1992) have suggested, features of graphs (for example, slopes) are the concepts of the 'language' of graphs through which meanings about them are conveyed. Without practice in the use of appropriate vocabulary, it may be difficult for students to progress from qualitative description to quantitative description of variable relationships.

A third important issue concerns the apparent need for training in thinking about data. This also relates to...
the need for students to become practised in talking about graphs. The observations noted above suggest that students can identify and talk about more than the superficial features of their graphs. However, students do not appear to identify these subtleties intuitively; they need to become practised in tuning in to them. By asking students to describe parts of a graph, to make comparisons, or to relate experimental events to particular graphical features, teachers’ interventions can help to focus students’ attention on these features. The use of appropriate questioning techniques enables students to demonstrate their understanding more explicitly.

Finally, the issues raised above point to the key role of the teacher as a manager of students’ learning. Far from being diminished in IT settings, management decisions require careful consideration by the teacher. The students involved in the above study were enthusiastic about IT, but their interactions with the teacher were important in maximising the potential benefits from its use.

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References

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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.

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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
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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.

![Diagram](image)

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
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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.
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. Software-supported exploration and interpretation of graphical data.
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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>
</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.
Lesson Phase Purpose

**Orientation**
- Set the scene
- Stimulate interest
- Define a problem
- Identify variables

**Planning**
- Exploatory class or group discussion
- Generate pupil questions
- Demonstration & discussion
- Interactive teacher exposition

**Operation**
- Gather data
- Monitor equipment
- Observe events
- Compare predicted outcomes

**Review**
- Personal reporting
- Group discussion: "say what you see"
- Group discussion & report back
- Controlling equipment
- Using software tools to analyse data

Types of Activity

- Interactive teacher exposition
- Demonstration & discussion
- Group discussion & report back
- Exploratory class or group discussion
- Generating pupil questions
- Defining the question
- Identifying variables
- Stimulating interest
- Setting the scene

Figure 3: Model structure of a data-logging lesson.
LEONARD R. NEWTON

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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Insight 2 software is available from Longman Logotron, 124 Cambridge Science Park, Milton Road, Cambridge CB4 4ZS, United Kingdom.
Data-logging in practical science: research and reality

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Considerable importance has been attached to the use of computer-based approaches to UK science teaching. Data-logging techniques have been available for some time but, despite research findings identifying their benefits, they appear to be under-used. This article sets out some of these benefits and describes research into routine use of data-logging in some UK secondary schools. The interview data presented reveal that implementation of data-logging in classrooms is not straightforward. It is shaped by a complex set of influences including provision of resources, planning strategies and the level of teachers' understandings of the scope and potential of data-logging activities. It is argued that these issues need to be better understood in teacher's own educational contexts if the higher order benefits of data-logging for pupils are to be secured.

Introduction

Data-logging methods (occasionally known outside the UK as microcomputer based laboratories (MBL)) involve the use of electronic devices to sense, measure and record physical parameters in experimental settings. Data can be collected remotely using a data-logger and subsequently downloaded into a computer. Alternatively, in 'real-time' data-logging, measurements are made and displayed almost instantaneously on the computer screen. Data collected in these ways can be displayed in tables and graphs; recent dedicated data-logging software also allows for sophisticated analysis of data. With the development of hand-held 'pocket book' computers, it is now possible to complete the whole cycle of data collection, storage, display and analysis in a wide variety of experimental settings at (and away from) the laboratory bench.

This article surveys some of the benefits claimed for data-logging methods that have been identified through research. It discusses findings from research, which sought to explore the translation of these benefits into the 'real-world' of science classrooms, and which identify more clearly the range of influences on science teachers adopting and developing data-logging methods.

Prospects for ICT from research

The application of new technology to science education offers a contemporary approach to practical work in schools. Researchers in the UK and elsewhere have been interested for some time in the possible value added to the pupils'
learning experience by computer-based approaches. Some of this research has been set within the general context of effective computer use in the science classroom, whilst other studies have focused more specifically on the use of data-logging by pupils in practical settings (Harlen 1999). Computer-based approaches can have labour saving benefits, but there are benefits which can be considered to be of a higher order than the time-saving effects associated with new technologies. Several important themes emerge from published research in this field.

