STS
Scope includes Science, Technology and Safety

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For those working in science or technology education

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Opening a book - what's the odds?

According to a study, funded by the Publishers' Association, investment in ICT kit in the Primary sector over recent years has been running at an average of £30 or so a head. This has produced measurable improvements in the standard attainment tests so popular furth of the border. Snag is, say the bookies, that investment in printed material for school libraries over the same period has only been about £19 a skull, yet the returns, in terms of improved test performance, have been better. Almost twice the improvement from books than from ICT investment. I see worms in cans begging questions here. Whilst we might mix metaphors with the best of them, we should at least try not to compare dissimilar fruits nor make five from two and two. There's something useful in this study, but I'm still note quite sure what, apart from the questions it both begged and now in turn raises. As to the worth of the answers . . ?

The news of this publishers' study came at about the same time that the Scottish Science Advisory Group published the results of its own survey into ICT in science at the secondary level (see page 4). So, what's the connection - if any?

One of the more intriguing results of the SSAG survey was a set of responses to questions on personal priorities for further professional development and ICT in science. It seems that there is a developing shift of emphasis away from routine training in the usage of standard applications (such as DTP packages). Apart from the perennial interfacing for datalogging, one of the top priorities was attached to further training on the applications of ICT for effective learning and teaching. Such a shift is most welcome. There is a desperate need for more classroom practitioners to engage in informed debate on the proper role for ICT applications in science education.

For example, the results of the publishers' study may seem to suggest that a lot of what we've seen to date has been a waste of time and money. Has it? If it has then, what do we do now? Are print and electronic media in an unavoidable conflict or could they be complementary? And, if so, how? Can electronic media bring new dimensions to learning and teaching which enhance and enrich the experiences of students in ways not achievable by print alone? Are improvements in the acquisition of facts allied to improved test scores to be the only yardstick for investment?

On the other side, what of the protagonists for ICT in learning either in or outwith the classroom. Is their protagonism any less self-interested than the apparent propaganda of the pro-print brigade? We've scanned bits of the relevant literature and looked at some of the discussion and research sites emerging on the web. Again, we have yet to see much convincing argument or objective research results to help us decide the case either way.

We've a few ideas of our own, on applications of ICT which might assist and enrich learning in science. As yet, we have no evidence either way of the likely efficacy of such approaches. We shall have to trial them, in the time honoured traditions of good ol' suck it and see. Only now, as more practising teachers begin getting seriously interested in finding appropriate applications for ICT in teaching and learning, are we likely to see developing professional practices which may properly address these issues.

News and comment

One day 'industrial' courses

A programme of one day courses allied to industrial visits, organised through the *National Centre : Education for Work and Enterprise* and its various partners, continues to expand.

The Education for Work and Enterprise Centre has a national focus in areas of strategy, development and dissemination. It works locally through its partners in Education Business Partnerships, Education Authorities and others. We have posted on the SSERC website details of, and in several cases the brochures for, the published programme for the end of the current school and college session and the beginning of next. By the time this Bulletin has been printed, many of this Summer's dates will have passed. We thus give below the dates and venues only for those visits in the early part of the next session, for which we have sufficient information. Most of these courses attract a fee of between £60 to £80 for the day. For up to date details, and possibly additional courses announced after publication of this issue, see www.sserc.org.uk (visitors' or members' sites).

Higher Still Chemistry

These courses are organised jointly by the National Centre: Education for Work and Enterprise and The Royal Society of Chemistry :

- Quintiles, Edinburgh, 12 September
- Roche Vitamins, Dalry, Ayrshire, 26 September

Higher Still Physics

- Health Physics, Ninewells Hospital, Dundee, 14 September
- Lasers and optoelectronics, Thales Optronics, Glasgow 3 October

Higher Still Biology

One-day industry courses and visits at :

- Dollar Academy, Dollar, and at Quest International, Menstrie 19th September
- Cancer Research Campaign, Beatson Laboratories, Bearsden, Glasgow, 25th October

Biotech consortium launch

The Scottish Colleges Biotechnology Consortium (SCBC) was launched, at Bell College Hamilton, in the early Summer. The consortium is funded by the Scottish Further Education Funding Council and supported by Scottish Enterprise. The aims of the initiative include the provision of high quality technical training for industry and the develop-ment of strategic partnerships within the school sector.

