ICT IN SUPPORT OF SCIENCE EDUCATION

A Practical User's Guide: 2005 Edition

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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 help 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 first edition of this guide was published in 2002. Since that time there have been significant changes in the ICT infrastructure in many schools and colleges, in the expertise and confidence developed by science teachers and in the availability of resources to support science teaching. This second edition builds on the themes and ideas in the first edition and extends, develops and brings up to date all of the sections in the original publication.

The Guide is in two sections. Section A gives some general principles and will be of interest to Head Teachers, 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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Bob Campbell
September 2005

This Guide has been written by Derek Denby, Director of the Science Centre of Excellence at John Leggott College, Scunthorpe, and edited by Bob Campbell, Acting 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 science education and chemistry education in particular. The Salters' Institute supports curriculum development through 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 Group are also developing Twenty First Century Science: a new GCSE course for 2006. 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 education. 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 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 education 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 and colleges and educators with special interest and expertise in the use of ICT science teaching and learning. Their assistance is gratefully acknowledged.

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. Although the context of this report is support for science education, ICT issues are generic and apply across the whole 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 range of ideas and sources of further information to help teachers develop the use of ICT within their own departments.

Section A
General Principles

2 Background to ICT in Science

2.1 Recent developments

In the past, hardware, software and training limitations have tended to reduce the impact of ICT on science education. In recent years, however, hardware costs have fallen, hardware has become more reliable and the ICT skills of teachers have improved. The improvement in ICT infrastructure in many schools and colleges and in the ICT skills of teachers and students has been significant since the first edition of this guide was published three years ago. Teachers have also used the opportunity to develop strategies for using ICT in science. These factors combine to make significant progress in the use of ICT to support science teaching a reality in some institutions and a real possibility in others.

In the last few years there has been a shift from the use of science as a vehicle through which students learn to use ICT skills to the use of ICT skills as tools to assist learning in science. There has been a growing recognition that students bring to science classes ICT skills that they have learned elsewhere and which can they can use to help their understanding and enjoyment of 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. Strategies suggested within the National Secondary Strategy (formerly Key Stage 3 Strategy) help teachers see the merits of combining both types of activity in a blended approach to the use of ICT.

This has led to greater emphasis on the role of the teacher and recognition of the need for training to help them learn operational skills to use new equipment and software and, crucially, application skills to ensure that new technologies add value to learning.

2.2 The benefits of ICT in science

There is considerable evidence that learners are more highly motivated when their learning is supported by ICT. Newton and Rogers (2001) provide a review of claims and evidence. It is now recognized that:

- ICT has a positive impact on teaching and learning in the classroom (BECTA, 2002);
- 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. However, 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 provide more frequent and more accurate experimental readings;
- computers 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;
- ICT can extend learning beyond the constraints of a traditional teaching space. 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 science teachers to be creative in their teaching and for students to be creative as they learn.

3 Hardware Resources

3.1 ICT suites

In the early 1990's, a main thrust of introducing new ICT hardware in schools and colleges was often to centralise this provision within the institution. This led, typically, to networked computer systems and groups of computers concentrated in dedicated ICT suites as part of a whole school or college policy. The driving force at this time was a desire to assist learning about ICT rather than using ICT as a learning tool in curriculum areas such as science.

This approach to introducing ICT resources tended to create barriers to the use of ICT in supporting science. The logistical difficulties and time and forward planning required 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 meant that ICT was perceived by teacher and student as an 'add on' to normal learning rather than an integral part of it.

IT suites may still have a role to play where ICT infrastructure in the science department is limited. With appropriate pre-planning, teachers can make use of the Internet, CD ROMs and DVDs. In addition, data collected using a logger can be downloaded to the school or college network so that all of the class can be involved in activities such as drawing and analysing graphs derived from the data.

3.2 Laptop computers

In recent years 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. Some years ago this represented an expensive option, but as prices have reduced and specifications of hardware have increased, cost is becoming less of a barrier.

The use of laptops by teachers has also become much more common. The weight of the laptop is important since it really does need to be portable so that it can be integrated into the teaching process. This can lead to difficult choices sometimes since the addition of DVD and CDRW facilities, which make the machine more useful add to the weight.

The power, scope and availability of Personal Digital Assistants (PDA's) have also increased very rapidly. They are of low cost and very portable. Their use in conjunction with some data logging equipment has already been developed and other uses are currently being explored to make use of their relative low cost and portability.

3.3 Whole class viewing systems

An alternative and often complementary 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.

There may, however, also be potential drawbacks to this development as it can easily reinforce a didactic style of teaching in which students are the passive receivers of teacher generated ideas and information, albeit, rather more richly illustrated with images, PowerPoint presentations and animations.

3.4 Data projectors

The installation of a Liquid Crystal Display (LCD) projector, permanently fixed to the ceiling and wired to appropriate sockets and projecting on some form of permanent screen has made a significant impact on the use of ICT in science in many schools and colleges. This arrangement significantly lowers the threshold of difficulty teachers face in using ICT in support of science and thereby increases the likelihood of real progress in this area.

There are two main types of projector, SVGA (with a resolution of 800 ◊ 600 and usually in a lower price bracket) and XGA (with a resolution of 1024 ◊ 768). XGA offer much higher quality screen images. The resolution of the projector should match the resolution of the PC or laptop that will be used with it. As laptops have improved their display settings have got better and higher quality screen resolution is needed to make full use of the quality of image available. When choosing a projector the luminosity and sound are important. For most rooms a projector of at least 1200 ANSI lumens is needed so that the image can be easily seen without blacking out windows. The luminosity should not be too high, however, as this will make the image too bright to see in comfort. The loud speakers in some projectors are fairly basic and may not do justice to the sound files. It is often 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 be wired to connect to 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.

If a single projector has to be shared between several science rooms then one solution is to set up a multimedia trolley. This might include a PC, VCR, projector and loud speakers all connected together and bolted down to the trolley. The teacher only has to wheel it into a room, connect it to the mains supply, and a network cable if available. Care is needed not to move any projector while it is cooling down after use since this can seriously shorten the working life of the bulb which is very expensive to replace.

The handsets of some projectors can be used to control what is on the screen as if it was a remote mouse. A mouse with a wireless connection will also allow control of the screen from anywhere in a room and so allow greater flexibility in teacher use and student involvement. One disadvantage of remote devices of this kind is that they are small and easily removed. Some projector handsets also include an infrared beam that can be used to pick out and emphasise specific parts of the screen. These interactive features are not standard on all projectors and it may be necessary to purchase these as extras.

There are many companies who will provide schools and colleges with projectors and laptop computers. The market is very competitive. There are considerable economies of scale to be made if a large number of systems are purchased at the same time. In general, the more you pay for a projector, the more sophisticated it will be and the bulbs will last longer.

3.5 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.

Increasingly, however, video clips are being transferred to a digital format on CD ROM or DVD which provide advantages of greater storage capacity and ease of selection of specific footage. The CD ROM and DVD also have a higher image quality and last longer. Digitised video can be stored on a school or college network but such a video uses up a lot of space. The advantage, however, is that the video can be accessed by more than one student at the same time.

3.6 Use of cameras with a projection system

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

A camera will permit whole class viewing of any text, image or 3-D object, including students' written work, books and pictures. It can act just like an overhead projector (OHP) except that there is no need to create a transparency first. A camera with a wireless connection offers great flexibility of use.

3.7 Data logging

Data logging in science is a facet of ICT which is unique to science and is a developing area of activity. It is increasingly seen as an excellent mechanism for stimulating students to think about and discuss the ideas which they meet in science. Detailed applications of data logging in science are covered later.

3.8 Screens and whiteboards

There are several alternative ways of viewing the images from a LCD projector. The simplest methods are to use an ordinary screen or whiteboard. This may often be already in place when the projector is installed. These are low cost options which are 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. The disadvantage is that a shiny white board can give rise to some reflected glare. A matt white board does not have this problem. A traditional projector screen also provides a clear non-reflective surface. A combination of a projector screen that can be lowered in front of an ordinary white board is regarded as an advantage.

Modern projectors are equipped with remote control devices that include a narrow infrared 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.

3.9 Interactive whiteboards

There is a range of interactive whiteboards available commercially. These 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 include a range of useful features. 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.

