ICT IN SUPPORT OF SCIENCE EDUCATION

A Practical User's Guide

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The cover shows students at Archbishop Holgate's School, York, a specialist science college, investigating dynamics using ICT.

Cover design by BP Design

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Preface

Information Communications Technology (ICT) has an important role to play in science teaching. Rapid developments in hardware and software mean that a great deal is now possible, yet there remains a considerable gap between the aspirations of experts and the realities of the classroom. This Guide is intended to bridge that gap by providing guidance on what can be done by teachers in every school and college.

The idea for this Guide originated in a seminar on ICT in Support of Science Education held by the Chemical Education Group at Salters' Hall in May 2001. The Guide builds on the seminar themes, drawing on the results of visits to schools, colleges, publishers and software developers.

The Guide is in two sections. Section A gives some general principles and will be of interest to headteachers, principals and those with strategic responsibility for ICT within an institution, as well as to teachers of science. Section B has specific examples that will be of practical help to science teachers.

We hope the Guide will prove helpful in enabling science departments to make the most of what ICT can offer in support of teaching science. We are most grateful to the Salters' Institute, whose support has made the production and distribution of this Guide possible.

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September 2002

This Guide has been written by Derek Denby, Director of the Science Centre of Excellence at John Leggott College, Scunthorpe, and edited by Professor John Holman, Director of the University of York Science Curriculum Centre.

This Guide can be accessed in electronic form from www.uyseg.org or from www.saltersinstitute.co.uk

The Salters' Institute and The Chemical Education Group

The Salters' Institute

The Salters' Institute is the major charity of the Salters' Company. The Salters' Company is one of the ancient London Livery Companies: established originally to trade in salt, their main interest is now in charitable work, particularly in support of chemistry education and science education.

The Salters' Institute supports science education through curriculum development, based at the University of York Science Education Group, where the Salters' curricula in Science, Advanced Chemistry, Advanced Physics and most recently Advanced Biology have been developed. The Institute manages the Salters' Chemistry Club and Salters' Festivals of Chemistry for 11–13 year olds and Chemistry Camps for 14–15 year olds and acts as convenor and host for the Chemical Education Group.

The Chemical Education Group

The Chemical Education Group consists of the Presidents and Chief Executives of the nine professional institutions and trade associations most closely concerned with chemistry education. It was established to provide closer collaboration and where appropriate, develop a collective action between the institutions and companies in support of teaching. The member institutions are: The Association of the British Pharmaceutical Industry; The Association for Science Education; The Chemical Industries Association; The Institution of Chemical Engineers; The Royal Institution; The Royal Society; The Royal Society of Chemistry; The Salters' Institute; The Society of the Chemical Industry.

Contents

1 Introduction

1.1 A practical and pragmatic approach

The purpose of this report is to review the use of Information Communication Technology (ICT) in support of science education. It attempts to describe current practice and to identify and to clarify some of the issues that face schools and colleges in trying to improve the ways in which they make use of new technologies to enhance teaching and learning in science. It does not claim to comprehensively cover every aspect of ICT in science but aims to contribute to current thinking about this topic by presenting a practical and pragmatic evaluation of some of its key features. The report is based upon many conversations with practitioners in schools, colleges and other institutions and their assistance is gratefully acknowledged in Appendix 2.

1.2 General principles

The report has two sections. Section A looks at the general principles of using ICT to support science education. It covers some of the key issues that science departments face as they explore the use of ICT to facilitate improvements in teaching and learning. The context of this report is support for science education but ICT issues are generic and apply across the curriculum. The content of section A will, therefore, be of interest to Head Teachers and College Principals and others involved in the strategic planning of ICT across an institution, as well as to members of science departments.

1.3 Specific examples

Section B looks at specific examples of the use of ICT to support science education. It reviews the detailed application of ICT and provides a large number of ideas and contacts to help teachers develop the use of ICT within their own department.

Section A

General Principles

2 Background to ICT in Science

2.1 Recent developments

In the past, hardware and software limitations have tended to reduce the real impact of ICT on supporting science education. Recently, however, hardware costs have fallen, hardware has become more reliable and the ICT skills of teachers have improved. These factors combine to make significant progress in the use of ICT to support science teaching a real possibility.

In recent years there has been a shift from the use of science as a vehicle through which students learn and use IT skills to the use of ICT skills as tools to assist learning in science.

There has also been growing interest in the use of ICT to support whole class teaching and learning to complement ICT based activities for individual students.

This has led to greater emphasis on the role of the teacher and a recognition of the need for training to help them learn operational skills to use new equipment and software and application skills to manage learning effectively using new technologies.

2.2 The benefits of ICT in science

- There is considerable research evidence that learners are more highly motivated when their learning is supported by ICT. See Newton and Rogers*, Teaching Science with ICT* for a review of research evidence.
- Students are more engaged in activities, they show increased interest and demonstrate a longer attention span.
- ICT can provide access to a huge range of resources that are of high quality and relevant to scientific learning. In some cases the resources fill gaps where there are no good conventional alternatives; in other cases they complement existing resources. In some cases ICT resources are less good than conventional alternatives and do not add to learning.
- The multi-media resources available enable visualisation and manipulation of complex models, three dimensional images and movement to enhance understanding of scientific ideas.
- ICT widens the range of material that can be used in teaching and learning to include text, still and moving images and sound, and increases the variety of ways that the material can be used for whole class and individual learning. This means that a teacher can go some way to meeting the needs of students with different learning styles. ICT also allows teachers with different teaching styles to modify materials and the way they are used in different and effective ways.
- ICT can improve the quality of data available to students. Information gleaned from the internet can be more up to date, and data obtained from loggers can include more frequent and more accurate experimental readings.
- Computers also allow repetitive tasks to be carried out quickly and accurately so that more student time can be spent on thinking about the scientific data that has been generated.

- Many ICT tasks do not require the use of a specific classroom or laboratory. They can, therefore, extend learning beyond the teaching space and class contact time, and place the use of ICT at the heart of the learning process rather than as an additional peripheral experience. An activity, started in one classroom, can be continued in a different room later in the day or at home in the evening.
- ICT provides opportunities for teachers to be creative in their teaching and in student learning.

3 Hardware Resources

3.1 IT suites

Over the last decade, the main thrust of introducing new IT hardware in schools and colleges has been to meet the needs of students working alone or in small groups. This has led, typically, to networked computer systems and groups of computers concentrated in dedicated IT suites as part of a whole school or college policy. Often the emphasis has been on learning about IT rather than using IT as a learning tool in curriculum areas such as science.

This approach to introducing centralised IT resources has tended to create barriers to the use of ICT in supporting science. The logistical difficulties and time and forward planning required have proved a considerable disincentive for many science teachers to take advantage of the resources. In addition, the physical separation of ICT resources from the normal science teaching space means that ICT is perceived by teacher and student as an ‘add on’ to normal learning rather than an integral part of it.