The member colleges are : James Watt College; Falkirk College of Futher and Higher Education; Fife College of Further and Higher Education and Bell College (Hamilton), an HE institution. More detail on the Consortium and its proposed activities can be obtained from Dr John Porter, the SCBC Project Manager, who is based at Falkirk College of Further and Higher Education.

SSERC Website

Since publicising the registration process for the members' section in the last issue, the number of those signing up for user names and passwords has grown steadily. We were also both pleased and flattered to see the following complimentary little review of the SSERC website on BBC Scotlands' own web guide:

"SSERC www.sserc.org.uk This is a must for those with an interest in science. There is a members section which is accessible by teachers. However fear not science buffs there is plenty of other stuff to interest you. Everything from a recipe for slime to a section which allows you to be a cheer leader (all in the interest of science of course!) Good links to other science sites here."

Ian Birrell, SSERC's web designer, is to be congratulated on developing and maintaining such an attractive and information packed site.

Reference

BBC SCOTLAND Web Guide Education Subjects Science May 2001 see -

http://www.bbc.co.uk/scotland/education/webguide/science.shtml

Summer schools

This year three very successful science Summer Schools were run in Edinburgh, hosted by the University on its Kings' Buildings Campus. As the dust settles it looks like all three (biotechnology, chemistry and physics) will be offered again in late June next year.

Science Centres

Congratulations to all of the staff at The *Glasgow Science Centre* which, after some little local difficulties, was opened officially by Her Majesty The Queen in early July.

From the beginning of June until the end of August *Sensation,* the Dundee Science Centre, is staging *Tour de Force* a travelling exhibition from the Glasgow Science Centre. This explores the physics of light, sound and forces. It features some "brain teasing puzzles".

Also at Sensation, and back by popular demand, is another run of their *Dig that Dinosaur* workshops for P2 to P7 pupils.

This programme will run from the 5th of September until the 7th of October. Schools should note that Sensation offers free preview visits to teachers planning to organise school trips to the centre.

SSERC AGM

This year the SSERC Conference and Annual General Meeting will be held on Friday the 9th of November. The venue will be *Discovery Point* Conference Centre in Dundee. We did consider holding the event in one of the new Scottish Science Centres but, ironically, we found that our budget just doesn't stretch that far. The good news however is that for those that wish to see around the famous ships we have arranged for trips after the meeting.

An outline programme and booking forms will be circulated soon after publication of this bulletin issue. A more detailed timetable and programme will be provided nearer the date of the meeting. Each of our annual meetings has been well attended and places are always limited. Unlike other educational conferences these days, the fee for the SSERC gathering is very reasonable. Anyone wishing to attend is thus advised to get a booking in as soon as possible.

3M OHPs and asbestos

In the last issue we published a safety note on asbestos heat shields in 3M type 299 AHB, 500 watt projectors. Since then we've had a number of enquiries on similar models but where the type suffix ends with a "P" (viz AHP not AHB). We've sought clarification from the Visual Systems Group of 3M who confirm that what counts is not the letter suffix but the serial number. All model 299 machines with a serial number up to and including 2925151945 were manufactured with "a sheet of hard-formed asbestos as a heat insulator within the body of the machine".

The 3M offer, first made in 1984, to pick up any OHP so affected and have it delivered to a specialist company which will remove the board, still stands. The machine may then be returned to the school minus the board. Because these devices are now so old, 3M no longer carry any spares and so this offer does not cover any machines requiring other repairs. The projector will be retained for disposal should it be no longer required. Note that, according to 3M, removal of the board has no adverse effect on performance or safety. Despite 3M's supply of an instruction sheet for DIY removal, our advice is not to contemplate doing this at school but to take up the 3M offer for pick up and return or disposal. Should you wish to contact the relevant section of 3M, the full address and other relevant detail is provided in the final column of the back page of this issue.