In the UK, for example, Rogers and Wild (1994, 1996) studied the laboratory use of data-logging in a small number of schools. This study identified certain attributes of the data-logging approach which appear to have potential benefits for pupils. It indicated the importance of the context of use and teaching approach adopted for the achievement of these benefits. More recently, Rogers (1997) has described the development of software tools, which afford new opportunities for pupils to explore data and so offer further potential benefits for pupils’ investigative work.

Barton (1997) has reported a comparative study of the computer approach to graphing with pupils of secondary school age. This research provided evidence of the contribution computer-generated graphs of data can make to pupil’s appreciation of the meaning in the data, and of the advantages of computer-drawn graphs over manual ‘pencil and paper’ methods.

In a review of research, Weller (1996) considered the benefits of new technology for science learners. With respect to data-logging, research indicates that the opportunity to collect and work on first-hand experimental data offers genuinely scientific experiences to pupils. Moreover, data-logging can contribute to pupils’ skills in scientific inquiry and add to their understanding and interpretation of graphically presented information.

In North America, the Technology-Enhanced Secondary Science Instruction (TESSI) project, where a wide range of technology was fully integrated with carefully structured teaching approaches, has reported findings that pupils in IT-rich settings began to work in more independent ways (Pedretti et al. 1998). These researchers have identified the importance of the social dimension in pupils’ personal response to this learning environment. Like Rogers and Wild, they recognize that factors other than the attributes of the technology appear to be influential in the successful integration and use of new technologies in the classroom.

Research interest has also focused on pupils’ conversations in computer environments. This focus concerns the value of spoken interactions and socially constructed understandings between individuals working at the computer. The rationale for this approach comes from social constructivist psychology (Mercer 1995). In the UK, the Spoken Language and New Technology (SLANT) project has identified the occurrence of educationally useful kinds of talk in IT settings in Primary School contexts (Mercer 1994). Related work, again with younger pupils, has been carried out in Australia and has revealed similar patterns in pupils’ discourse in computer-based settings (Wild and Braid 1996).

In the USA, discourse analysis techniques have been applied to MBL work in twelfth grade (post-sixteen) physics classes and have revealed aspects of the role of the computer in group work. The pattern of group interactions indicated that the computer could be seen as a group member in conversation because of its ability to contribute information for discussion. However, these contributions needed to be interpreted by pupils through their group talk. Pupils drew on the computer
representations for support in their developing thinking in experimental work (Kelly and Crawford 1996).

One of the benefits of data-logging methods is that they can apparently allow pupils to take more responsibility in practical work. Automatic data collection and graphing reduces the pupils' need for support from the teacher. However, the value of teacher intervention remains high in IT-based lessons. Teacher interventions can mediate pupils' interpretations of computer presented graphical data. Skilful questioning of the pupils by the teacher can, as Barton (1997) has shown, assist the pupils in their interpretations of data. However, even without the direct influence of the teacher, there appear to be benefits in pupils attending to emerging graphs in real time data-logging as argued elsewhere (Newton, 1997). Although some of the research discussed above is classroom-based, Nakhleh (1994) called for more 'real-world' research in this field.

At its best, practical science involves pupils in the activity of interpreting and explaining data in terms of their knowledge and understanding of science. In principle, the skills of data interpretation and the identification and explanation of anomalous results are well supported by data-logging methods. This is so for several reasons. The electronic systems can collect large amounts of high quality data which means that pupils are not confronted by insufficient data or data which is too 'messy'. The software reduces the effort pupils must invest in presenting data graphically so that they can invest more effort in interpretative activity. Software tools mentioned previously here allow pupils to explore the data and present it in different ways with a low investment of time and effort. They can try 'looking' at the data in different ways to identify trends and patterns and to test ideas about it. Pupils who exercise these skills to synthesize explanations and interpretations of phenomena are engaging in higher order cognitive activity. There is then, the prospect of raising pupils' standard of achievement in these skill areas through the use of data-logging (Newton 1999).