Some advantages of the interactive white board over the projection of images onto a screen are:

- electronic resources can be access from the screen without having to move away to a PC or laptop;
- pre-prepared screens can be annotated during a lesson and the new screen saved to be looked at again or for printing paper copies;
- it is easy to move between screens to return to earlier work or to recap at the end of one lesson or at the start of the next one;
- the drag and drop facility can be used to move items around the board to, for example, label diagrams, group or separate words and assemble apparatus for experiments;
- colour or highlighter can be used to focus attention on specific features on the board to link similar ideas or distinguish between different features. With some boards it is possible to cover part of the display and reveal it only when needed or to use a spot light facility to make one feature on the board stand out from the rest of the display;

- drawings and text can easily be cut, copied and pasted around the board. This adds to the fluidity of discussion;
- most students like using an interactive white board, particularly kinesthetic learners;
- the temporary nature of additions to the board encourages students to speculate and take risks in their responses.

The Mimio® and eBeam® devices are examples of a low cost pieces of equipment that can be linked to a laptop and an ordinary, non-interactive whiteboard to make it interactive. It can be used to save what is written on the board to the computer for later use. A mouse pen also makes the board interactive when an image is projected onto it from an LCD projector.

Many teachers consider that an ordinary white board installed alongside their interactive white board provides useful flexibility of use.

3.10 Associated technology

A number of associated technologies have been developed to complement the projected image on an interactive white board:

- graphics tablets or slates allow the interactive white board to be controlled from anywhere in the room by writing on it with a special pen. The movement of the pen across the tablet controls the movement of the cursor on the board. One advantage of this device is that it allows students to contribute who are not able or do not wish to write on the board in front of the class;
- a remote keyboard links to the projector by a wireless connection so that text can be added to the screen from anywhere in the room;
- a remote mouse, sometimes called a gyromouse, is a low cost way of controlling what happens on the board. It requires some practice in order to make it function effectively;
- a tablet PC provides great portability and flexibility. It can also be used from any part of the room as it uses a wireless connection to a projector;
- voting systems consist of a class set of small, hand held devices that allow students to choose from a small number of options. The options may be answers to multiple-choice questions or an indication of the extent to which they feel confident about a particular idea or technique. Students vote anonymously and may be more likely, therefore, to express uncertainties or to speculate about answers to questions. This feedback gives the teacher an instant snapshot of class views and teaching can be modified in the light of such information. Disadvantages of this system are the time needed to set up the questions and the closed nature of the responses.

3.11 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 and therefore do not need a projector, but they are not interactive. They are currently quite expensive but the initial expense has to be weighed against the ongoing cost of projector bulbs.

3.12 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 disadvantages are that the size of the image is limited by the size of the TV monitor, and the system is not interactive.

3.13 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, budgeting for replacement is important. Schools and colleges often have a replacement policy in place for PC's but may not have thought through the financial implications of replacing or updating laptops and projectors or of replacing projector bulbs. Some schools and colleges have opted for leasing agreements rather than purchase 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 access ICT equipment, it becomes even more important that they should be sufficiently well trained to make use of the new opportunities they are presented with. 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 ICT 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 driver of ICT use.

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, however, 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 and the role of the teacher in sessions when students are using ICT. This requires recognition of the continuing importance of basic teaching skills such as linking activities to learning outcomes, classroom management and promoting student discussion and thinking. Use of ICT can change the role of the teacher and may well make their contribution to student learning even more important.

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 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 and ICT support staff.

Training and ICT infrastructure need to be considered together. Where teachers have individual laptop computers, ICT can more easily 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.

4.2 ICT Skills Audit

A useful first step when thinking about teacher ICT operational 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 appointees 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 and experience.

4.3 Online training materials

There are many examples of training material in the use of generic ICT packages such as the Microsoft Office suite of programmes available on the Internet. Searching the Internet for Word, Excel or PowerPoint tutorials will usually provide many examples to choose from.

Some examples of support materials are to be found as follows:

The LSDA Information and Learning Technology (ILT) Materials Downloads are available at http://www.ccm.ac.uk/ltech/cfet/materials/materials.asp

The entire collection of video software tutorials from the Ferl 16-19 Conference 2002, together with the conference content material are available at http://ferl.becta.org.uk/display.cfm?&resid=3784&showArchive=1

4.4 Accessibility and inclusion

TechDis is a JISC-funded service (Joint Information Systems Committee) which aims to enhance provision for disabled students and staff in higher, further and specialist education and adult and community learning. It has relevance for schools catering for 14-19 year olds and much of the advice it offers it applicable to all learners. While accessibility and inclusion are whole institution issues, Techdis offers practical advice that can be used by teachers when devising their own electronic materials. Information about Techdis is available at http://www.techdis.ac.uk.

4.5 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 laptop computers, as well as more dedicated science equipment. They may also be responsible for aspects of the science department administration such as stock control.

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 relatively new feature of ICT in science has been the development of commercial ICT based resource packages as major components of the science curriculum.

Research Machines, for example, have produced material for science at Key Stage 3, Heinemann have developed a comprehensive resource and management package to support the Salters-Nuffield Advanced Biology AS and A2 specifications and the Advancing Physics AS and A2 specifications use an ICT package that is distributed on a CD ROM.

The new Twenty First Century Science is supported by ICT resources that have been designed to be an integral part of this course. Each module of the course is supported by a range of electronic resources including PowerPoint presentations, animations, video clips, interactive applets, images, sound files, student activity sheets, links to relevant web sites and on-line tests linked together in a coherent package that helps teachers access appropriate high quality materials easily and quickly.

It is now commonplace for publishers to offer CD ROMs linked to their paper-based resources. These may include multimedia resources, interactive features, databases of relevant information and assessment items. Publishers also offer additional web-based resources to complement paper-based materials. There is a clear expectation that teachers in schools and colleges will seek to support teaching and learning in science using ICT.

These initiatives will tend to accelerate the use of ICT 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 for the level and location of ICT hardware in science, particularly if courses with integrated ICT 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 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 one for the whole institution. 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. This will involve evaluating how students can gain maximum benefit for their learning from such a facility.

Resources placed on a VLE or MLE allow students to access them at their own time of choosing and to work at their own pace. This can be particularly useful during holidays or if students are not able to attend school or college. A system of this kind also provides a useful organisational framework for science resources.

5.3 ICT and the 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.

The DfES National Secondary Strategy (formerly Key Stage 3 Strategy) team have published extensive support and exemplar materials illustrating the use of ICT in supporting teaching and learning across the curriculum, including science. These materials are designed to promote effective use of ICT in science by embedding ICT in science teaching. They build on the Key Stage 3 National Strategy ICT strand and so recognise the ICT skills that students have developed which can be harnessed to help them learn science.

The DfES Standards Unit's post-16 initiative called 'Success for All' includes science as one of the four curriculum areas in the first phase of development. The science team have identified 'Gaining from Technology' as one of its three key themes and showcases the use of ICT in teaching and learning science on biology, chemistry and physics CD ROMs distributed to providers of post-16 science in England.

Section B
Specific Examples

This section of the guide presents a practical and pragmatic account of ICT in the context of science education in schools and colleges. It aims 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 evidence that learning in this format is promoted by small group interactions. A key strength of effective electronic worksheets is that they are interactive and require the student to be an active participant in learning.

6.2 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 and on students’ computers at home.

Word can be used in a number of ways:

- use of writing frames and templates to help students develop skills of report writing;
- 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 to promote discussion and thinking;
- words that are jumbled up in sentences and sentences that are jumbled up in paragraphs that 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;
- still pictures, video images and sound files embedded within the document to provide stimulus material on which questions are based in what has become a multimedia resource;
- use of hyperlinks from a word document to other files on the network system or to websites;
- use of comment boxes to provide extra support for students such as explanation of scientific terms or more detailed instructions;
- use of drop down boxes to create multiple-choice questions using the ‘form’ menu.

6.3 Test construction software

Hot Potatoes (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.

This software can be used to construct multiple choices and short answer quizzes, cloze tests where students fill in gaps left in sentences, sentences that have been deliberately jumbled up, matching exercises and crossword puzzles.

One way of using this package is to ask small groups of students to construct tests or crosswords based on a particular topic for other groups to answer. This helps students to appreciate the standard of work they are aiming for and promotes self and peer assessment.

Quia is a similar piece of software www.quia.com. You have to pay a license fee for this but you get access to tests already constructed by others.

6.4 Mind Mapping

There are a number of inexpensive mind mapping programmes available commercially such as Mind Manager, Mind Genius and Inspiration. This type of software allows students to build a web or spider diagram in which they link together ideas and information relevant to a particular topic. Typically, major headings are linked to branches with related headings, which may in turn be linked to further sets of branches containing increasing detail. Icons or photographs can be added to the diagram to illustrate ideas and make the diagram more attractive.