New microbiology code

Moves are afoot to revise and update the *Code of Practice for Safety in Microbiology* originally drawn up under the auspices of what was then the Strathclyde Regional Council Education Department. The code has proved a useful document, particularly in the context of the COSHH Regulations and microbiology. It has been adopted or adapted by most Scottish Education Authorities as a source of risk assessment results and control measures, but by now it is showing its age. New biotechnology courses and practical protocols, a third edition of the ASE's *Topics in Safety*, changes in disinfection techniques, and several other recent developments, have all brought pressure to review and renew the code for educational microbiology.

It is hoped to start work over the Summer, in partnership with successor authorities to Strathclyde Regional Council (which EAs inherited the intellectual property underpinning the code). The intention is to produce a new edition for approval by all thirty two of the Scottish Unitary and Islands Councils as educational employers.

CASE Materials

There are a number of errors of ommission with safety connotations in the *Thinking Science* [1] materials produced in support of the CASE (Cognitive Acceleration through Science Education) programme. Technical enquiries to Centre staff have again drawn our attention to some lack of detail in the Technician's and Teacher's guides for CASE. Just one example involving pyrogallol (benzene-1-2-3-triol) came up again recently. This is in the Teacher's Guide material for Activity 14 "Combinations".

The CASE materials do not mention that alkaline pyrogallol is hazardous (see SSERC Hazardous Chemicals Manual [2]), nor is a concentration stated. The guide also fails to indicate that once made alkaline a solution of pyrogallol will rapidly absorb oxygen from the air. When made up in the conventional way, with sodium or potassium hydroxide, alkaline pyrogallol must be protected from the air with a layer of liquid paraffin or some other arrangement. This is inconvenient and messy [3]. The resulting solution is also corrosive and unsuitable for handling by pupils in S1 or S2.

A better arrangement is to store neutral aqueous pyrogallol solutions in airtight, screw top, containers (eg a McCartney bottle) and only to make them alkaline just before use. In addition, it is better to use a saturated solution of sodium hydrogencarbonate to increase the pH.

Alternatively, just before the activity the teacher or technician can add a few crystals of pyrogallol to a saturated sodium hydrogen-carbonate solution. Such a reagent can then be handled by pupils wearing eye protection. Note however that alkaline pyrogallol made up in this way will absorb oxygen more slowly and carbon dioxide not at all.

Our sister organisation CLEAPSS has produced a Position Statement [4] which helps greatly to plug such gaps in the provision of information by CASE on safety and resources. The CLEAPSS statement covers this and several other activities where there is insufficient detail on technical or health and safety matters. Copies of this statement can be made available also to our members on request - to the Director of SSERC please.

References

1. *Thinking Science. The curriculum materials of the Cognitive Acceleration through Science Education project*, 2nd Edition, Adey, Shayer and Yates, Nelson, 1995.
2. *Hazardous Chemicals : A Manual for Science Education*, SSERC, 1997 ISBN 0 9531776 0 2 *(or the CD ROM version thereof).*
3. *Gas analysis : Biology Notes*, Bulletin 60, SSERC, 1973.
4. *The CASE Project: Safety & Resources*, PS44, CLEAPSS, 2000.

(Copies available to SSERC members from the Centre).

Survey on ICT usage in Secondary Science

This article is based, with permission, on a presentation prepared by John Sharkey, Science Adviser, Western Isles Islands Council, on behalf of the Scottish Science Advisory Group. Copies of the survey results have also been circulated to Scottish Councils as Education Authorities. SSERC's comments are made in italicised blocks or text boxes.

In early 2001 all of the Scottish Education Authorities were invited to take part in a national survey on the use of ICT in secondary school science departments. A questionnaire was drawn up by a sub-group of the Scottish Science Advisory Group (SSAG). Each Authority in Scotland is represented on SSAG by an adviser or other representative. SSERC, HMI and Learning and Teaching Scotland also attend meetings of the group.

Some of the collated results of the survey are presented here together with a selection of the figures used to illustrate the survey report and presentation.

The aims of the survey were to:

- review the current position of ICT in science education in Scottish secondary schools;
- provide feedback to schools and authorities to allow them to identify strengths and development needs;
- provide feedback to the Higher Still Development Unit (HSDU) and other providers to enable staff development;
- identify good commercial software which can be recommended and teacher produced software which might be distributed on a shareware basis.