Investigative work has been a prominent feature of the science curriculum in England and Wales (DFE 1995). At the time of writing, latest developments in the future National Curriculum indicate that enquiry-based practical work will remain significant. It is noteworthy that the use of ICT, including data-logging, to support pupils' investigative work is a more explicit feature of the new curriculum (QCA 1999).

The previous discussion has identified potential benefits of computer approaches to practical work, yet data-logging seems not to have won the widespread professional support of teachers. In the UK, information from inspection of schools (OFSTED 1998) indicates that the application of information and communication technologies (ICTs) to teaching is erratic despite being a requirement of the National Curriculum. There may be many reasons for this, including problems of provision and access to resources and training. Added to these is the challenge posed by implementing innovation in classrooms. The UK government has a programme of investment in ICT resources and skills training for teachers in order to capitalise on the perceived benefits of applying ICTs to teaching in general (TTA 1998).

It is in the classroom that science teachers will implement data-logging methods and where any benefits for pupils must be secured. Given that research suggests that context of use is a significant determinant of realising the potential of
data-logging, it seems appropriate to consider the practicalities of using data-logging methods at the classroom level.

Method

The foregoing discussion has set out some of the research findings pertaining to the use of ICTs for science teaching. The focus for the rest of this paper is the reality of some science teachers' experience of using data-logging in their science teaching. The findings presented here form part of a small-scale qualitative study of the use of data-logging in UK secondary schools. This part of the main study sought to explore a number of issues relating to the use of data-logging in routine science teaching. These issues were:

- Teachers' rationales for using data-logging methods in science;
- Identification of factors which influence the way activities for data-logging are selected;
- The influence of the National Curriculum on practice of data-logging;
- The ways in which a data-logging activity might be integrated into a lesson sequence;
- The skills needed to be developed by pupils and teachers using data-logging; and
- Identification of aspects of data-logging the teachers would like to develop next.

A series of semi-structured interviews was carried out with five science teachers. These teachers worked in four different secondary schools. At the time of the study, two of these schools had special status as 'technology schools'. As such, these schools were relatively well provided with ICT resources. Moreover, ICTs are a prominent feature of their pupils' experience across the curriculum. The other two schools did not have specialist status, but had acquired ICT resources for science teaching over time and had established its use in the science curriculum.

Each teacher had volunteered to be involved in the wider research study and had been invited to do so because of their interest of using data-logging methods in the laboratory. By working with teachers who were familiar with ICTs, it was hoped that the problems faced by novices in learning to use data-logging equipment would be avoided, thus allowing the research to focus on the application of the technique in the laboratory. These teachers were enthusiastic about the use of ICTs in particular and (with one exception) had some years of experience in science teaching.

Following a series of observations of lessons involving data-logging, the teachers were interviewed to explore their thoughts about, and general experiences of, using the data-logging approach. Each interview was conducted, by negotiation, in the teacher's school and tape recorded with their permission. The interviews were then transcribed and the interviewees invited to review the transcript and to correct or amend it. No substantive amendments were requested to the transcripts by the interviewees.
Findings and discussion: exploring the teachers' perspective

The interview data presented here help to develop understanding of the factors which influence teachers when they adopt data-logging methods and develop classroom approaches using the technique. For the purposes of the present discussion, the findings are considered under four themes. These themes are: teacher's rationales for data-logging; obstacles to implementation of data-logging methods; strategies for overcoming these obstacles; and finally, developing learning objectives. The discussion is illustrated using verbatim quotations from the interview data.

Teachers' rationales for data-logging

Although in the UK there are pressures on teachers to make greater use of data-logging methods, the teachers interviewed saw beyond the requirements of National Curriculum science to other reasons for using these techniques. These included the need for pupils to be aware of new technological approaches to measurement and recording of data and also to the potential contribution of the new methods to science teaching.

The teachers interviewed saw data-logging as meeting a need to provide pupils with opportunities to use present-day technology. This was thought to be educationally desirable both in terms of pupils' future needs and also from the viewpoint of appealing to the inherent general interest some pupils show for computer technology:

It's modern technology and pupils should be confronted with up to date stuff.

It is how industry is working: the idea of remote logging or logging some industrial process.