Use of this kind of software allows students to make connections between related ideas, encourages lateral thinking and helps students organise their thinking. It is particularly helpful in providing a framework for a synoptic view of work that students have covered, and comparison of student mind maps can generate very productive discussions. This kind of activity is particularly valuable for visual learners.

It is possible, of course, to construct a mind map using text boxes and arrows in MS Word.

6.5 Animation Software

Flash (www.macromedia.com) is a more sophisticated software package which offers the facility to design high quality images, attractive animations and interactive quizzes. It requires significant technical skills to make use of them, but this expertise is becoming more common in schools and colleges.

6.6 Microsoft PowerPoint

The interest in presentation software has increased in recent years 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. For example:

- 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. The process of animation is much easier with newer versions of the software;
- 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;
- presentations can be used as stimuli in starter or plenary sessions to introduce, review or promote thinking about ideas in science.

The process of preparing slides for a PowerPoint presentation can be very helpful to teachers. It provides an opportunity to re-think about the key points which need to be communicated and the most effective way of achieving this in a simple and logical manner. One approach that many people find useful is to devise a ‘storyboard’ on paper before using the computer. The storyboard provides a framework or skeleton for the presentation with each slide representing one part of the story.

PowerPoint presentations can be made available to absentees and to others to reinforce teaching and aid for revision.

6.6.1 Helpful PowerPoint tips

- Choose a contrast between the background colour and the font colour. The background colour should be quite dark. Black and white can be difficult for some people who have dyslexia.
- Use a clear font that is easy to read. Some people suggest that a sans-seris font such as Arial or Helvetica works best. The font Verdana is also said to be easy to read. Italic script is more difficult to read. Make sure also that the font size is large enough to ensure that it can be read.
- Use the same background, font style and font size for all slides in a presentation.
- Beware of using too many bullet points. The ‘dim body text’ feature can be used to highlight just one bullet point at a time.
- Don’t try too many special 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.
- Don’t put too much text on a slide because students will concentrate so much on reading that they will spend little time on thinking about what they have read. You can always use the ‘add notes to slide’ facility and print them out for handing out later.
- 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.
- Do include animations.
- Finish with a slide that summarises the key points of the presentation, or at least indicates that it is the last slide.

6.6.2 PowerPoint and students

Groups of students can be encouraged to create their own presentations on particular topics to show the rest of their class. This can assist their understanding of science, as well as develop their communication skills. To help ensure that the maximum time is used in focusing on the science, teachers can make available a bank of useful resources which might include text, still and video images and sound files. Students will need to choose and sequence these elements, and add to them, in order to make a suitable narrative presentation.

Students can also be supported in producing presentations, where appropriate, by providing the ‘bare bones’ of a PowerPoint presentation, and asking them to complete it by annotating text boxes etc.

There are several advantages to be gained from involving students in creating PowerPoint presentations.

- Students can participate whatever their writing ability and can produce a presentation of much higher quality than they might be able to manage on paper.
- Students can present information and ideas in their own way which encourages creativity and thinking.
- Students are encouraged to engage in higher order thinking to synthesise their own response to a stimulus rather than regurgitating a set response given to them previously by the teacher.

- Working within a group to create a presentation allows students to articulate and to discuss their ideas about science.
- Use of images and text helps students to make connections and reinforce ideas.
- Use of hyperlinks means that students can develop their ideas in unusual ways since they are no longer restricted to a linear presentation.
- Choosing appropriate words and phrases increases students' facility with technical vocabulary and accurate spelling.

6.6.3 Drawbacks of PowerPoint

The use of PowerPoint by the teacher in whole class teaching can soon become a lecture in which the teacher does all the talking and the students are passive observers and are not engaged in the learning process. This potential danger can be avoided by using PowerPoint in short bursts or by using slides to pose questions and leaving time for students to develop their responses, perhaps after discussion in groups.

Because the slides have been pre-prepared, teachers may be tempted to move through them too quickly and not provide students with enough time to reflect upon an idea before moving on to the next one.

Teachers may be tempted to look at the screen during a presentation and neglect eye contact with their students and be less aware of how their students are reacting to the session.

PowerPoint may send out unfortunate messages about science, presenting topics as a series of bits of information to learn rather than stimulating students to think about ideas and speculate about explanations of the phenomena they observe.

6.6.4 PowerPoint and schemes of work

Effective schemes of work are working documents, which provide a clear summary of content, learning objectives and outcomes, teacher and student activities, assessment items and resources relevant to a particular time span. They should be accessible and easily modified. One way of achieving this is to construct them electronically as a set of PowerPoint slides. This format lends itself to showing a week of work on one slide so that it is easy to find relevant information. Hyperlinks on each page to electronic resources on the school or college Intranet and on the Internet can make them available when the teacher needs them and solves the problem of trying to remember where the particular resource has been stored. This is a very effective way of sharing good practice across a department.

6.7 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 are 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).

6.8 Presentation by students

The use of ICT packages by students to present their own work, or for small group or class presentations, is often 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 observational work;
- producing quality notes;
- making worksheets or posters for use by other students.

6.9 Spreadsheets

Spreadsheets are very powerful tools that can be used in science for the calculation, analysis and display of data. The power and versatility of a spreadsheet lends itself to many uses in science. Some spreadsheets have already been designed for the user and are targeted at specific topics such as The Periodic Table. Microsoft Excel is a generic software package, which finds widespread uses in science.

6.9.1 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 partially completed spreadsheet which is locked so that the only cells that can be edited are the ones into which students enter data;
- 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 students 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. Students can be helped further in a pre-prepared spreadsheet by the use of different colours for columns that contain different types of data so that cells they put data into are red, cells that contains numbers that are not to be changed are blue and cells that contain the results of calculations are yellow. This allows students to focus on the input of data and interpretation of results rather than on the calculation in between.

However it is generated, the data in a spreadsheet can be used in a variety of ways.

The same 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.

- 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 and products in a chemical reaction, and thereby to arrive at the concept of the equilibrium constant.

- Spreadsheets can be used to display and analyse experimental data collected by students. This is likely to be particularly motivating since students have ownership of the activity. It can be undertaken in most institutions since only one computer is required.
- Spreadsheets can also be used to analyse data collected from interactive science CD ROMs. For example, data taken from a CD ROM which explores the effect on the yield of ammonia in the Haber process of changing temperature and pressure can be entered by students into the spreadsheet and appropriate graphs drawn using this information. In this approach, the student becomes directly involved in the process of analysing and interpreting the data.
- The ability to handle large data sets is a feature that is very useful in biology. It allows classes to work first with data they have collected, to extend their activity to include data from other classes in the school or college and then to access external stores of data to see if the trends and relationships they have detected in smaller samples are to be found on a larger scale.
- Spreadsheets are particularly useful in AS/A2 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.
- The macro function of a spreadsheet allows quite sophisticated activities to be automated and so generate a user-friendly interface for students in an electronic worksheet. This can include the provision of instant feedback to students on what they have input as answers in the form of a colour change of cells or in words using the devices of conditional formatting or 'IF' statements. This kind of approach is particularly suitable for repetitive actions such as self-check calculations.

Producing, trying out and developing spreadsheets takes expertise and time. There is much to be gained by sharing this task and sharing expertise across a science department.

6.9.2 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. Some students will need help to develop the operational skills needed to produce good quality graphs using the full range of options within a package such as Excel and will also need help in choosing between these options and on deciding which is most suitable for a particular task.

In addition, generating graphs from spreadsheet data highlights the thinking skills required to design graphs to ensure that they 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 use their time to look 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 occasions, 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. This approach has the benefit that students have to think about the choices available and they become more aware of erroneous or unusual points.

6.10 Modelling

Modelling behaviour is a very important activity in research science and when used with students it can provide a very motivating insight into the potential of modern computers.

A spreadsheet such as Excel can give a glimpse of this potential when used to predict population growth in predator prey case studies or to look at the consequences of changing variables such as the mass and distance from the sun of planets.

Software designed specifically for modelling such as VnR and World Maker for younger students and Modellus in post-16 classes provide a much greater opportunity for student creativity. These tools encourage students to share their ideas and to think precisely about each step in making links between connected phenomena.

6.11 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

Databases:

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

7 Using Science Software

7.1 Using Multimedia Resources

A growing number of CDs and DVDs have been produced commercially, with the specific aim of supporting science education (see Appendix 1 for supplier details). Most publishing houses also produce multimedia resources and web based resources which offer support to text based resources and so provide a comprehensive package of materials for students, teachers and technicians. Some advantages of these resources include:

- they are 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;
- if the resource is made available on a school or college system students can look at a particular feature over and over again and can work at their own pace and at a time of own choosing;
- students can get rapid feedback from interactive features of the resource;
- CDs and DVDs can be more convenient, easy to access and reliable than connection to the Internet.