The distribution of questionnaires was undertaken by local authority SSAG representatives. Returns were received from 23 of the 32 authorities. Separate science departments in schools were invited to complete the questionnaire. The total number of responses was 488 distributed as follows:

Biology	142
Chemistry	139
Physics	157
Science	50*

*Some schools completed a single science return, some completed questionnaires for the discrete sciences but also provided an overall science return.

Computer provision

The average number of computers of all types available for use in secondary science departments is 5.3. (This does not include networked computers in rooms away from the science department).

The average number of computers per science department is shown for small, medium and large schools (Table 1).

Size of school	Average number of computers available for the sciences
Less than 400 pupils	3.7
400 to 800 pupils	5.2
More than 800 pupils	6.2

Table 1 *Computer provision and school size*

Table 2, below, shows a breakdown of computers in science departments by type, as a percentage of the whole.

Type of computer equipment	% of Science Departments
Desktop PC	70
Desktop Apple	17
Archimedes	5
Laptop PC	8
Laptop Apple	0.5
BBC	24
Palmtop	0.5
Graphing Calculator	0.1

Table 2

Table 2 *: We were surprised to see so many BBC computers (almost a quarter of the total) still in use. Similarly unexpected was the small proportion of the total taken up by laptops and palmtops, which have the advantage of relatively small 'footprints' for use in practical activities and investigations.*

Networks and E-mail

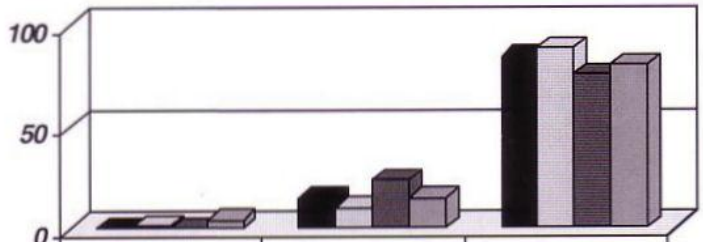
Only 45% of science departments yet have access to a computer network where such access is located within the department itself. Approximately 60% of science teachers have access to Email at school, not necessarily in the department.

Interfacing

Science departments were asked to state how often interfacing equipment was used in science classes and to indicate such frequency of usage at various stages. The results are summarised on the facing page.

Interfacing and datalogging cont./

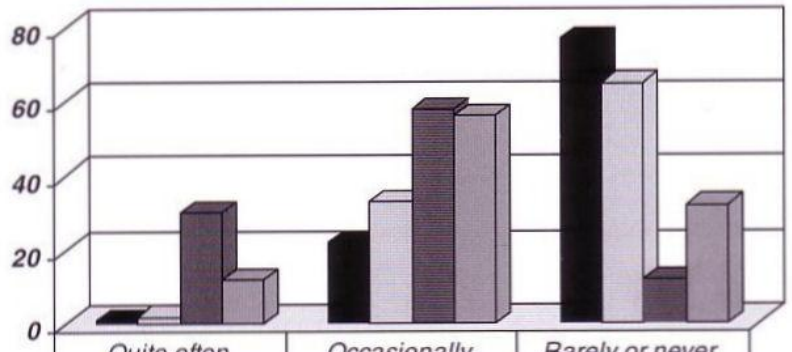
S1/S2 usage



	Quite often	Occasionally	Rarely or never
Biology	0	15	85
Chemistry	1	10	89
Physics	0	24	76
Science	4	15	81

***Figure 1** : The low level of interfacing and datalogging activity in the first two years of Scottish secondary science is striking, given that dataloggers are routinely used in some schools at upper primary stages and that there is likely to be increased emphasis on investigative work at the S1/S2 level. There are clearly opportunities for development of more relevant, yet relatively simple, practical activities here.*