3.2 Laptop computers

More recently, strategies to bring ICT support into the science teaching space have received much more attention. One approach is the use of a class set of laptop or notebook computers within a science area. These computers can be linked via a wireless connection to the school network to access the full facilities that this provides. Computers of this kind can be stored and recharged on a trolley so that they can be easily moved into different rooms on the same floor of a building. This is a flexible system that lends itself to individual or small group work in the science area and also provides ready access to data logging activities. The drawback is that class sets of laptop computers are expensive.

3.3 Whole class viewing systems

A different approach to bringing ICT into the laboratory or science classroom is to install a whole class viewing system for electronic resources. The advantages of this approach are:

- ICT can be used as an everyday, integral part of learning,
- the ‘teacher led’ style of teaching is one with which most teachers are familiar and comfortable,
- it is a very effective solution to the problem of bringing ICT into a laboratory where overall space is limited or where existing bench space is needed for practical work,
- it is more cost effective than the use of class sets of laptop computers.

3.3.1 Data projectors

The single biggest impact on the use of ICT in science areas is brought about by the installation of a Liquid Crystal Display (LCD) projector, permanently fixed to the ceiling and wired to appropriate sockets placed near some form of permanent screen. This arrangement significantly lowers the threshold of difficulty teachers face in using ICT in support of science and thereby significantly increases the likelihood of real progress in this area.

When choosing a projector the luminosity and sound are important. For most rooms a projector of at least 1000 and preferably 1200 ANSI lumens is needed so that the image can be easily seen without blacking out windows. The loud speakers in some projectors are fairly basic and may not do justice to the sound track of videos. It may be better to make connections to external loud speakers that are fixed to the wall. This is best included as part of the initial installation process.

The projector system can be linked to a PC dedicated to this purpose or it can provide a plug in facility for a laptop computer. In some schools and colleges, each teacher is loaned a laptop which becomes used as a lesson folder. This arrangement does seem to drive forward whole staff ICT progress and promotes the sharing of expertise and ideas. Connecting the system to the school network expands the usefulness of the arrangement.

There are many companies who will provide schools and colleges with projectors and laptop computers in a very competitive market. There are considerable economies of scale to be made if a large number of systems is purchased at the same time.

3.3.2 Use of video with a projection system

LCD projectors can readily be switched to video mode, which allows existing video resources to be viewed at an increased image size. Some schools have a VCR device permanently wired into the projector system which further reduces barriers to its use and facilitates sophisticated multi-media presentations using a single, permanently fixed viewing system.

3.3.3 Use of cameras with a projection system

The video input to a projector will also accept a signal from a range of cameras including flexible neck video cameras, camcorders, digital cameras and webcams. The application of these devices in the context of science is covered later in this report.

A simple camera will permit whole class viewing of any text, image or 3-D object, including students' written work, books, pictures and microscope images. It can act just like an overhead projector (OHP) except that there is no need to create a transparency first. Hardware devices such as these can be added once the main projection infrastructure is in place.

3.3.4 Data logging

Data logging in science is a very underdeveloped area of activity. Projection systems enable teachers to demonstrate data logging experiments and to help prepare students to use the associated computer software. Detailed applications of data logging in science are covered later in this report.

3.4 Screens and boards

3.4.1 Screens and ordinary whiteboards

There are several alternative ways of viewing the images from a LCD projector. The simplest method is to use an ordinary screen or whiteboard, which may often be already in place when the projector is installed. This low cost option is effective and trouble free. A white board has the advantage over a projector screen in that the image can be annotated using ordinary white board pens.

Modern projectors are equipped with remote control devices that include a narrow infra-red beam, a zoom facility and the ability to act as a mouse for computer software. This means that the teacher and students can manipulate and place emphasis on images at some distance from the screen.

3.4.2 Interactive whiteboards

There is a range of interactive whiteboards available commercially that are connected to the computer and projector, and allow the image to be controlled from the board itself. Some boards are operated by finger pressure or the use of dummy pens, while others make use of an electronic pen specially dedicated to the system. The boards behave exactly like a computer screen, using the finger or pen instead of a mouse. Most boards also have specially designed software that allows images on the board to be annotated and saved, and permits rapid and very useful movement between current and previous screen images. Some manufacturers have developed notepads that link to the whiteboards, so that students can contribute to what is on the main board from their seat in class.

The Mimio device is one example of a low cost piece of equipment that can be linked to a laptop and an ordinary, non-interactive whiteboard. It can be used to save what is written on the board to the computer for later use. The mouse pen also makes the board interactive when an image is projected onto it from an LCD projector.

3.4.3 Plasma screens

Plasma screens are large, flat surfaces that permit the viewing of big images without distortion. They can be free standing or wall mounted and, because they are quite thin, fit into limited spaces. They are connected to an LCD projector and a computer, but they are not interactive. They are currently quite expensive.

3.5 Scan converters

Scan converters are a low cost alternative technology for whole class teaching using ICT. A signal from a laptop or PC is fed through the device and into one or several TV monitors. In this way the system allows any image that can be viewed on a computer to be seen by a class on a TV. The advantage of the system is that it is inexpensive to buy, and may make use of equipment that is already in the school or college. The disadvantage is that the size of the image is limited by the size of the TV monitor, and the system is not interactive.

3.6 Purchase and replacement of hardware

Purchase of ICT hardware often involves institutions in considerable capital expenditure. Some items such as computers have relatively short useful lifetimes, and the policy of budgeting for replacement becomes an important issue. Some schools and colleges have opted for leasing rather than purchase agreements in order to ensure that they have up to date equipment.

4 Training and Support

4.1 ICT skills for teachers

In the most effective examples of progress in the use of ICT to support science, training of teachers has accompanied the installation of hardware infrastructure. As it becomes easier for teachers to use ICT equipment, it becomes even more important that they should be sufficiently well trained to make use of the new opportunities they are presented. NOF (New Opportunities Fund) training has provided significant support for teachers in some schools and more emphasis is also now placed on the ICT training of teachers in colleges.

The role of the teacher in using ICT in science is changing. When classes had to move to a computer suite to find IT facilities such as science CDs placed on the school network, the role of the teacher was fairly peripheral, and limited to organisation of the activity. When ICT facilities are brought into the science teaching space, the teacher becomes the main user and driver of ICT.

A basic level of skills in the use of ICT hardware and software is required by all science teachers. This is usually a whole school or college issue and has implications for the provision of technical support and training for teachers. More important, and often much less well developed, are strategies to meet the training needs of teachers in terms of approaches to learning using the new technologies. In some schools and colleges, the introduction of an effective ICT infrastructure has led to a re-evaluation of styles of teaching and learning in science, and a sharing of expertise and ideas. In examples of effective practice, ICT activities are used in the laboratory or classroom, and students continue them outside of class time, sometimes at home, so that ICT becomes an integral part of learning.

More frequent use of ICT by teachers may well give an impetus to the production of ‘in house’ resources. This will have implications for the provision of training in software package skills such as MS Office, PowerPoint and Front Page, for the specific purpose of producing presentations and electronic worksheets. This is often a whole institution issue, and raises questions about sharing of expertise between teachers and the effective use of ICT champions.