7.2 Information and retrieval software

Some of the CDs are designed to be large 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.

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.

7.3 Simulations and animations

Simulation software models scientific phenomena. The model is based on appropriate mathematical relationships and provides a good representation of how the phenomena changes under different conditions. Software based on laws of motion are good examples. Animations on the other hand, try to illustrate the phenomena and may simplify the picture to aid understanding. The movement of electrons in a wire is an example. It is helpful for the teacher to be aware of the differences and make these explicit so that students do not absorb any unhelpful messages.

Many CDs are designed to simulate experiments and industrial processes or to illustrate key scientific concepts. They can be particularly useful because they can show aspects of science that are not possible in other ways such as:

- they can speed up the very slow (eg plant growth) and slow down the very fast (eg movement of athletes);
- they can make the invisible, visible (eg interactions between atoms and molecules);
- they can show hazardous experiments (eg radioactivity);
- they can enable the student to explore the very large and the very complex (eg the solar system and ecosystems);
- they can simulate industrial processes (eg the Haber process);
- they can allow students to practice using a microscope. Bioscope is a simulation of a real microscope and includes a large number of botanical and zoological microscope slides at a range of magnifications. www.cambridge-hitachi.com

- if the multimedia resource is interactive, students may be able to change the value of variables and so ask and get a rapid response to 'what if' questions;
- they can allow students to carry out virtual experiments. 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.

Other advantages of multimedia resources are that they tend to motivate students and can help provide differentiation by use of resources to provide support and practice for basic tasks or provide extension activities for gifted and talented students.

7.4 Some limitations of CDs and DVDs

Some limitations of CDs and DVDs are:

- they can be quite expensive;
- they can go out of date;
- they may not cover a topic or place emphasis in exactly the same way as the teacher would choose to do so that the teacher has to modify their style to suit that on the CD or DVD;
- the images used in multimedia resources tend to give the impression of science as a very neat and organised activity without the 'noise' that is present in reality;
- some of the simplification introduced in an attempt to make learning easier may lead to misconceptions taking root in the mind of the student;
- there can be a temptation to replace real experiments with virtual experiments if laboratory time is limited or if technical support, materials and equipment are not readily available.

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. 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.

7.5 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

There are a growing number of Internet sites that have been created to support science education.

- Professional bodies such as the Association for Science Education (ASE), Institute of Biology (IOB), Institute of Physics (IOP) and The Royal Society of Chemistry (RSC) each have comprehensive websites and are rich sources of ideas and information.
- Many sites have been created by schools, colleges and universities in this country and abroad and searching for particular topics will often lead to these web pages. They can provide interesting and innovative approaches to learning and may provide students with a different way of explaining ideas, which complement their classroom experience. College and university sites in the UK have addresses ending in.ac whereas universities in the USA have sites ending in.edu.
- The National Learning Network (NLN) is the home of the growing list of NLN materials. www.nln.ac.uk/Materials.
- The Joint Information Systems Committee (JISC) supports thirteen Regional Support Centres (RSCs), each of which has a website together with a national RSC website that contain a wealth of information about creating electronic learning materials www.jisc.ac.uk/rsc.
- The Resource Discovery Network (RDN) is a JISC funded subject portal with links to a number of subject gateways including PSIgate for chemistry, physics earth science and astronomy www.psigate.ac.uk and Biome which is the hub for life sciences http://biome.ac.uk/. These gateways are most suitable for post-16 courses but they include an enormous range of material. The RDN site also has a ‘behind the headlines’ section which offers background information to the latest headlines.
- The Virtual Training Suite for Science is a free web tutorial to enable teachers to access resources for science. www.vts.rdn.ac.uk/tutorial/science.
- The Ferl site is part of the Becta website and is an essential place to look for post-16 science resources. It includes many resources shared by teachers and it has a comprehensive set of ‘how to do’ guides to help teachers create their own resources. http://ferl.becta.org.uk.
- The National Grid for Learning contains links to a large number of resources. www.ngfl.gov.uk.
- The Royal Society of Chemistry has developed a site, which contains a wide range of resources for use in teaching chemistry from 11 to 19 which provide many ideas for other areas of science. www.chemIT.co.uk.
- The BBC science learning site is to be found at www.bbc.co.uk/sn/.
- Ingenious is a project website created by the Science Museum. www.ingenious.org.uk.
- Some sites are sponsored by specific industries to provide information about their activities while ‘Industry Supports Education’ funds electronic learning materials at www.schoolscience.co.uk.
- The schoolzone site is aimed at AS and A level students www.s-cool.co.uk.
- The Chemist’s Net is aimed at chemistry teachers and lists useful sites for AS/A level and provides access to a discussion group for A level chemistry teachers. www.chemclub.com/teachers/.
- Classroom clipart provides a wealth of free images. http://classroomclipart.com.
- Roger Frost writes extensively about the use of data loggers and other aspects of ICT in science and his website contains much useful information www.rogerfrost.com.
- The website of Sheffield College contains several thousand annotated, categorized and searchable links in science. www.sheffcol.ac.uk/links/.
- There are many sites which are of interest to science teachers. These include sites hosted by the Awarding Bodies in the UK which provide information relating to assessment, government initiatives such as Secondary National Strategy, formerly Key Stage 3 Strategy and the post-16 initiative Success for All, inspection reports and teacher forums such as those hosted by Salters Advanced Chemistry and Twenty First Century Science.

8.2 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 of 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.

Google provides advice about basic search strategies at www.google.co.uk/help/basics and some more advanced search techniques at www.google.co.uk/help/refinesearch. Google Sets allows you to enter words like atom and nucleus and leads to many related terms, each with associated links. Google Image Search leads to an extensive library of images. Google Scholar provides access to academic papers.

Search Engine Colossus is an international directory of over a thousand search engines located in different countries around the world which may be of use in finding unusual bits of information. http://www.searchenginecolossus,com.

Copernic Agent chooses ten search engines and gets them all searching at the same time for ten matches to the key words that have requested. They ignore duplicates so that a hundred different sites are suggested in order of relevance. http://www.copernic.com.

Webselect has been developed by Nelson Thornes as a search engine specifically for use in Key Stage 3 science. All of the sites have been evaluated by teachers to ensure that they match the national curriculum and are appropriate for the target age group. www.nelsonthornes.com.

Two of the key issues in searching for information are 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.

Another feature of Internet information which teachers will wish to highlight with students is the authenticity of the information provided. This can be a useful starting point for discussion about ethical issues in science. The technique of ‘triangulation’ to compare three or more sources of information about the same topic can prove useful in helping students appreciate that different sites may treat the same issue from a very different perspective.

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.

8.3 Making websites available

Information from Internet sites can be made available in a number of ways:

- prepare a list of ‘bookmarks’;
- construct a webpage with hyperlinks to relevant sites. These can be sites for use in a particular lesson or a more general list to support a topic. One advantage of this strategy is that the list can easily be modified;

- include web addresses as hyperlinks in an electronic scheme of work so that the information is available where and when it is needed.

Students may well wish to include text and images taken from the Internet in their written reports. They should acknowledge the source by copying and pasting the site address and also giving the site name and date accessed.

8.4 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 and its development RasTop, Chime and Web Lab Viewer, and chemical drawing packages such as ChemDraw, ISIS Draw and Chemsketch, 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 molecular models available on the Internet that can be viewed and manipulated using a molecular modelling package.

8.5 Three-dimensional visualization

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 (see 8.6 below) 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 http://www.karmanaut.com/cosmo/player/ 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.

8.6 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. Applets can be found that are useful in all sciences although they are particularly abundant in physics.

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.

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

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, although 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’. Such ‘plug-in’ software can be downloaded automatically when required.

At a very simple level, animations can be constructed using the sequencing and timing options within PowerPoint. Even more impressive examples may be constructed using Macromedia Flash. Some teachers may have or may develop the expertise to use this software to devise their own animations.

The potential drawbacks of simulation and animations noted in the section on multimedia resources may also be a consideration when using applets from the Internet or using home constructed alternatives.

8.7 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, although on a busy school or college network, streaming may not be possible. Alternatively, video clips can be saved to a local machine or network. Video clips do use up a lot of memory. 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.

The Science Video Network has been setup by a group of UK science teachers. By subscribing to this network teachers can obtain copies of broadcast programmes they may have missed and get detailed advice about editing and encoding of video clips. The network has a bank of material from which teachers can choose and be sent items on a CD. (www.sciencevideonetwork.org.)