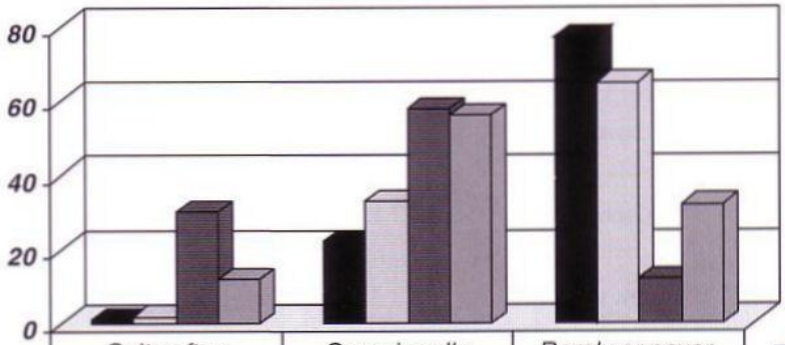
S3/S4 usage



	Quite often	Occasionally	Rarely or never
Biology	1	22	77
Chemistry	2	33	65
Physics	30	58	12
Science	12	56	32

***Figure 2** : There is some increase in the use of interfacing devices at Standard Grade. Physics and "Science" (or whole science department responses) take a clear lead over biology and chemistry as fairly frequent or occasional users of such approaches.*

S5/S6 usage



	Quite often	Occasionally	Rarely or never
Biology	1	22	77
Chemistry	2	33	65
Physics	30	58	12
Science	12	56	32

***Figure 3**: Increasing usage of interfacing devices is sustained by physics into S5 and S6 courses with biology and chemistry showing some further increase in occasional usage.*

Interfacing packages in use

Science departments were asked to state which interfaces and, or, dataloggers they used. The responses are summarised in Table 3.,

DEVICE/MAKER (Figures as % of Total)	DJB/Alba	Dr Daq (Pico)	Philip Harris	Texas Instru-ments	LogIT Datameter 1000	Unilab	Pasco
SCIENCE DEPT.	3	0	38	0	6	16	38
BIOLOGY	0	0	49	2	20	0	29
CHEMISTRY	1	0	64	0	10	1	23
PHYSICS	30	1	19	1	1	19	29

Table 3 : *Interfaces held by subject and by maker (percentages of total returned). Note that as for other summaries "Science" means a return made by the whole science department possibly on behalf of PTs of all subjects.*

These responses are analysed by subject with figures expressed as percentages of departments using such an interface package from each manufacturer. Caution is needed in interpreting these figures since departments were only asked to state which maker's or supplier's devices they used and not how many of each particular device type their department held. This means, for example, that whilst approximately equal numbers of physics departments would seem to hold either DJB/Alba or PASCO devices we don't how many of each such device they might have.

Other software

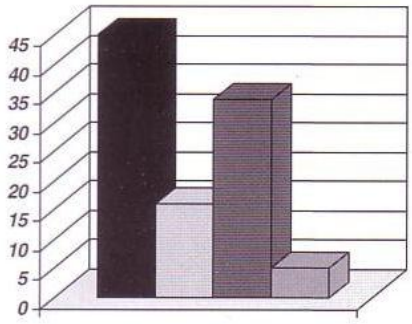
Science departments were asked to name other commercial software for learning and teaching which they had found particularly useful. The percentage of science departments naming each software package is shown in Table 4 below.

BIOLOGY	%	CHEMISTRY	%	PHYSICS	%
NEWBYTE Ed software (various)	30	New Media Chemistry Set 2000	67	Crocodile Physics	35
DK Encyclopedia + others	27	Royal Society of Chemistry software	13	Virtual experiments in H Physics	20
Focus Ed software various	12	Crocodile Chemistry	11	Intelligent Interaction - Int 2 & Credit physics	16
Cyber Ed Software - photosynthesis	9	Chemcord	4	ALBA software	9
Eye Witness Encyclopedia of Nature	6	SSERC Graphics Library	2	Focus Ed software	5
Garland Structure of DNA	6	Eyewitness science set	1	HSDU multimedia solutions	5
Harvard Graphics	6	Attica Periodic Table	1	SCETNET	5
Anglia Multimedia Cell City	3	Dorling Kindersley Encyclopedia	1	BBC Bite size	3
SCETNET CD	0	SCETNET CD	1	Pasco Data Studio	1