I think there is something about when you do anything with technology, there is more realism in it - the students take it more seriously. It matters what data they capture, it becomes far more relevant or meaningful than just take a few numbers down as the thermometer changes.

It's fun! I've got to include that because the kids do find it fun. To get over scientific ideas in a different way and in a way, certainly these days, that they can relate to.

The greater value attached to the use of ICTs may reflect the ways in which it is used in some classrooms. Although for some pupils use of ICT may be seen as novel, underlying the teacher's comments was the feeling that pupils could have greater control over what they did in a data-logging activity, for example:

[The computer method] ... adds quite a nice dimension, at a more personal level - of them having control over something, in a more explored way using data-logging, rather than having a prescribed 'cook-book type' experiment to do.

The notion of pupils' having to tackle demanding tasks also emerged as a reason for data-logging:

If they can see it on a computer screen it's 'true'. To do something a little different, ... to stretch the kids a bit further.

Data-logging provides an opportunity to test them at the highest level because of the trickiness of what they have got to set up.

The increased demand of data-logging activities arises in part from the sophistication of the experimental set up. Developments in hardware have made it more user-friendly; nevertheless, pupils using data-logging approaches have an addi-
tional 'tier' of computer equipment to manage. As argued earlier, this investment of additional effort can reap rewards at later stages of the activity, particularly in relation to the quality of data collected and the relative ease of software-facilitated data analysis.

A second facet of the increased demand posed by some data-logging activities relates to the degree of responsibility pupils take in managing their work. Potentially, pupils have greater opportunities to exert control over the management of their activity. For example, the rapidity of the data collection process can mean that pupils can complete more experimental cycles and so the potential for exploratory styles of work which can enhance pupil control is presented. So, demand can be higher in data-logging activities because they lend themselves to more open-ended approaches to practical work.

A key word here is potential: whether pupils experience the increased demand is dependent on how the teacher wishes the class to work. The way in which an activity is conceived by the teacher in terms of its degree of openness and the experience of the pupils are just two of many factors which will determine the demand of a task. Some of the teachers involved in the present study indicated that the use of data-logging had changed the ways in which they could teach science. For these teachers, who were IT enthusiasts, the possibility of using data-logging to develop new teaching activities emerged:

It allows me to do experiments and get data that I couldn't easily get in other ways.
It opens new opportunities to explore things that we couldn't do before. For example we've started logging from balances. So I have started to think about what I can measure with a balance. So we have started using mass potometers which weren't there before. Perhaps we are trying things with pH and oxygen that we didn't do before because there was no easy way of doing that in biology.

This reveals a shift in thinking about using computers in practical science, which turns technology on its head. Implementation of innovation often begins with users assimilating new approaches within existing schemes by adopting ideas from others (Rogers 1995). However, the teacher here is thinking about what can be done with data-logging. The novel teaching tool is being used to invent new teaching activities. So data-logging seems to offer new opportunities in terms of activities which some pupils find motivating, new experiments and new 'angles' on established activities.

**Obstacles to implementation**

The positive tones of these comments reflect the teachers' ambitions for using data-logging methods in their science teaching. However, the same teachers were realistic about the difficulties of using new technologies in science teaching. For example here a teacher acknowledges the need to plan a data-logging activity to minimise problems with the technology - an implicit expectation that they may occur and recognition of the potential negative impact on pupils and teachers of equipment failures:

We don't want a mix of quite a difficult practical and quite a difficult data-logging set up all in one. Because we're going to have breakdowns and failures, we've got to eliminate as many of those as possible to keep it quite tight. Therefore I think we start with something quite basic.
The same teacher later in the interview, raised the implications of having to ‘trouble-shoot’ problems in the teaching situation. Teachers using data-logging need to develop the confidence to know when a system is malfunctioning and to be able to deal with it effectively:

... If a machine goes down, then some staff who are not familiar [with ICTs], may not recognize straight away what the problem will be; cannot diagnose it and therefore will end up spending an inordinate amount of time sorting that one problem out, and therefore they are away from the rest of the class and you have got a control problem.