8.8 Freeware

There are many 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. Free software can also be found at www.tucows.com.

8.9 Publishing work on the web

A number of science teachers place information on their institution web site. In some cases this consists of core 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. This has become much easier to do in recent years because later versions of word processing packages include an option of publishing work directly to the Internet.

Publishing work on the Internet can provide a mechanism for dialogue and collaboration between students in different schools, and indeed, in different countries. The ScI-Journal site collects together student reports on their experiments and also lets other students add their own comments. www.ScI-Journal.org.

Teachers should, however, ensure that what is published conforms with the school's Acceptable Use Policy (AUP). This will probably mean that specific names, photographs and e-mail addresses of students are not included so that they cannot be identified by others outside the school. See DfES (2002) *Superhighway Safety* http://saftety.ngfl.gov.uk.

8.10 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

8.11 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.

8.11.1 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.

8.11.2 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 http://www.britishcouncil.org/montageworld/teachers/index.htm, which is the British Council-sponsored web site.

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, in examples devised by the Secondary National Strategy (formerly Key Stage 3 Strategy) team and in the QCA criteria on which the new AS/A2 level specifications for biology, chemistry and physics introduced in 2000 are based.

When it is used effectively, data logging has a number of benefits:

- it allows students to concentrate on interpreting data rather than on data collection. Students have time to watch and think rather than being preoccupied with gathering data;
- student can see a clear, real time link between the phenomena they are investigating and the graph that represents that phenomena;
- the graph is the starting point for thinking and discussion, not the end point of the activity;
- students look first at the overall shape of a graph and undertake a qualitative analysis of the phenomenon there are exploring in contrast to the more traditional hand plotted graph which involves manipulation of numbers first and the qualitative analysis comes second. Manual plotting of graphs tends to focus on the importance of individual points whereas in computer generated graphs it is the overall shape and trends that are important;
- students can also see trends emerging as an experiment proceeds;
- data logging can extend those measurements available by the use of our own senses by the use of a wide range of sensors such as high temperatures, infra red and ultraviolet radiation and liquid and gas volume;
- measurements can be more precise and more accurate than is possible using traditional methods and therefore data logging can generate good quality data;
- very fast and very slow changes can be measured;
- several variables can be measures at the same time such as oxygen, pH and conductivity;
- conditions can be chosen in advance to automatically trigger the start of data collection;
- short activities can be repeated several times to test the reproducibility of data or to compare the consequences of changing variables;
- data loggers allow students who find graph drawing challenging to become involved in interpreting automatically drawn graphs and drawing conclusions from them. Some students find selecting appropriate scales and drawing appropriate lines very difficult and any error at this stage will make the subsequent analysis more problematic. The focus on interpretation rather than collection of data supports the least able while providing an appropriate challenge for the most able;
- there is a significant time save using automatically plotted graphs since students take three to four times as long to plot graphs themselves;
- remote data logging extends collection of data beyond the classroom or laboratory and allows data collection to take place over extended periods of time although this is dependent on the capacity of the internal battery of the logger;
- data logging can be particularly valuable in project work since it can enable open ended investigations and it encourages divergent thinking;
- students can carry out 'what if' experiments and try out their own ideas.

9.1.1 Recent data logging developments

Data logging in science is now very different from when it first appeared in schools and colleges. Hardware is much more reliable and straightforward to use. There is a considerable range of commercially available equipment that offers teachers a clear choice in terms of cost, speed of operation 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.

9.1.2 Data loggers in detail

Data loggers vary enormously in the speed with which they can sample data and care should be taken in choosing a logger where this is important as, for example, in some physics experiments. Promotional literature from manufacturers may describe the speed of data collection as a sampling rate such as 20k/s (20,000 samples per second) or 7.8kHz (7,000 samples per second) or may describe it in terms of the minimum time between readings such as 25μs (25 microseconds or a sample rate of 40,000 samples per second) or 100ms (100 milliseconds or a sample rate of 10 samples per second).

Loggers may also be described as 12 bit or 10 bit. This provides a measure of the precision of the readings recorded with 12 bit giving more precise data than 10 bit.

The resolution given for a logger describes the minimum time between readings and provides a guide to the speed of events which can be recorded. For example, a logger that can record digital timing to a resolution of 8μs could not be used to detect a change that happens in a 5μs.

Some loggers have wireless connections using a IrDA or infrared link or the longer range bluetooth connection via radio waves.

Examples of loggers available in May 2005 are described below.

Casio EA-200 Data Analyser

This is a graphic calculator-based device requiring a high level calculator such as the FX1.0 Plus or FX2.0 Plus, although cheaper calculators can be programmed with these and then used with the data analyser. This system is very powerful indeed having features usually expected only of PC software. Areas under graphs, gradients, derivatives, statistics, zooming and the like are all possible. Set-ups are through wizards which make these tasks easy.

The data analyser has an in-built microphone sensor and a loudspeaker for playback. It has three analogue input ports for Casio and Vernier sensors (all with auto-ID), one digital input port designed mainly for using with an ultrasound motion sensor, one digital I/O port and a serial port. Its fastest sampling rate is 50,000 samples per second. The system can be programmed from the calculator or PC keyboard and many programmes are available on the web. It comes with a temperature sensor, voltage sensor and a light sensor. It has a Flash memory which allows upgrading by replacing the memory storage card.

Data Harvest

Data Harvest have been in the data logging business for a long time. Their current data loggers are Easy Sense Link, Easy Sense Fast, Easy Sense Real-time, Easy Sense Advanced and Easy Sense Flash Logger.

Easy Sense Link has three analogue/digital inputs. Sensing is 12 bit with the fastest sampling speed per channel of 40,000 samples per second and digital timing to a resolution of an 8 millionth of a second. It is USB-based without any display. It is easy to set up and good value for money. It is not portable and needs connection to a computer.

Easy Sense Fast is a serial connection device and again has no display. Its sampling rate is a minimum of 28,000 samples per second. Easy Sense Real-time is similar but with a minimum sampling rate of 25 samples per second. They each have six analogue/digital inputs. It is not portable and needs to be connected to a computer.

Easy Sense Advanced has a two-line LCD display to show readings but not graphs. It has six analogue/digital inputs, 12 bit resolution and fastest sampling speed per channel of 28,000 per second. It has rechargeable batteries with a fast-charge mode, as well as an external power supply. It is both USB and serial based. Pre-triggering is available. It is portable.

Easy Sense Flash Logger connects to an iPAQ Pocket PC and also to laptops and tablet PCs with compatible cards and, through these, has a graphical display screen. It has three sensor input sockets. It runs Sensing Science CE software which gives a good range of display and analysis techniques together with on-screen worksheets. It is however very slow with a sampling rate of just 20 samples per second.

The Sensing Science Laboratory Data Capture and Analysis software provides a good range of tools: area under a graph, gradients, derivatives, and incorporates the capacity to display analogue gauges, dials, digital meter displays and colour change displays. On-screen wizards aid the displaying of timings, speeds/velocities and accelerations. Lots of worksheets are available.

A good range of ‘Smart Q’ sensors is available from Data Harvest which are automatically recognised, can store calibration settings and can adjust ranges where appropriate.

This is a reliable and easy to use range of data loggers. None, except the Flash Logger, provide on-screen displays and that is very slow.

dib microtech ALBA

The ALBA system has a large following in Scotland where it was developed. The interface has two analogue sockets for auto-ID sensors and two more with 4mm sockets, plus two digital input sockets through DIN or 4mm sockets. It also has two digital outputs. Whilst being a serial-based device it can be used with a USB converter.

Activities can be approached in two ways. The supplier has produced a large range of activities on CD-ROMs matched to ALBA sensors and associated equipment and these can be loaded with complete setting up instructions and automatic setting of parameters. Additionally, new activities can be designed using the Investigator where the teacher can design and set-up as they wish and these set-ups can be saved if necessary. The fastest sampling rate is of 16666 samples per second with one channel operating or 8333 samples per second with two channels in use. If the unit is being powered remotely by battery then a sample rate of only 10 samples per second is possible.

The software is excellent and provides easy means of measuring the areas under graphs, gradients, best-fits, derivatives and statistics, as well as the incorporation of error bars. Various trigger settings are available

This is a well tried and tested unit but it has to be connected to a PC in order to get a graphical display.