Training and ICT infrastructure need to be considered together. Where teachers have individual lap top computers, ICT can become a part of the teacher’s normal activity, and not as some ‘bolt on’ or enrichment experience. The very process of creating this kind of infrastructure, however, immediately brings with it a demand for training, so that teachers can feel familiar with hardware and software.

4.1.1 ICT Skills Audit

A useful first step when thinking about teacher ICT skills is to carry out an audit of the current situation. Many schools may have already done this in preparation for NOF (New Opportunities Fund) training. A helpful way forward is to compile a schedule of ICT skills that are needed by teachers, to make effective use of the infrastructure within the school or college. The schedule can be broken down into skills to do with hardware, and skills to do with use of software. This is often another whole institution issue, and it is possible to devise a set of key ICT skills that all teachers need to make use of generic hardware and software in a school or college. This list can be extended for particular groups of teachers, like those in science who have additional ICT skill needs to do with equipment such as data loggers.

An audit sheet can be created based on the key ICT skills for teachers, and used initially to identify individual training needs. The audit sheet represents a set of descriptors which teachers can use to assess their initial and ongoing training and support needs. Such a set of descriptors can be used by new appointments to the institution in a similar way. In addition, they can be also used to audit the current state of ICT skills of teachers, and to provide a measure over time, of the increase of skills as a consequence of training.

4.2 Technical support

The introduction of hardware infrastructure, and the raising of expectations about the integration of ICT within teaching and learning in science, has implications for the level of technical ICT support available to teachers. Systems need to be maintained in a good state of repair and training is needed in the use of hardware and software.

Training is also needed for technicians who work in science areas, since they will often be expected to make available equipment for teaching. Their training needs may include the use of general ICT equipment such as trolleys of lap top computers, as well as more dedicated science equipment.

In examples of effective practice, support from the senior management of the school or college is often clearly evident. In some cases a senior manager has an identified role to lead progress in this area and to ensure that systems and resources are put in place to train and support teachers.

5 Organisational Issues

5.1 Commercial packages for the science curriculum

A quite new feature has been the recent development of commercial ICT based resource packages for major components of the science curriculum. This follows some very successful pilot initiatives in mathematics.

Research Machines, for example, are producing material for science at Key Stage 3, Heinemann are developing a comprehensive resource and management package to support the new Salters' Nuffield Advanced Biology AS and A2 specifications, and a number of schools are already using online materials for Intermediate GNVQ Science produced by Kingshurst City Technology College. The Advancing Physics AS and A2 specifications require the use of an IT package that is distributed on a CD Rom.

These initiatives will tend to accelerate the use of IT in science and will provide exemplars of the kind of activities that are effective applications of ICT in science education.

Commercial ICT packages have significant implications about the level and location of ICT hardware if such new courses and resources are to be adopted by a school or college.

5.2 Learning environments

An increasing number of institutions are looking at the installation of a Virtual Learning Environment (VLE) or a Managed Learning Environment (MLE) to provide the framework for curriculum resource materials. The VLE is an extension of the intranet systems that many schools and colleges have begun to develop in recent years, but is devised by a commercial provider and can include additional functions such as controlled access and student tracking. A VLE is an integrated system that can ease uploading of materials and can offer customisation of the ICT environment. A MLE is a broader facility that includes the whole range of information systems and processes of the institution, including the VLE, that contribute to learning and learning management. The decision to develop a VLE or a MLE will be a whole institution issue. A Head of Science may be expected to devise resource material to be made available to students via the ICT environment, and may be asked to manage the on-line learning.

5.3 ICT and the national curriculum

The publication *Science: The national curriculum for England* (DfEE/QCA, 1999), sets out the legal requirements of the National Curriculum in England for science, and provides information to help teachers implement science in their schools. At each key stage, particularly at Key Stage 3 and 4, opportunities are identified for students to use ICT as they learn science.

The ICT references within the National Curriculum indicate very clearly where activities such as data handling and analysis using spread sheets and data bases, simulation software, video and CD Rom resources, data logging and internet searches can be used within the programmes of study. Detailed links between ICT and the National Curriculum are indicated in later sections of this report. To make use of these opportunities, however, schools need appropriate equipment and teachers need appropriate training.

Section B

Specific Examples

This section of the report presents a practical and pragmatic account of the application of ICT in the context of science education in schools and colleges. It aims is to raise awareness of the range of ICT applications; to provide sufficient detail about particular applications; to help teachers develop their own thinking about how they might use ICT in their own context; and to comment upon some of the issues that face teachers as they plan to make effective use of new technologies in teaching and learning.

6 Using Standard Applications

6.1 Electronic worksheets

Electronic worksheets may be produced ‘in-house’ by teachers for use by students within class or as an extension to laboratory/classroom activities. They may well be designed for individual student use, but there is some evidence that learning in this format is promoted by small group interactions. A key strength of electronic worksheets is that they are interactive and require the student to be an active participant in learning.

6.1.1 Microsoft Word

The advantages of using Microsoft Word to construct electronic worksheets are that most teachers will be very familiar with the software package and that it is commonly available on school network systems.

Some ways in which Word can be used are as follows.

- Creation of text boxes linked to parts of drawn or scanned diagrams/photographs in which a student can write brief notes.
- Provision of randomly arranged parts of pictorial or flow diagrams that must be dragged and dropped into appropriate positions.
- Construction of sections of text which contain deliberate errors or misunderstandings that have to be identified and corrected. This allows the teacher to utilise their knowledge of common problems in a topic and to ensure that these points are confronted by students.
- Sections of text written with gaps in key places. Words or phrases are copied and pasted by the student from a list that includes distracters.
- Words that are jumbled up in sentences and sentences that are jumbled up in paragraphs have to be placed into an appropriate sequence. This approach allows for some differentiation between different ability levels through the extent to which the meaning of the text is disguised.
- A still or video image embedded within the document to provide stimulus material on which questions are based.
- Use of live links from a word document to other files on the network system or to websites.

6.1.2 Microsoft Excel

The use of Excel as a spreadsheet in science is considered elsewhere in this report. The software package can also be used to construct sets of multiple-choice questions using the ‘form’ facility. The package will provide automatic brief responses to correct and incorrect student answers.

6.1.3 Microsoft Front Page

Front Page is a software package that allows links to be made from within an electronic worksheet to other files including text, still and video image, animations, audio clips and internet sites. It is fairly easy to use and allows students to view questions and stimulus material on the same screen.

6.1.4 Test construction software

Hot Potato (http://web.uvic.ca/hrd/halfbaked/) is one example of test construction software. It is a package that is free to education and which enables a range of types of test to be constructed. It is easy to use and some of its facilities, such as feedback to multiple-choice question responses, are very useful and allow teachers to provide a graded range of responses to students' answers.

6.1.5 Mind Mapping

There is a number of inexpensive mind mapping programmes available commercially (a search engine can be used to search the internet for information about mind mapping software). These pieces of software allow a web diagram to be built up in which ideas and information relevant to a particular topic are linked together. Typically, major headings are linked to branches with related headings, which may in turn be linked to further sets of branches containing increasing detail.

Use of this kind of software allows students to make connections between related ideas and encourages lateral thinking. It is particularly helpful in providing a framework for a synoptic view of work that students have covered, and student maps can form the starting point of very productive discussions. Many of the programmes include a facility to annotate the mind map with little icons, to make it visually more attractive.