The above statement raises a contrasting set of influences of the practice of data-logging. Although these teachers articulated a positive case for incorporation of data-logging methods in their teaching, they also identified important influences that can negatively affect its implementation in the classroom. One such influence is the presence in schools of older technology. This was seen as potentially demotivating for pupils, but acquisition of newer equipment requires investment and will take time:

... Pupils being confronted with old technology is just a bad example of the way we progress, but obviously the undermining feature is the cost [of new technology].

The ability to invest in new equipment for schools will inevitably lag behind the latest technological developments. A teacher in a different school that was using older non-Windows technology for data-logging, highlighted the extent to which some teachers in his department had become de-skilled in the operation of the old technology, because of the prevalence of Windows-driven applications. In this department head’s view:

Some people are less happy with a BBC computer — they find it more of a difficult thing to use ... [teachers] are familiar with Windows now, they’re not familiar with this other system.

Technical difficulties were regularly cited by the teachers as obstacles to successful use of data-logging. Technical problems can present novices with problems in data-logging activities; but it is also the occurrence of these problems in the classroom, which seems to exacerbate the impact of such difficulties for teachers. As one teacher put it:

I suspect that other staff may feel uncomfortable if things go wrong — whether they will be able to deal with it ... with large sets [of students] and all the problems inherent in that. So there’s not the same problem with Year 12 [post-16 students], with class management issues some staff are uneasy about the use of large amounts of technology.

This comment serves to emphasize the fact that classroom management involves a complex set of interactions which can be further complicated for the teacher by the addition of unfamiliar technology. The additional burden posed can make data-logging lessons more risky for the teacher than conventional activities. There is a tension here in that whilst data-logging methods offer potential advantages for pupils, for the teacher relatively inexperienced in the IT approach, the organizational and management skills needed to successfully run such an activity are greater.

Whilst the additional burden and increased pupil management risks may diminish with teachers’ growing familiarity with the technology, this threat may explain some of the apparent reluctance of some to adopt the new approaches. One
strategy for addressing this issue could be investment in more in-service training for teachers. In the UK there have been courses to support development of teachers’ skills in these areas offered by of science teachers’ professional associations and initiatives funded by government and other sources, for example the New Opportunities Fund (NOF 1998). However, teachers need to perceive the benefits in personal and professional terms of investing in such training opportunities. Furthermore, there needs to be in place the equipment resources for teachers having been trained, to develop data-logging approaches in their teaching. If these requirements are in place, what advice can experienced users give for strategies which can facilitate use of data-logging?

Factors that can facilitate the use of data-logging in teaching

Practical support

The costs associated with developing data-logging emerged amongst the teachers’ concerns. There are costs in terms of finance for the purchase of equipment, but also personal investment of time needed to become familiar with equipment use. Added to this was the importance of a stimulus to making the initial investment to develop data-logging:

A lot of people don’t have the time to sift through 'data-logging for beginners' and find the ideas, so if you have got an IT person, a co-ordinator, who says 'right, that fits nicely into our scheme, you are going to do it and we are going to spend an INSET day training you', then I don’t think you’ll have many people say 'no, we won’t do it'.

A teacher in a different setting commented that:

I’m not necessarily saying it is an expertise thing, it’s almost a prompt, a push, a nudge a bit of encouragement … yes we ought to get that as a higher priority. … I think what will probably happen is that once the ‘shove’ has come, that will precipitate and then things will get done over the following months. But it is actually getting on that road and getting a number of us – more than one of us on that road. … actually getting the catalyst to precipitate that.

Having enthusiastic and experienced colleagues to lead and support is of high value in promoting the use of IT by others. This practical support needs to continue beyond the start-up phase into developing good technical support to have equipment maintained in functional condition. In some schools this support extended to the equipment being set up by technicians ready for the pupils to work with in the laboratory.

Planned opportunities

The UK National Curriculum requirement to use ICTs in practical work presents teachers with the planning issue of identifying suitable activities for using data-logging. One purpose of planning at the departmental level is to map the required curriculum content and learning opportunities to which all the pupils are entitled. The notion of pupils’ entitlement is enshrined in the requirements of the science National Curriculum Orders. Teachers have to be pragmatic in their response to these planning needs, so that their local situation can be accommodated within the
required curriculum framework. It is not a straightforward task to plan an ICT activity to be presented by all a department's teachers, when they possess varying levels of skill, competence and enthusiasm for ICTs. Indeed this is one focus for training to raise UK teachers' skills in classroom use of ICT (TTA 1998).