Fourier

MultiLog Pro is a robust school data logger with an LCD screen of reasonable size for displaying graphs, meters and tables of data. Up to eight analogue and four digital sensors can be in use at any one time. Automatic recognition is available for Fourier sensors and others can be calibrated and set up for use. Some adapters are available for Vernier and Philip Harris sensors. There is an excellent range of sensors available from Fourier. Logging is done to 12-bit resolution and a maximum sampling rate of 20,800 samples per second. Pre-loaded notes can be placed on the device. It has a rechargeable battery to enable use outside the laboratory and substantial memory to store data from many experiments. Programmable triggering. USB and serial connection to computer is available as required.

TriLink is as for MultiLog Pro but with both Bluetooth and USB communication with PC, Mac, Pocket PC and Palm PDAs. It is both battery and mains based enabling use inside and outside the laboratory.

MultiLab software is an excellent package with a host of features running on all the systems. It is easy to obtain gradients, areas under graphs, statistics, derivatives, best-fits, functions etc. Also provided are digital and analogue meter displays. Wizards are for setting up and file analyses such as those required in calculating velocities and accelerations. Worksheets can be generated together with pre-set parameters for experiments if required. Videos of experiments can be recorded and played back. Additionally the Video Motion Analyser software provides an opportunity to record data logging events and then use the MultiLab software to analyse them.

TriLink is notable for its great flexibility of use and effective future-proofing, providing good screen displays on PDAs as well as on larger PCs. As PDAs develop further their features should be able to be made use of. This will almost certainly make data logging cheaper too, as well as getting students to use tools they may well use later.

i-button

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.

Lego

The Lego RCX Brick in conjunction with RoboLab software provides users with both sensing and control facilities. At any one time three sensors and three actuators can be connected to the brick. Whilst Lego make a few sensors and actuators, DCP Microdevelopments makes a much larger range to match the brick and many more are available DIY from books and on the web.

The software is based on LabView and is provided as an icon-based programming language at a variety of levels from the early years of primary school to post university. The programming can incorporate both control and sensing, or one or the other. All programming set-ups are done on a computer and transferred by an IR link to the RCX brick which then becomes an independent device. On gathering data the RCX brick transfers back to the computer through the IR link and graphs can then be plotted, best-fit lines drawn, gradients determined, areas under graphs drawn, statistics produced, derivatives and integrals plotted and much, much more. Its one drawback is relatively slow data logging but it is robust and inexpensive.

Levbold Didactic – CASSY

Leybold have developed a number of systems, Sensor-CASSY, CASSYDisplay, Pocket-GASSY and Mobile-GASSY, to suit situations of classroom demonstration, small group work and individual use.

Sensor-GASSY is more of a demonstration device. It has two inputs which connect to sensor boxes and then to sensors. Resolution is 12 bit and it has fast sampling rates up to 200,000 samples per second. The units can be cascaded to access more inputs. It also has a power output of up to 16V 200mA and a changeover relay. There is no display. Connection to a computer is USB or serial.

GASSY-Display is a two-channel large digital display device and no computer is required to operate it. It has data storage facilities and data can be transferred to a computer for graphing and analysis. Connection to a computer is USB or serial.

Pocket-GASSY is an inexpensive single channel USB interface and up to eight can be connected to a computer via its USBs or a hub. It is also 12 bit but is slower than Sensor-GASSY with a maximum sampling rate of 7,800 samples per second. There is no display.

Mobile-GASSY is a held-held interface with an LCD display capable of displaying digital data but not graphs. It is very slow with a sampling rate of only five samples per second. It will also only take one sensor at a time and is limited in other ways too.

The associated software GASSY-Lab is excellent with graph, meter and table displays, best-fits, FFTs, derivatives, integrals, functions, areas under graphs, gradients etc. All sensors are auto-ID and there is a good range. Automatic set-ups are available but self-set-ups are easy to do too.

These are very tough and reliable products.

Loan' Data Vision CX

This has a colour LCD display of good size. Up to six analogue or digital sensors can be connected at one time. In oscilloscope mode its fastest time base is 10μs/div. Used for measuring times, velocities and accelerations with light-gates the resolution is 1μs. Fifty data files may be stored on the data logger with up to 20000 readings per experiment.

It has a very robust aluminium case. It is USB or serial based and has rechargeable batteries making it portable without a need for permanent connection to a PC. There is a good range of auto-ID Microsense sensors.

The on-screen software provides graph plotting, tables, digital meters and a small degree of analysis which can be extended by using LogIT Lab on a connected PC. A good data logger but its on-screen software somewhat limited.

Matrix Multimedia FlowLog

There are two devices, FlowLog Lite and FlowLog Standard. They both have essentially the same control and sensing features but the latter has an IrDA link to a Palm as well as a parallel port connection, together with rechargeable batteries and charger and 4mm sockets. Both have the same built-in temperature, light and sound sensors, two analogue BT type input sockets, one digital BT type input socket, four other digital inputs, two other analogue inputs and four power outputs 8V, 300mA. The unit can deal with sensing and control.

Sampling time is 25,000 samples per second with an 8 or 10 bit resolution. In oscilloscope mode there is access to a dual channel analogue oscilloscope with an input range of 0 to +5V at 25kHz bandwidth and a four channel digital oscilloscope 0 to +5V at 100kHz. Various trigger modes are available and data is collected from all sensors simultaneously regardless of selection. The Vernier range of sensors is recognised automatically and provides a good choice.

The software is good with wizards to guide one through set-ups. It has a control and sensing programming language built in which can be put to good effect in robotics as well as in other areas. An extra Graphical Analysis package enables more detailed analysis to be conducted by importing data from FlowLog.

FlowLog Lite is particularly good value for money if a fairly basic control and sensing application is needed with essentially a PC-based oscilloscope.

Nicholl Digital spectrometer

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.

Pasco

Pasco makes a large range of interfaces: USB Link, Xplorer, PowerLink, Xplorer GLX, Science Workshop 500, Science Workshop 750 and the Imagi Probe SD.

The USB Link has only one sensor input socket but more than one can be connected to a PC via USB sockets or a hub. Its fastest sampling rate is 1,000 samples per second. It has no display and is used connected to a computer.

Xplorer is a hand-held interface with one sensor port and is portable. Sampling rate is a maximum of 1,000 samples per second. It has a two-line LCD screen to display data values but not graphs.

PowerLink is a three-sensor port device with a USB connection to a computer. Sampling rate a maximum of 1,000 samples per second. It has no display and is used connected to a computer.

Xplorer GLX can sample at rates up to 50,000 samples per second dependent on the sensors connected to it. It has four built-in sensors – two temperature, one voltage and one sound, plus a sound output through a mini loudspeaker. It has four sensor sockets and a large LCD greyscale screen display providing digital and analogue meter displays, graphs, calculator, tables etc. Printouts can be made direct from it to some HP printers. It is portable with rechargeable batteries. Built-in software provides very good graphing and analysis capacity.

Science Workshop 500 samples up to a rate of 20,000 samples per second, has two digital inputs and three analogue inputs. Science Workshop 750 samples at rates up to 250,000 samples per second and has four digital and three analogue inputs.

All share a superb range of auto-ID sensors. Similarly the Data Studio software is excellent, providing just about everything you might think of for analysis and further processing including curve fits, areas under graphs, gradients, statistics, derivatives etc. Data Studio also has the capacity to provide video playback of experiments synchronised with the data collected.

ImagiProbe SD connects to a Palm PDA and allows the use of up to two sensors at rates of up to 500 samples per second. Data transfer can be made to a computer and analysed using Data Studio. The ImagiProbe software provides a good set of facilities for graph plotting, tabulating, showing meters and a degree of analysis. A fair range of sensors is available.

An excellent set of interfaces matched by high quality software which tends to be more expensive than some other equipment. Pasco also make a lot of other equipment to support data logging.

Philip Harris e.Log system

The e.Log system is an addition to the Philip Harris range. For secondary school use there are two data loggers, e.Log II and e.Log IIS. The former has four sensor inputs, a good range of auto-ID sensors and a large 8MB memory for data storage and for upgrading its application program. It has a fairly large black and white LCD screen display and is operated by a built-in keypad. It has one of the fastest sampling rates available on any data logger – up to 36,000 samples per second, together with a burst mode of 250,000 samples per second on one channel for a very small time period. The e.Log IIS is similar but has a high-resolution colour touch screen has two output ports and an IrDA port. They both have rechargeable batteries making them portable. They can also be powered through a USB connection for a PC or via a power supply.

Its software is e.Log-Vision which is backwards compatible with previous data loggers. Experiment settings can be stored and a range of templates for experiments are available. Philip Harris have established a web server through which schools can exchange worksheets etc. Calculations of areas under graphs, gradients, statistics, best-fits etc are all available, as is a spectrum analyser (FFT), and various trigger settings are possible via a PC. The e.Lof has limited analysis facilities.