6.1.6 Other Software

More sophisticated software packages such as Toolbook Instructor (www.click2learn.com), Dream Weaver (www.macromedia.com) and Flash (www.macromedia.com), offer facilities to design very elaborate worksheets that include high quality images, complex links and attractive animations. The drawback is that they require significant technical skills and a significant time allowance to make use of them.

6.2 Presentation software

6.2.1 Microsoft PowerPoint

The interest in presentation software has increased recently as projection systems in laboratories and classrooms have become more common. The most widespread package used by teachers is PowerPoint. This is a powerful yet easy to use package that is capable of much more than a list of bulleted points. Slides can contain text, still and video images, animations and audio clips. Elements within a slide can be animated to attract attention and sequenced to closely follow the desired teaching pattern of ideas and information. Links can be created to allow easy movement between different slides. Once created, presentations can be shared between groups of teachers and updated easily. They provide a useful, shared focus for whole class teaching, and provide a clear framework for learning.

6.2.2 Helpful PowerPoint tips

- Choose a dark background colour for slides.
- Use the same background, font style and font size for all slides in a presentation.
- Don't try too many fancy effects as they distract from the main message and quickly become very annoying.
- Don't put too much information into a single slide. It is better to use two simple, rather than one complicated slide.
- Use short phrases rather than long paragraphs.
- Use different text colour to create emphasis, but make sure that you can read it against the slide background.
- Use simple diagrams.
- Do include pictures.
- Do include short video clips.

6.2.3 PowerPoint and students

PowerPoint presentations can be made available to students after a class for any absentees and for revision and to reinforce learning. Groups of students can also be encouraged to create their own presentations on particular topics to show the rest of their class to assist their understanding of science, as well as developing their communication skills. One interesting variation is to provide the ‘bare bones’ of a PowerPoint presentation, and to ask students to complete it by annotating in text boxes etc.

6.3 Image manipulation software

When constructing presentations or devising worksheets, it is often helpful to manipulate images that have been scanned or drawn. This can involve simple cropping and resizing, or much more elaborate manipulations. There is a number of commercial software packages that will do this, ranging from the inexpensive Paint Shop Pro (www.jasc.com), PhotoImpact (www.ulead.co.uk), Photosuite (www.mgisoft.com), PhotoPlus (www.serif.com) and Photo Express (www.ulead.com), to the much more wide ranging and costly Photoshop (www.adobe.com).

6.4 Presentation by students

The use of ICT packages by students to present their own work, or for student group or class presentations, is often very underused, even though it can prove a highly motivating learning strategy. This might include:

- the use of word processing or desk top publishing packages,
- annotating images captured from experimental or microscope work,
- producing quality notes,
- making worksheets or posters for use by other students.

6.5 Spreadsheets

Spreadsheets such as Microsoft Excel are very powerful tools that can be used in science for the calculation, analysis and display of data. While the power and versatility of a spreadsheet lends itself to many uses in science, it also means that teachers and students need to spend time to acquire the operational skills needed to make use of the sophisticated features that are available.

6.5.1 Ways of using a spreadsheet

To take account of the differing competences that students may have in the use of spreadsheets, they can be presented in ways that make increasing demands on such skills. For example;

- a completed spreadsheet containing data is provided which students might sort, in order to pick out trends, patterns or differences,
- a substantially complete spreadsheet is provided that students add to, by inserting new columns that contain related data,
- a template is provided that may, for example, contain column headings to which student add data and insert additional columns,
- students design and enter data into a blank spreadsheet.

The provision of a complete or partially complete spreadsheet can overcome difficulties that students may have in constructing the spreadsheet, and can save time that students can use to think about and to evaluate the data.

However it is generated, the data in a spreadsheet can be used in a variety of ways. A spreadsheet containing the nutritional details of different foods can, for example, be used to:

- sort the data to find out which foods have the highest proportion of protein, fat or carbohydrate,
- compare the nutritional make up of different menus,
- work out a menu that will meet the nutritional requirement, for some given situations.

Spreadsheets can be used in a whole class activity, to provide a framework for the collection and averaging of class sets of data.

Spreadsheets enable complex calculations to be carried out quickly and accurately. This means that a student can test a range of predictions based on the same data to explore possible relationships between variables, and derive other information related to the original data. Some examples follow.

- In the study of domestic electrical appliances, the power and operating voltage of items such as a kettle, hair dryer and food mixer can be inserted into an appropriate spreadsheet and used to calculate the current that flows through them. Students can be asked to decide on the value of the fuse that they would need to use to protect each appliance. The task could be extended by getting students to use the spreadsheet to calculate the energy consumption of each appliance, and to calculate the cost that this would incur.
- In a more demanding biological example, students can simply be given a formula that relates the number of fish that can survive in a pond with the number of fish at the beginning of a year, and a constant that is a measure of the ability of the fish to breed. The student task is to set up a spreadsheet, and to change values of the constant and the starting number of fish, to work out what combination will ensure that changes in the fish population from year to year are as small as possible.
- Another spreadsheet application is to use experimental data to explore relationships between variables. A spreadsheet can, for example, be used to investigate the relationship between the equilibrium concentrations of reactants in a chemical reaction, and thereby to arrive at the concept of the equilibrium constant.
- Spreadsheets are particularly useful in AS/A level physics, and students' skills in use of them may be tested in examination questions. A spreadsheet may, for example, be used to model behaviour such as the swing of a pendulum or the fall of a parachutist, using step by step calculations.

6.5.2 Drawing graphs from spreadsheet data

Although spreadsheet data can be used directly, it is often easier to detect changes and to observe patterns from charts or graphs. This brings with it a new set of operational skills that students need to learn to produce their displayed data. Many students will need considerable help in producing good quality graphs using the full range of options within a package such as Excel. In addition, it highlights the thinking skills required to design graphs, whether they are drawn by computer or by hand, to ensure that they are of an appropriate type and include appropriate axes, scales and limits.

An advantage of a computer generated graph is that it frees students from the graph drawing process, so that they can look more critically at the data. Computer drawn graphs also allow students to see quickly the effects of changes in experimental variables. A further advantage of graphs generated from spreadsheets is that they can be based on data that does not contain the 'noise' expected from experimental results, making it easier for students to identify relationships and patterns. 'Noise' can be deliberately introduced into spreadsheet data on another occasion, to help students focus on issues such as anomalous results and lines of best fit.

It is important to encourage students to look critically at the line produced by computer generated graphs, because the line that is drawn may not always be scientifically appropriate. Sometimes it is more productive to get the computer to plot the experimental points and for the student to draw the appropriate graph using them.

6.5.3 Data handling and the National Curriculum

References within the publication *Science: The national curriculum for England* (DfEE/QCA, 1999) identify the following opportunities to use data handling, spreadsheets and data bases to support learning at key stages 3 and 4:

Data handling:

- Key Stage 3 sections 2d, 2j
- Key Stage 4 sections 2d, 2k

Spreadsheets:

- Key Stage 3 section 2a
- Key Stage 4 sections 2b, 4a, 4b, 5a

Data bases:

- Key Stage 3 section 1a
- Key Stage 4 sections 1c, 1d, 3c, 3d, 3e, 3h, 3i

7 Using Science Software

7.1 Science CD Roms

A growing number of CDs have been produced commercially, with the specific aim of supporting science education (see Appendix 1 for supplier details).