Yet the need to plan data-logging tasks into the work schemes can be seen as driving development in this area:

It has got to be written into the schemes of work - without a doubt. We still have not got it written into our schemes of work fully, because that forces the issue. They've got to do it whether they like it or not! . . . I know X and Y will do it here, but I also know a lot of people won't touch it with a barge pole unless there's that expectation.

Writing data-logging activities into schemes of work invests them with status and gets teachers to take notice. It is questionable whether even extensive provision of examples of ICT-based activities in curriculum documents, or other sources of general advice carry sufficient weight to drive their implementation in the classroom. However planning at department level may better achieve this goal since it can be matched to planning for progression in ICT's skills development for pupils:

. . . It's got to be done in a very structured way so that it is built in and develops the skill through time.

Suitable contexts

The choice of contexts in which to adopt a data-logging approach was seen as being important for several reasons. The importance of teachers making critical judgements about the purpose of an activity and the potential value added to it through data-logging emerged. One highly experienced teacher made the following point:

I think it should be an integral part of the topic, just like it's another teaching and learning style. Within a topic sometimes data-logging is not of any use. It shouldn't be there for the sake of it, it should be there to complement and extend the science as we see it. There may be topics where data-logging doesn't come into its own . . .

This point was echoed in another school, where the point was made that chosen data-logging activities:

. . . Need to fit in with the course we're doing - so they've got to be relevant. They have got to make the experiment easier for the students, they've got to let the students get more out of the investigations.

However, the need not to be too ambitious when selecting a task was also emphasized in a third setting:

. . . We've got to think of something that is 'plug in and go' basically. Something that is quite simple as a practical.

The need for simplicity can be driven by availability of resources, but there are also other factors in play here. As discussed earlier, reducing the technical complexity of a task increases its accessibility for users and minimizes the impact on matters of classroom organization and control. It seems likely that simple data-logging approaches are more likely to win teachers' support.
Developing pupils' skills in data-logging

For pupils to become effective users of data-logging equipment, they need to have acquired skills in its assembly and to be familiar with what can be achieved with it. There is a sense in which this is no different from pupils learning how to use and understand the purpose of any other method in practical science. The skill of operating data-logging equipment can be taught in a range of practical contexts. Provided with appropriate experiences of a wide range of contexts of use, there is the prospect of pupils themselves choosing a data-logging approach for investigative work.

Some of the teachers interviewed for this study used detailed worksheets to prescribe the operation of the data-logging equipment in particular activities. This was seen as a means of supporting the pupils' work without too much teacher intervention. It was a means of encouraging the pupils to take responsibility for their work and to develop skills in dealing with problems that might arise. One teacher commented that in data-logging activities, pupils needed to learn how to 'multitask' so:

That while the machine is collecting data, they can be doing something else [that is] valuable. Very often they don't, they just sit and watch the machine, instead of getting on with something else.

This need to recognize that data-logging methods make time available was recognized by other teachers interviewed:

... Again it is class management. You have got to recognize that once it [data-logging] has started it frees them up. ... So therefore what I tend to do with the worksheets I have developed is to ask questions that they can do as the experiment is going on. Perhaps asking them to think about that practical a bit more -- asking them 'is this a fair test?'; 'what controls would be useful?'; 'what do you expect to happen?'; etc., etc. So it's engaging them still in that practical but it is keeping them on task while their hands are free.

The above statement emphasizes the need for science teachers to carefully plan data-logging activities to meet the science objectives and to consider the management of pupils through tasks.

It emerged in the interviews that particularly for real-time data-logging tasks, teachers saw value in pupils closely monitoring emerging data and issues of pupil management and classroom control remained a high priority. Finding ways of organizing activities to encourage more emphasis on interpretation of emerging data remains a challenge in real-time data-logging.