Pico Technology's interfaces

Pico make quite an array of what are effectively PC oscilloscopes (PicoScope) with a slower speed data logger (PicoLog). For schools DrDAQ has proved a very popular and very inexpensive device having built-in temperature, light, voltage and resistance sensors, plus two extra sockets for other sensors, and a special pH probe socket. Pico can supply additional pH, temperature, humidity, oxygen in air and reed switch sensors. An adapter to allow the connection of a teachers' own design of sensor is also available. It also has one TTL digital output. Sampling is relatively slow at up to 15,000 samples per second but is dependent on the PC. Its input voltage range is from 0 to +5V.

The PicoScope software provides a graphical display, spectrum analyser, and digital meter display, and a range of trigger settings. PicoLog plots at slow rates over long periods. No gradients or areas under graphs calculations can be obtained but the data can be exported to a spreadsheet for this if required.

For bipolar voltage use many schools have used the ADC40 or ADC42 which are single channel devices with input in the range ±5V at an 8 or 12 bit resolution and speed of 20,000 samples per second at fastest.

The ADC200 would be of use as a two channel bipolar device with speed of sampling up to 100Msamples/s. It would deal with the speed of a pulse down a coaxial cable or along a fibre optic cable.

Pico make many other virtual oscilloscopes/data loggers, some of which would be of use in schools. All currently connect to PCs through a parallel port but a USB converter is also available. Portability is dependent on use of a portable PC. None have displays. A new series has a USB connection.

Pico have established a schools' website with lots of teacher-produced activities for their products.

Sciencescope

This company makes a number of data loggers: Logbook WL, Logbook UL, Logbook ML, Logbook XD and Logbook SE.

Logbook WL is the latest of the series. It has Bluetooth (10 metre range radio wave) connectivity to a PC for graphical display and detailed analysis, as well as via a USB. Four inputs sockets are provided for their wide range of auto-ID sensors. Data capture is at a rate of 16393 samples per second and 4800 data points can be stored per channel. There are no built-in sensors. A rechargeable battery is incorporated with a fast charger/mains adapter. Fast recording mode allows triggering on two channels and there is a snapshot mode. The two-line LCD does not show graphs.

Logbook UL is like the WL but without the Bluetooth connectivity.

Logbook ML has a rate of data capture with a maximum sample rate of 16393 samples per second. It has built-in temperature, light and sound sensors and auto-ID. Input is possible from two sensors simultaneously and a large range is available. Connection is through serial or USB ports to a PC. The LCD displays data but not graphics. It is however portable. Various modes of triggering are available, as is a snapshot mode of data acquisition.

Logbook XD has a four-channel input and a capture rate of 16393 samples per second for 207 points on one channel, 200 samples per second for 5000 points on two channels and 100 samples per second for 5000 points on four channels. Again it has serial and USB connections and an LCD screen to display data only. It is also portable. It has no built-in sensors.

Logbook SE has built-in sensors for temperature and light and two other sensor input sockets. It is portable in terms of collecting data but needs a computer for graphical display. As with the others, connection is through serial or USB ports. This is a slow data logger with a remote mode operating at only 8 samples per second on four channels and a similar data collection rate with a PC connected.

All have an excellent range of sensors (including 2 and 3 axis accelerometers and a range of gas sensors) available and the Datadisc Pt software is very good. It provides a spectrum analyser (FFT), envelope functions, gradients, areas under graphs, derivatives and the like. It should deal with pretty much all that would be needed in schools. This new software also allows multiple data logger use to one PC and incorporates Datamass – a record and analysis packages for compatible balances. Philip Harris sensors can also be used with these data loggers. Sound experiment guides are also available.

Vernier Go!Link and LabPro

Go!Link is a single channel interface. Whilst it allows access to most of the Vernier range of sensors, it does exclude the digital ones at present and so the motion sensor and light gates cannot be made use of. All operate as auto-ID. It is not very fast having its quickest rate at 200 samples per second. Its connection is via a USB port to a PC and, through additional sockets or a hub, further Go!Links and associated sensors can be connected.

Go!Link is supplied with Logger Lite software which is somewhat limited and would not be useful beyond Key Stage 3 in the UK. Logger Pro 3 provides for more complex usage with computation of areas under graphs, gradients, more complex statistics, derivatives etc, plus video analysis. However, for younger students Logger Lite provides an easy means of data logging, giving graphical, digital and analogue meter displays, and simple statistics. Go!Temp is a dedicated USB temperature sensor but Go!Link can perform this function.

Go!Link is a very inexpensive, if limited, product.

For many years Vernier have provided the LabPro data logger which can link with a PC or Mac, TI handhelds, Palms and the AlphaSmart Dana. It can sample at rates up to 50000 samples per second on six channels and also has one analogue output channel. Displays are onto graphic calculator, Palm or PC/Mac screens. It uses Logger Pro 3 software which is excellent and provides pretty much everything needed in the secondary school sector. Lots of practical activity resources are also available.

9.1.3 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 and most loggers now support ‘sensor recognition’ so that changing sensors is straightforward. The manufacturers of most loggers produce their own sensors which only work with their hardware although ‘Vernier’ sensors can be used with a range of different loggers. Sensors fit into either an analogue port in the logger when they measure over a range of values such as temperature or light or fit into a digital port when they record a change in value only such as a light gate.

- Biologists are able to monitor heart rate, heart beat and lung expansion with specially designed sensors. They can also use oxygen, temperature, light, sound and humidity sensors to measure changes in the environment during fieldwork.
- Chemists can now use a colorimeter sensor, sensors for measuring the concentration of selected ions, pressure sensors to monitor the amount of gas produced during reactions and drop sensors to measure the volume of liquid such as that delivered from a burette during a titration.
- 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.

Some sensors such as pH and oxygen need to be re-calibrated regularly while others such as light may not be calibrated and used only for comparative purposes. In some more sophisticated sensors it is possible to choose from a range of units and to choose from a number of different data ranges (eg temperature in Centigrade, Fahrenheit, Kelvin or as a voltage).

9.1.4 Choosing and managing data logging activities

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. The learning objectives need to be very clear so as to ensure that data logging adds to the student experience.

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).

Data logging does not lend itself to ‘one-off’ measurements and conventional measuring strategies are likely to be more useful in such situations. It can, however, be much more effective than conventional methods when small changes require that the data collected is very precise or when changes in a measurement are required so that a series of readings must be taken in rapid succession.

Conventional measurement uses different and distinct measuring instruments for each type of measurement and this allows students to appreciate the difference between them. Data logging can lead to a potential difficulty here since all measurements involve a similar arrangement of sensor connected to a logger or interface and students do not experience much of a difference. One way of dealing with this situation is to encourage students to explore what the sensor can do in a qualitative way before using it to collect quantitative data. A light sensor may, for example, be pointed towards light sources and be shielded from them to see the impact on a real time graph. A conductivity sensor can be placed in a solution which is rapidly diluted.

Data loggers can be used in plenary sessions to generate data to stimulate discussion. A graph becomes a starting point for thinking. Data logging provides an opportunity for students to suggest explanations for what they observe and to discuss their own ideas and the ideas of others. The graph generated from data logging provides a shared focus for both students and their teacher, particularly if it is projected on a large screen by a data projector. To increase the involvement of students, they can be asked to predict the shape before demonstrating the change, perhaps drawing the anticipated graph on the white board on which the graph will appear. Use of data logging and the discussion of ideas arising from graphs in plenary sessions can mirror and exemplify what is expected of students when they carry out this type of activity themselves.

Student use of data loggers allows them to get much closer contact with the phenomena and the graph that is generated by it and to have ownership of the data produced. Simultaneous use of loggers by all students may not be possible because of equipment requirements but this difficulty can be overcome by:

- use of data loggers in parallel with traditional methods. This approach has the advantage that results from both methods can be compared and pros and cons discussed;
- use of data loggers as part of a ‘circus’ of activities;
- use of loggers on a rota when the activity is quick;
- collection of data using one set of equipment followed by download to the school or college network so that all students can analyse it in an ICT suite.

Longer activities involve the different management issue of what student should do while the data collection is in progress. Effective strategies include:

- visual observation and recording of changes during the experiment such as noting what happens in terms of gas evolution when measuring the amount of gas collected using a pressure sensor and noting significant measurement changes;
- intervention to explore the impact of shaking or stirring a solution;
- making short term predictions about the shape of the graph using predictive sketch graphs;
- complementary work to support the data collection and reinforce the underlying scientific ideas.