7.1.1 Information and retrieval software

Some of the CDs are designed to be enormous information storage and retrieval systems. Since each CD can store the equivalent of a quarter of a million A4 pages of text, they are clearly capable of storing a vast amount of information. They also have the advantage over books of being able to combine text, still and moving images, sound and animation, to create attractive and dynamic learning packages which meet the needs of a variety of student learning styles.

Many CDs of this kind make use of embedded hyperlinks that facilitate movement and navigation within the resource, so that it does not have to be used in a linear manner. They may also make use of 'hotspots' that enable features such as text, images or sound to become active when the mouse is moved over them or clicked on them. This device, which is available for the creation of 'in-house' materials in more sophisticated software, removes clutter from the original screen and means that a single screen can meet the needs of a range of students. It is possible, for example, to provide extra detail via hotspots that would be valuable to students for whom English is not their first language, but which would interrupt the science flow if it were on screen all the time.

7.1.2 Simulation software

Other CDs are designed to simulate experiments and industrial processes or to illustrate key scientific concepts. Their content is often chosen to cover situations that are hazardous, not readily accessible or take a long time.

7.1.2.1 Scientific concepts and industrial processes

CDs include: simulations such as biological systems; industrial chemical plants such as the Haber process; and concepts such as radioactive decay and interactions within ecosystems, populations and food chains. Some of these CDs are interactive, so that it is possible for the user to change the value of variables and observe consequent effects on the simulated system.

7.1.2.2 Virtual experiments

A particular type of simulation is the virtual experiment. In some cases students can start at the beginning with a choice of apparatus, and move on to decide on amounts of materials or operating conditions. The software tabulates data arising from the experiment and often generates an appropriate graph from it. This kind of software can be used by teachers to complement student practical work. It can be used as part of a pre-lab discussion to set the scene for the experiment, or to stimulate post-lab evaluation of experimental process and results. It may also be used to extend student coverage to more and/or different practical contexts, or to provide differentiated tasks for particular students within a group.

7.1.3 Student use of CD Roms

A key issue in the use of some CDs is how teachers can ensure that it is an effective learning tool. There is a danger that students' navigation through information, or interaction with features, will lack focus and direction and will not be productive. As usual, the role of the teacher in thinking about the learning situation and the desired learning outcomes is crucial to the success of the activity. In many cases, a carefully structured worksheet to guide students through the task, and to make clear what they need to do, is a very helpful strategy to ensure that the resource is used effectively.

7.1.4 Science software and the National Curriculum

References within the publication *Science: The national curriculum for England* (DfEE/QCA, 1999) identify the following opportunities to use simulation software and video and CD Roms to support learning at key stages 3 and 4:

Simulation software:

- Key Stage 3 sections 1a, 2n, 3a, 5f
- Key Stage 4 sections 1b, 1c, 1d, 2b, 2c, 2d, 2e, 2i, 3n, 6d

Video and CD Rom resources:

- Key Stage 3 sections 3a, 4a, 4c, 4e
- Key Stage 4 sections 2a, 2b, 2d, 2h, 3a, 3b, 3c, 4a, 4b

8 Using Communication Technology

8.1 Using the internet

8.1.1 Searching for information

The internet is a vast store of information that can be highly relevant, detailed and up to date. It can provide information ranging from data on atmospheric ozone levels and medical research to photographs from the Hubble space telescope. Unfortunately, much information can also be irrelevant, and a distraction from tasks set for students, so that they waste much time on fruitless searches.

Search engines such as Yahoo, Google, Altavista and Ask Jeeves produce best results when the search request is made as specific as possible, using their advanced search facilities. If you are looking, for example, for information about the contribution of John Harrison to the measurement longitude, then in Altavista you could insert the advance search phrase of “John Harrison” AND “longitude”. The quotation marks ensure that John Harrison will be found as one phrase, and the AND means that only sites with both John Harrison and longitude will be listed. Other search engines use a + sign to link words in a single site together, or contain advanced search buttons to match the site with all the words that are being searched for.

The key issues are again effective task selection and class management, to ensure that students spend most of their time engaging with science. This means that the teacher needs to have tried out the task beforehand and either transferred relevant information to the school or college intranet, or provided clear navigation instructions to enable students to find the appropriate resources quickly.

Students often find, however, that the most difficult aspect of using the internet is not finding the appropriate resource but selecting that part of it which is relevant to their needs. It is the same difficulty that they experience when selecting relevant material from a section of text and diagrams in a book. The skills required for successful use of the internet therefore need to be developed through appropriate, progressive activities.

8.1.2 Molecular modelling and chemical structure drawing packages

In addition to providing information, the internet can also be a valuable source of free or inexpensive programmes, to support science education. Molecular modelling and chemical structure drawing packages are good examples. These programmes were originally designed for use in chemical and biological research. They have moved through several versions and become much more powerful, sophisticated and complex. While the up to date versions are very expensive, the older versions, which contain all the features required in schools and colleges, have been made freely available for download from the commercial web site.

Molecular modelling and structure drawing packages allow ideas and concepts that may have been introduced using physical molecular models to be explored further, beyond the constraints of the classroom. Molecular modelling packages such as RasMol, Chime and Web Lab Viewer, and chemical drawing packages such as Chem Draw and ISIS Draw, are particularly useful in Advanced level courses in chemistry and biology. These packages can be downloaded free from the appropriate internet site. The site can be found by putting the name of the package into a search engine and following instructions on the web site to download the programme onto a computer. There are huge numbers of molecules available on the internet that can be viewed and manipulated using a molecular modelling package. One good site is www.webmolecules.com.

8.1.3 Applets

The internet is also a rich source of animated images, called applets or small applications, which are programmes designed to run in a web page.

These include the following.

- Simulations of experiments – often ones which are difficult to carry out in the laboratory, such the effect of changing the value of gravity on a spring. Experiments might also be chosen that take a long time to set up or require expensive equipment. The applet simulation can generate results very quickly, and so allow students to spend most of their time thinking about the data rather than gathering it.
- Visualisation of ideas, concepts and mechanisms. Animated and three dimensional images can often provide easier access to concepts such as the electric motor, which may be very hard to grasp when described by text and a series of two dimensional diagrams in a book. Concepts such as the effect of mutation, or predator-prey relationships, that involve long timescales can also be illustrated very easily.

The main technologies for creating applets are Java and Shockwave. Java file or files that make up an applet are called .class files, and they will automatically run in most modern web browsers. Unfortunately, some schools may have deliberately chosen to operate with Java–disabled browsers. Shockwave technology produces applets or animations specifically for browsers: these are called .swf files. More modern web browsers will automatically support Shockwave, but others will need a readily available ‘plugin’ or small helper programme available from www.shockwave.com.