Defining learning objectives: collecting data and interpreting data

Experience suggests that the operational skills can be quickly acquired, but there seems to be a current emphasis on the use of data-logging for gathering data, rather than using the software to explore the data for scientific meaning. One teacher interviewed suggested that this emphasis was a possible reflection of the relative assessment weightings in science examination syllabuses given to operational and interpretative skills. Nevertheless, the teacher recognized a need to integrate more evaluative and interpretative activity into data-logging practicals:
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There's still not enough evaluation of the data, because the emphasis in courses is still on acquiring the data. In terms of Science 1 investigations, there's a big emphasis on the planning and acquiring the data and I know there is a need to evaluate more and interpret the data more, which is quite high level skill; but to do that you need to practice it more and forget about the other bits. And I think the teachers are still (me included) more worried about getting it all done rather than spending a lot of time on the evaluation. Perhaps we should be spending more time ... if the evaluation and interpretation was given greater weighting, then perhaps we would do it better.

Shifting the balance of pupils' data-logging activity towards more interpretative work demands different teaching strategies (Newton 1998). Steps which teachers can take that may help achieve this goal include planning lesson structures which offer pupils opportunities to engage in tasks which:

- Encourage interaction between pupils to talk about data;
- Give pupils responsibility for decision making in activities;
- Help pupils know their role in tasks; and
- Teach pupils to notice events and data features and be critical of data.

The need to shift greater emphasis from operating data-logging technology to interpreting data gathered in this way seems to be a necessary step to realizing the full potential of the technology. However, the issues raised in this small sample of interviews suggest that it will be challenging to achieve in the classroom, all the potential benefits of data-logging revealed by research.

Concluding remarks: research and the reality of school life

The potential contribution of data-logging methods to pupils' learning in science is considerable. Yet the classroom implementation of new teaching tools and activities in ways that can achieve these benefits seems unlikely to be straightforward.

The interview data and previous discussion indicate that a number of features of data-logging practice need to be in place to provide a basis for development of more interpretative activity in practical science. First:

- Availability of adequate and up to date hardware and software;
- Provision of technical support to ensure that equipment is serviceable; and
- Teachers skilled in the technical use of the equipment.

These factors are a prerequisite to establish a resource platform from which more developed data-logging practice can emerge. Experience and familiarity with equipment and its classroom use is necessary to foster the next level of professional awareness of data-logging; namely:

- Understanding of how data-logging can change classroom management needs;
- Understanding of a fuller range of benefits of data-logging approaches; and
- Developing teaching approaches, which exploit attributes of the technology.

These understandings take time to emerge but, in the hands of experienced ICT enthusiasts, they can lead to well developed rationales for using data-logging in science teaching. These rationales extend the apparently 'surface-level' curriculum requirements to potentially deeper and new understandings of the potential of
the approach. It is perhaps through understandings at this level that more of the benefits of data-logging identified by research are likely to be achieved in the hands of science teachers working in real classrooms.

It is possible that a mature appreciation of the potential of data-logging as a teaching tool can encourage science teachers to identify and clarify learning objectives for practical science which draw on the attributes of the new technology. But it is likely that this will need to be lead by the curriculum through:

- Planned curriculum opportunities for use of data-logging; and
- Assessment incentives to encourage greater use of data-logging.

Used in this way, the curriculum can drive further development of data-logging. It provides opportunities for less experienced ICT users to gain experience and it can help to ensure that pupils have the benefit of using it.

Despite the compelling research evidence of the rewards to be won through effective use of data-logging, science teachers are faced with the realities of their own school contexts. Pragmatic decisions have to be made about teaching with ICT, which reflect the wide range of influences which bear on them.

If the potential contribution of data-logging to practical science is to be fully realized, more research needs to be done which acknowledges and explores the classroom constraints in which it is used. In addition to addressing these factors, there is a need to develop thinking about planning pupils' activity with the new technology in mind. It seems that doing so will require teachers to better understand not just the attributes of the technology, but the way in which these change laboratory life during pupils' practical work. The prospect is that planning in light of these new influences will lead to more effective use of the technology and fulfilment of the contribution data-logging can make to raise pupils' achievement in science.

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