9.1.5 Data logging software

All data loggers work with special software that enables gathered data to be stored, retrieved and displayed. This software may be supplied by the logger manufacturer or by a third party. It is also usually possible to export data to a spreadsheet programme like Microsoft Excel for graph drawing and analysis.

Most of the data logging software 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;
- the option of removing ‘noise’ from the graph in order to focus on the main trends and patterns;
- ability to superimpose several graphs on the same axes to compare data sets from repeat experiments or to compare changes in different variables during the same experiment;
- the potential to draw secondary graphs derived from original data;
- use of curve fitting tools;
- 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.

In order to interpret data logging graphs effectively students need help and practice to develop their understanding of the ‘language’ of graphs so that they can interpret the story described by the graph. They need to experience the effect of changing scales and units on axes. They need to be able to articulate what it means when the graph is going up, going down or remains horizontal. They need to be able to relate a shallow or steep curve to the context of the experiment, which the graph describes. One way of achieving all of this is to design activities specifically for this purpose which require students to focus on, describe, discuss and interpret prepared graphs.

Data can be linked with modelling and prediction of change. Students can use a repeated cycle of predict – test – evaluate. They can also combine the potential and power of data logging and multi media resources by comparing data from experiment with that generated from simulated experiments.

9.1.6 Computers for data logging

Data logging software may not need all the power and speed of modern computers so that older computers, recycled from other areas of a school or college, may be perfectly adequate. Laptop computers have the advantages of portability and of taking up little space but they may present a security issue. The portability feature is particularly useful when planning scientific field trips. Some loggers have been designed to work with graphical calculators or personal digital assistants (PDA's). These solutions offer a low cost and flexible solution to whole class involvement in data collection.

Where an institution is just beginning to develop data logging it is probably advisable to begin slowly and make sure that each step is thought through thoroughly. Teachers could, for example, focus on using loggers in whole class teaching first where a good quality logger, laptop computer and a few sensors can be linked to a data projector and make an immediate impact. This could be followed by a phased introduction of further equipment to be used by students when clear needs have been identified.

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 are 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, they 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 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.

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:

- as a focus for discussion in starter activities;
- in PowerPoint presentations produced by teachers and/or students;
- as stimulus material in electronic worksheets;
- showing via a data projector how complex or unfamiliar laboratory equipment is to be connected together at the start of a lesson;
- as a tool with which students can collect images from experiments or from the wider world such as evidence of the effect of acid rain on local buildings;
- within students reports and coursework;
- printed out as a hard copy for visual display.

Images 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.

Images taken by digital cameras can be saved to a computer and 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 uncompressed TIFF format. If images are to be printed out to provide a hard copy then a digital camera with a resolution of three or four 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, camcorders can be used creatively to support student learning from practical work.

Students are involved in a great deal of practical work in science in the UK, 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. Absentees have no direct visual image to refer to. 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 views 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 to be carried out 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 hazardous 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 since they allow direct recording of images onto a computer and produce higher quality images the extra cost may well be worthwhile. In recent years digital cameras have become far more common than their analogue counterparts. 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 compared to that captured on videotape is that the teacher can move quickly in either direction through the 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 way of using cameras 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. One effective approach is for them to create a ‘story board’ on paper to illustrate the sequence of images they plan to capture. 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.

9.2.5 Wireless cameras

Wireless cameras include a small device which transmits a signal to a receiver connected to a digital projector, a computer or VCR. This means that they are very flexible and portable in use. They are relatively inexpensive as they are produced for the home market for property surveillance and are sometimes referred to as ‘spycams’.

Wireless cameras can, for example, be used to:

- display students written work, pages from books or text or drawings that the teacher has prepared;
- show on a large scale small items such as electronic components;

- focus on specific features such as grains on the surface of a rock sample;
- focus on key features during a demonstration experiment such as the contents of a test tube, a scale or meter or part of a piece of equipment than is normally obscured from view.

9.3 Digital microscopes

Digital microscopes are dedicated pieces of equipment designed to view and capture electronic microscope images. The images can be displayed in real time using a data projector and can be saved and subsequently inserted into electronic worksheets. The images make the invisible visible and can be highly motivating to students.

The image from a digital microscope is of a higher resolution than that viewed with a flexible neck video camera, and the on-screen measuring facility is very useful in helping students appreciate the scale of the object that they are looking at. Digital microscopes are available from a number of science equipment distributors.

9.4 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

Barton, R. (Ed.). (2004). *Teaching Secondary Science with ICT*. Open University Press.

Chapman, C., Lewis, J., Musker, R. & Nicholson, D. (1998). *ICT activities for Science 11-14*. London: Heinemann.

Chapman, C., Lewis, J., Musker, R. & Nicholson, D. (1999). *ICT Activities for Science 14-16*. London: Heinemann.

Frost, R. (1993). *The ICT in Science Book of Data-logging and Control: a Compendium of Ideas using Sensors in Science Teaching*. For Science from age 11-18. London: ICT 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: ICT in Science.

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

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

Osborne, J. & Hennessy, S. (2003) *Report 6: literature Review in Science Education and the Role of ICT: Promise, Problems and Future Directions*. A Report for NESTA Futurelab.

Parkinson, John. (2002) Reflective *Teaching of Science 11-18*. London: Continuum.

Sang, D. & Frost, R. (Eds.). (2005). *Teaching secondary Science Using ICT*. Association for Science Education.

Wellington, J. (Special Issue Ed.). (2003). ICT in Science Education. *School Science Review, 84*, 309.

Useful contacts

Association for Science Education	www.ase.org.uk
British Educational Communications and Technology Agency	www.becta.org.uk
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
The Biochemical Society	www.biochem4schools.org

Science software providers

4Learning	www.channel4.com/learning
Anglia Multimedia	www.anglia.co.uk
BBC	www.bbc.co.uk/education/schools
Biozone Learning Media	www.thebiozone.com
Boardworks	www.theboardworks.co.uk
British Nuclear Fuels	www.bnfl.com
Cambridge Science Media	www.csmedia.demon.co.uk
Cambridge University Press	www.cambridge.org/education
Crocodile Clips Ltd	www.crocodile-clips.com/education
Didactics	www.didacticsonline.com
Dorling Kindersley	www.dk.com
Fable Media	www.fable.co.uk
Focus Educational Software	www.focuseducational.com

Granada Learning	www.Granada-learning.com
Heinemann Education Ltd	www.heinemann.co.uk
Hodder Murray	www.hodderlearncdroms.co.uk
Immersive Education	www.ImmersiveEducation.com
IT in Science	www.whitehouseit.com
Letts Educational	www.lettseducational.co.uk
Logotron	www.logo.com
Longman (Pearson Education)	www.longman.co.uk
Maris Multimedia	www.maris.com
Matrix Multimedia Ltd	www.matrixmultimedia.com
Molecular Biology Notebook	www.aab.org.uk
Nelson Thornes	www.nelsonthornes.com
Newbyte Educational Software	www.newbyte.com/uk
Oxford University Press	www.oup.co.uk/oxed/secondary
PLATO Learning (formerly New Media Press)	www.platolearning.co.uk
Research Machines	www.rm.com
Schoolscience Resources	www.schoolscience.co.uk
Science Enhancement Programme	www.sep.org.uk
Science Multimedia	www.btlpublishing.com
Science Online	www.scienceonline.co.uk
Sunflower Multimedia for Science	www.sunflowerlearning.com
Viewtech Educational Media	www.viewtech.co.uk

Suppliers of data logging and other science ICT equipment

Casio Electronic Co Ltd	www.casio.co.uk
Commotion	www.commotiononline.com
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.com
Meta Scientific	www.metascientific.com
PASCO Scientific	www.pasco.com
Philip Harris	www.philipharris.co.uk
Pico Technology	www.picotech.com
ScienceScope	www.auc.co.uk
Science Enhancement Programme (for SEP temperature logger or i-button)	www.sep.org.uk
Scientific and Chemical Supplies	www.scichem.co.uk
Texas Instruments	www.education.ti.com/uk

Appendix 2: Acknowledgements

First Edition of the guide (2002)

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 guide. The help and support of those listed below is gratefully acknowledged.

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Second Edition of the guide (2005)

Chris Barber, JISC Regional Support Centre, Yorkshire and Humber
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ICT IN SUPPORT OF SCIENCE EDUCATION

A Practical User's Guide: 2005 Edition

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 first edition of the Guide in 2002 built on the seminar themes, drawing on the results of visits to schools, colleges, publishers and software developers. This new edition reflects the development in the use of ICT in science education since the original publication.

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