Search engines can be used to find applets, by using their advanced facility to look, for example, for electric motor and applet.

8.1.4 Internet video

There are many excellent video clips available on the internet. Some common types include .mpg, .mov and .ram files. The streaming of video so that it can be viewed directly from the web site is becoming more viable as connection speeds to the internet increase. Alternatively, video clips can be saved to a local machine or network. Video clips do use up a lot of memory, but the cost of writable CDs has fallen in recent years which makes them a viable option for saving video, since each CD can store several hundred short video clips. Some internet search engines, such as Alta Vista and Google, allow the user to search specifically for video clips.

8.1.5 Three dimensional visualisation

Impressive technologies have been developed to allow three dimensional visualisation of features of use in science teaching. There are specific, ready-made Java files to support 3D imaging, so that 3D Java applets are on the increase. The other main tool for 3D on the internet is VRML, or virtual reality modelling language. VRML files can be viewed in a web browser if a 3D plugin such as Cosmo Player (available from www.cai.com/cosmo/) is installed. VRML gives the user the ability not just to look from outside at objects, but to enter their 3D world. It is possible, for example, to go to the web site www.webmolecules.com and explore within a diamond or graphite crystal. The BBC’s Webwise resource at www.bbc.co.uk/webwise/ has a tutorial on VRML.

8.1.6 Freeware

There are many other excellent examples of freeware available from the internet that will support and enrich science teaching. There are for example, many versions of the periodic table. One way of finding out about these resources is to go to a shareware site such as www.zdnet.com/downloads/ and to look under the relevant categories. Alternatively, it is possible to search using search engines using keywords such as science + freeware to see what emerges.

8.1.7 Publishing work on the web

A number of science teachers place information on their institution web site. In some cases this consists of support material for students following particular courses, and in other cases it is interesting enrichment material. A particularly interesting use of the web is for students to publish and showcase their own work.

8.1.8 The internet and the national curriculum

References within the publication *Science: The national curriculum for England* (DfEE/QCA, 1999) identify the following opportunities to use the internet to support learning at key stages 3 and 4:

- Key Stage 3 sections 2i, 5a, 5c
- Key Stage 4 sections 2b, 2c, 2f, 2g, 3e, 3g, 3r, 3s, 4h, 5b

8.2 Communicating Electronically

As the electronic infrastructure of a school or college increases, so do opportunities to use it to communicate within and outside the institution.

8.2.1 Communicating via e-mail

E-mail can be used for the exchange of information such as experimental data, presentations and assessments between teachers and students within a school or college. It can also be used in a very imaginative manner to link different schools and even different countries together through the science curriculum. This can prove particularly useful where several schools with small post-16 provision operate a consortium arrangement in which a particular subject is taught on a single site.

8.2.2 Communicating via a video conference

There is an even greater potential for complex and sophisticated discussion and data sharing between teachers and students in different places using video conferencing. Some guidelines on ICT and video conferencing are to be found on the British Council sponsored web site, http://www.montageplus.co.uk/teachers/index.htm

9 Using Interfaces

9.1 Data logging

A wide range of data loggers and associated sensors and software have been developed for use in science education (see Appendix 1 for supplier details). There is a widespread belief that the technique should be included as part of students' experience in science, as is illustrated by references in the national curriculum schemes of work and in the QCA criteria on which the new AS/A level specifications for biology, chemistry and physics introduced in 2000 are based.

When it is used effectively, data logging allows students to concentrate on experimental technique and control of variables, and to concern themselves with what is happening in the experiment rather than on data collection. They can also see trends emerging as the experiment proceeds.

Data logging, however, is one of the most underdeveloped and underused features of practical work in science. The reality in many schools and colleges is that data logging is rarely used.

9.1.1 Past problems with data logging

One of the reasons for the low level of use of data logging is that when the technique was first introduced into schools, the equipment available at that time was unreliable and complicated to use. Another problem was the need for access to a computer to download data, and the need for familiarity with the software package used to analyse the data which was often specific to the brand of logger in use. Many teachers found themselves having to re-learn the technical skills needed to operate the hardware, and to manipulate the software every time they used it, because their use of data logging was so infrequent. The range of sensors that could be used with loggers was also relatively small to begin with. This led some teachers to believe that data logging was being encouraged for the sake of introducing ICT into science practical work, even when conventional techniques were equally or more appropriate.

9.1.2 Recent data logging developments

Data logging in science is now very different from the early days. Hardware is much more reliable and straightforward to use. There is currently a considerable range of commercially available equipment that offers teachers a clear choice in terms of cost and sophistication. Software has also improved enormously both in ease and speed of use and in the range of options that are available within it. The developments in loggers and software have been matched by innovation in sensors. There is greater variety now in any particular type of sensor, and there are new and novel sensors that have opened up opportunities for really creative practical investigations in science.

Data logging is particular useful

- for remote collection of data, on field work for example,
- for monitoring very fast changes,
- for monitoring very slow changes,
- for measuring changes very accurately,
- for measuring changes that are difficult to measure using conventional equipment such as high temperatures, infra red and ultraviolet radiation and gas volume,
- for measuring several variables at the same time.

9.1.3 Data loggers in detail

- Philip Harris have produced data logging equipment for many years and continue to build upon their reputation with a very wide selection of sensors. The company has recently launched a new device that makes use of 'smart card' technology.
- LogIT is another well known brand of logger that is reliable and cost effective. Users of this equipment can now buy a cable to connect it via a USB port to new computers and so ensure continuing compatibility.

- Data Harvest has introduced its Easy Sense range of loggers that can be connected to an increasing selection of sensors. They are sturdy pieces of equipment that offer choice between very easy and more sophisticated mode of use. They are particular useful for the collection of data remotely on a field trip, for example, when a power source is not available. A recent development allows the logger to be connected to a palmtop computer.
- The data loggers from PASCO are part of an extensive range of equipment initially developed for practical activities in physics. The logger can be linked to a particularly wide, sophisticated and innovative range of sensors suitable for a wide range of science activities and is supported by a very powerful software package. The system is rather expensive, but it is especially useful for AS/A level experimental work. The company has recently developed a parallel, lower cost system in which the ‘plug and play’ sensor is connected by a lead to the USB port of a computer for easy, real time data collection.
- Pico Technology is another company that is probably best known to physics teachers. It has produced an innovative general purpose logger called Dr Daq. This is a relatively low cost device with several built in sensors and sockets for additional probes. The equipment plugs directly into the back of a laptop computer and is used for real time collection of data.
- Economatics market the unique looking Jeulin UTT logger. It has a built in screen on which the collected data is displayed as a bar chart, table or graph.
- The i-button (available from Teaching Resources, Middlesex University) is probably the most unusual logger currently available. It is not much bigger than a button type battery, and measures temperature. It is programmed before use by connecting it to a computer via a docking device, to monitor temperature over a fixed period of time that can be several weeks. Data is downloaded to a computer and analysed using simple, supplied software. It is very portable and could be used, for example, to measure temperature changes as a result of exercise, by taping it to a student’s body.
- Another development in the data-logging field in recent years has been the emergence of graphical calculators as low cost alternatives to loggers, from companies such as Texas Instruments and Casio Electronic Co Ltd..
- More recently, companies such as Valient, ScienceScope and Matrix Multimedia have introduced low cost equipment aimed at the 8 to 14 age range, which exploits the reduced cost of electronic components. Logotron has updated its ‘Insight’ software that works with a range of different data logging equipment, and has the bonus of enabling the continued use of old alongside new hardware.
- Although not technically a data logger, a digital spectrometer (available from Nicholl Education Ltd) will capture and display the spectrum of a visible light source. This offers many creative opportunities for student investigations into direct, transmitted and reflected light.

9.1.4 Data logging sensors

Whatever the chosen logger, it usually needs to be connected to a sensor in order to gather data. The range and usefulness of sensors has been much improved in recent years. Biologists are able to monitor heart rate, heart beat and lung expansion with specially designed sensors. Chemists can now use a colorimeter sensor, sensors for measuring the concentration of selected ions and pressure sensors to monitor the amount of gas produced during reactions. Many experiments in physics, particularly those that involve very rapid changes, have always lent themselves to data logging, and there is now an extensive array of devices to measure all manner of variables.

9.1.5 Choice of data logging activity

The choice of data logging experiment is important in ensuring that the technique will be effective, and will be perceived by teacher and student as a relevant and useful activity. Changes that may take several days in biology, changes in physics that occur in a fraction of a second, and experiments in any topic where several different variables are monitored at the same time, are particularly appropriate. A number of books are available that suggest suitable data logging activities for different age groups: these are a very useful starting point for teachers trying to extend their use of data logging techniques (see Appendix 1).

9.1.6 Data logging software

All data loggers work with special software that enables gathered data to be stored, retrieved and displayed. Most of the graph plotting facilities have features that allow students to interact with the data and graphs, sometimes in a very powerful and sophisticated manner. These features include:

- ability to change the parameters of the graph including axes, scales, limits and labels,
- measuring facilities to provide accurate data about specific points, the difference between points, areas under graphs, slopes of lines, and statistical data such as means, maximum and minimum readings,
- zoom facility to look closely at the fine detail of graphs,
- ability to superimpose several graphs on the same axes,
- the potential to draw secondary graphs derived from original data,
- opportunity to annotate graphs or data to draw attention to features of particular interest,
- ability to print tables or graphs, to save them and to export them to other electronic packages.

9.1.7 Data Logging and the national curriculum

References within the publication *Science: The national curriculum for England* (DfEE/QCA, 1999) identify the following opportunities to use data logging to support learning at key stages 3 and 4:

- Key Stage 3 sections 2a, 3a, 3b
- Key Stage 4 sections 1c, 1d, 1e, 3n, 3o

9.2 Cameras

There is a range of camera devices that can be used in schools and college science activities. They include flexible neck video cameras, digital cameras, camcorders, webcams and digital microscopes. Images can also be obtained with a scanner.

9.2.1 Flexible neck video cameras

Flexible neck video cameras are essentially small video cameras on the end of flexible stalk. The image from such a camera can be viewed via a TV monitor or a data projector. Some models allow the image to be displayed and stored on a computer.

This type of camera is most frequently used in biology where adapters allow it to look down a microscope, and so permit whole class viewing of a microscope slide or a small specimen. In fact, its potential use is far wider than this. For example, it can be used for whole class viewing of:

- small features in other areas such as the liquid level against a burette scale,
- a micrometer scale,
- analogue meters,
- a variety of rock and mineral samples.

If this type of camera is connected to a data projector it becomes a very powerful and versatile tool. It can take the place of an overhead projector for example and does not even need the initial preparation of a transparency. All types of images can be directly projected and become the focus for whole class discussion, comment and evaluation. The images might be students' work, text or images from books or documents, three dimensional objects, pre-prepared material and material written or drawn at the time. It is an excellent facility that permits the use of spontaneous and improvised images to complement material that has been prepared before a lesson.

Flexible neck video cameras are available from distributors of scientific equipment such as Scientific and Chemical and Economatics or from specialist suppliers such as Meta Scientific.

9.2.2 Digital Cameras

The quality of the image from digital cameras has improved a great deal in recent years, while their cost has fallen significantly. They now provide a viable, easy and quick way of providing students with electronic images that are useful in science. Features of images can be highlighted and annotated using image manipulation software.

The images from digital cameras can be used in a variety of ways including:

- in PowerPoint presentations,
- as stimulus material in electronic worksheets,
- within students reports and coursework,
- printed out as a hard copy for visual display.

The image can be derived from experiments or apparatus, from field trips or from visits. A particularly creative use of a digital camera is to create a 360 degree picture of an object or an environment. A dozen or so photographs are taken in sequence so that the images overlap slightly. Software stitches the images seamlessly together. The user can scroll round the image and get the effect of standing in one place and gradually rotating through 360 degrees. An alternative lets you appear to walk around a stationary object. Both cases allow zooming in and out. This could be used, for example, to look at different outdoor habitats in biology, landforms in geology and complex experimental arrangements in chemistry and physics.

The Sony MAVICA range of digital cameras use ordinary floppy disks as the storage medium for images. This is a particular advantage in schools and colleges where many different students may wish to use the camera, and they can do this easily using their own disk.

Images taken by digital cameras can be manipulated by appropriate software. Images stored in JPEG format will take up less memory, but will be of slightly reduced quality than images stored in the non-compressed TIFF format. If images are to be printed out to provide a paper copy then a digital camera with a resolution of 3 or 4 megapixels is probably needed. If the main use of the camera is to produce images for web publication, then a resolution of a megapixel is likely to be satisfactory.

9.2.3 Camcorders

The cost of video camera recorders (camcorders) has also fallen in recent years, which makes this equipment a viable economic option for many science departments in schools and colleges. Except for the ability to look down microscopes, camcorders can perform most of the functions and therefore have most of the advantages of flexible neck video cameras. In addition, they can be used creatively to support student learning from practical work.

Students are involved in a great deal of practical work in science in this country, but there is a lot of evidence that the learning outcomes from the activity are quite limited. Students can be so involved in implementing complex instructions and manipulating unfamiliar equipment that the activity does not help them to learn, understand or think about the underlying science. Added to this, the pressure on the teacher to cover a syllabus or scheme of work and to prepare for tests and assessments, often means that classes move on to new topics without consolidating learning from practical activities.

One of the underlying problems is that practical science is an ephemeral activity. Once it is over, individual students are left with their own often different and often partial memory of it. Camcorders can help address this problem.

Camcorders can be used by one group of students during a class practical to record their experiment. The camera can be fixed in place on a tripod, so that there is a clear area of bench in focus on which the experiment is performed. This avoids the embarrassment that some students may feel if they are included in the image. Towards the end of the session, the recorded images, can be re-played through a TV monitor or a data projector. All of the class is now viewing the same image which can be the focus of teacher or student led discussion. The video clip can be used later by students absent from the class, by parallel groups who have carried out the same experiment, and as a stimulus for revision for tests. Assessments can be archived for use in future years.

As a variation on this approach, teachers may choose to video an experiment themselves under carefully controlled conditions. This allows pre-planning and thinking before starting the recording to ensure that the features that the teacher knows to be important are highlighted, and extraneous material is left out. This approach can be particular effective where the experiment is often not carried out because of hazards or expense, or where there are limitations such as working in a fume cupboard that limit the view of students.

Video sequences recorded in this way can be readily converted into a digital format and saved on a computer using inexpensive hardware and software. Digital camcorders are more expensive than their analogue counterparts, but allow direct recording of images onto a computer. In both cases, editing software enables teachers to produce a quite professional looking end product after only a small amount of practice. The advantage of the digital image is that the teacher can move quickly in either direction through the video clip, and can pause at points of particular interest to promote questions and discussion about the experiment and so support the learning and understanding of the underlying science free from the ‘noise’ present while carrying out the activity.

Another approach in the use of this equipment is to ask a small group of students to produce a video sequence of no more than five minutes length that will demonstrate a particular technique, or illustrate some particular aspect of science. They will need to think carefully about what images they are going to include before they begin recording. This technique is highly motivating to students and is a very effective learning technique.

Camcorders can also be used as data collection devices within experiments. For example, this might involve the use of time lapse photography in physics to record acceleration or the flight of a projectile (see Physics Review, April 2002 www.philipallan.co.uk)

9.2.4 Webcams

Web cameras (webcams) are some of the cheapest forms of camera available. They produce digital images that can be fed directly into a computer for storing and display. They lack the facilities and optical quality of other cameras, but they do provide a cheap alternative for gathering electronic images in science. They are very satisfactory for recording still images and they can also capture useful moving images, as long as the rate of change of the image is not too rapid. The webcam is particularly useful for recording slow changes and can be used for such applications in biology for example.

The long timescale of recording that is possible with a webcam can be used creatively to extend the boundaries of student experimental observations. Some internet web sites host real time web cam images. It is possible to set up an experiment in a school or college in which changes on a meter or in the appearance of a specimen are observed, using a webcam that is connected so that the images appear on the web site. Students can connect to the website and view the images using a home computer, and therefore follow the course of the experiment over a weekend or other extended period. It is difficult to think of other ways in which this could be achieved.

Webcams are available from retail suppliers such as PC World or from specialist companies that can be searched for on the internet.

9.2.5 Digital microscopes

Digital microscopes such as the Intel-Play computer microscope are dedicated pieces of equipment designed to capture electronic microscope images and store and display them on a computer. They can subsequently be inserted into electronic worksheets or displayed using a data projector. The image tends to be of a higher resolution than that viewed with a flexible neck video camera, and the on-screen measuring facility is useful.

Digital microscopes are available from science equipment distributors.

9.2.6 Scanners

Scanners have become increasingly available in schools and colleges and can prove very useful to both teachers and students in science. Teachers can use scanners to generate digital images for use in both whole class teaching using a projection system, or within electronic worksheets. Students can also make use of scanned images in reports and posters. Due attention must be paid to copyright issues.

Appendix 1:
Some Useful Publications and Contacts

Publications which contain useful ideas

Frost, R (1993) *The IT in Science Book of Data-logging and Control: a Compendium of Ideas using Sensors in Science Teaching. For Science from age 11–18*. London: IT in Science. See also www.rogerfrost.com.

Frost, R (1998) *Data-logging in Practice: a Practical Guide to using Computer Sensors in Science Teaching. For ages 11–18.* London: IT in Science.

Frost, R (2000) *The IT in Secondary Science Book: a Compendium of Ideas for using Computers and Teaching Science.* London: IT in Science.

Newton, LR and Rogers, L (2001) *Teaching Science with ICT.* London: Continuum.

Chapman, C and Lewis, J *ICT activities for Science 11–14.* London: Heinemann

Chapman, C, Lewis, J, Musker, R and Nicholson, D *ICT activities for Science 14–16.* London: Heinemann

Useful contacts

Association for Science Education	www.ase.org
British Educational Communications and Technology Agency	www.becta.org
Institute of Biology	www.iob.org
Institute of Physics	www.iop.org
UK National Grid for Learning	www.ngfl.gov.uk
Royal Society of Chemistry	www.rsc.org

Science software providers

4Learning	www.channel4.com/learningshop
Anglia Multimedia	www.anglia.co.uk
BBC	www.bbc.co.uk/education/schools
British Nuclear Fuels	www.bnfl.com
Cambridge Science Media	www.csmedia.demon.co.uk
Crocodile Clips Ltd	www.crocodile-clips.com/education
Heinemann Education Ltd	www.heinemann.co.uk
Dorling Kindersley	www.dk.com
Fable Media	www.fable.co.uk
Granada Learning	www.Granada-learning.com
Logotron	www.logo.com
Maris Multimedia	www.maris.com
Matrix Multimedia Ltd	www.matrixmultimedia.co.uk
Molecular Biology Notebook	www.aab.org.uk
Newbyte Educational Software	www.newbyte.com/uk
New Media Press	www.new-media.co.uk
Research Machines	www.rm.com
Schoolscience resources	www.schoolscience.co.uk
Science Multimedia	www.btlpublishing.com
Science Online	www.scienceonline.co.uk

Suppliers of data logging and other science ICT equipment

Casio Electronic Co Ltd	www.casio.co.uk
Data Harvest	www.data-harvest.co.uk
Djb microtech	www.djb.co.uk
Economatics	www.economatics.co.uk
Griffin and George	www.griffinandgeorge.co.uk
LogIT	www.dcpmicro.com
Matrix Multimedia Ltd	www.matrixmultimedia.co.uk
Meta Scientific	www.metascientific.com
Nicholl Education Ltd	www.nicholl.co.uk
PASCO Scientific	www.pasco.com
Philip Harris	www.philipharris.co.uk
Pico Technology	www.picotech.com
ScienceScope	www.auc.co.uk
Scientific and Chemical	www.scichem.co.uk
Teaching Resources, Middlesex University (for SEP temperature logger or i-button)	Tel: 020 8447 0342
Texas Instruments	www.education.ti.com/uk
Valient Technology	www.valient-technology.com

Appendix 2: Acknowledgements

A number of teachers kindly arranged for visits to their school or college to demonstrate how they make use of ICT in science. Others made helpful comments during discussions about the use of ICT in science, all of which has informed the writing of this report. The help and support of those listed below is gratefully acknowledged.

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ICT IN SUPPORT OF SCIENCE EDUCATION

A Practical User's Guide

Information Communications Technology (ICT) has an important role to play in science teaching. Rapid developments in hardware and software mean that a great deal is now possible, yet there remains a considerable gap between the aspirations of experts and the realities of the classroom. This Guide bridges that gap by providing guidance on what can be done by teachers in every school and college.

The Guide is in two sections. Section A gives some general principles and will be of interest to school managers as well as to teachers of science. Section B has specific examples that will be of practical help to science teachers.

The idea for this Guide originated in a seminar on ICT in Support of Science Education held by the Chemical Education Group at Salters' Hall in May 2001. The Guide builds on the seminar themes, drawing on the results of visits to schools, colleges, publishers and software developers.

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