Table 4

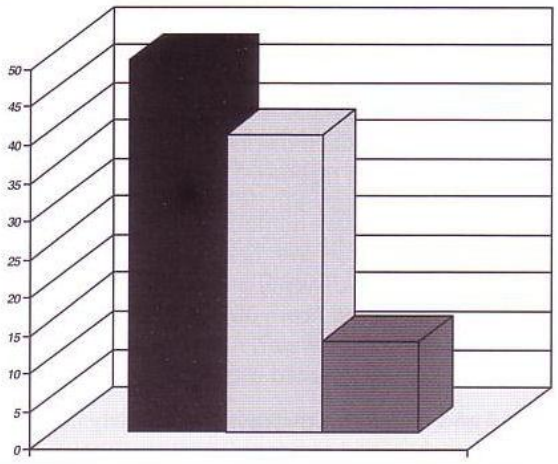
Setting up and maintenance

Departments were asked who set up and maintained their ICT equipment. Another question was asked on training to carry out such setting up and maintenance tasks. The percentage responses are shown in the Figures and tables shown below as Figures 4 and 5 respectively.



School/science technician	45
Regional technician	16
Teachers	34
Others	5

Figure 4 *Who sets up and maintains ICT equipment in science*



Yes	49
No	39
Don't know	12

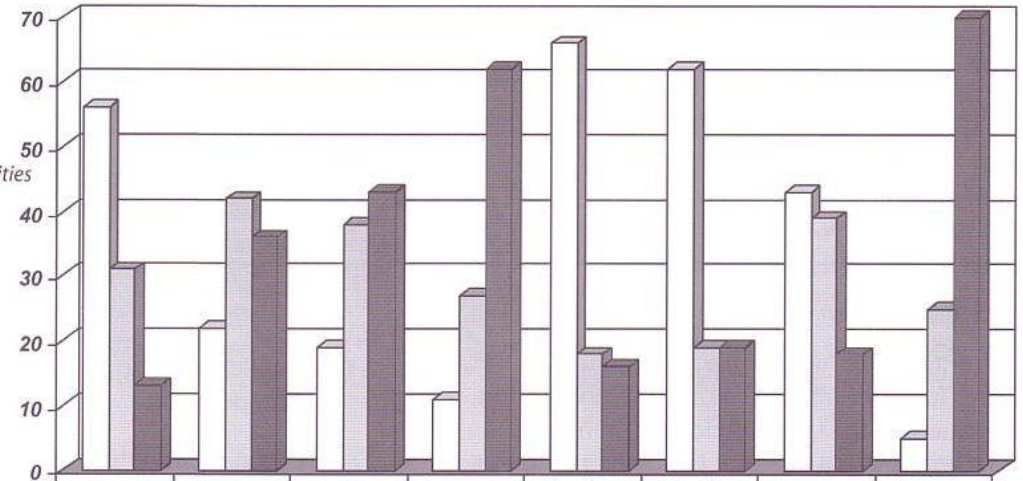
Figure 5 *How many think they have been trained to set up and maintain ICT equipment in science.*

We find the results shown in Figures 4 and 5 intriguing and worthy of further enquiry. For example who makes up these "Others" which account for 5% of responses as to who sets up and looks after ICT equipment? Are these third party service agreement staff in managed services arrangements? Even more curious, are the folk who don't know whether or not they've been trained and can that really be the case? Or is this apparent anomaly simply due to a lack of communication somewhere within the management system ?

Staff development needs

Science departments were asked to consider their needs for further professional development in the use of ICT. They were also requested to assign priorities to different categories of usage and training therein. Their responses are summarised in Figure 6 below.

Figure 6 *Science staff priorities for training*



	Word processing	Spreadsheets	Presentation software	Interfacing	Graphing calculators (data handling)	Graphing calculators (interface)	Internet/e-mail	ICT to improve learning
Low priority	56	22	19	11	66	62	43	5
Medium priority	31	42	38	27	18	19	39	25
High priority	13	36	43	62	16	19	18	70

The results shown in Figure 6 illustrate an apparent trend to which we allude in the editorial on page 1. There would seem to be a trend away from training in the use of the simpler generic software such as word processors and E-mail and toward the application of ICT to improve the effectiveness of learning and teaching. Interfacing techniques remain high on the agenda.

Biology, Chemistry, Physics

ICT in science survey cont

General Summary

The major points to emerge from this survey undertaken on behalf of the Scottish Science Advisory Group would seem to us to be as follows:

1. **Basic kit:** Although there have been improvements in the overall levels of ICT equipment provision generally in schools, kit directly accessible in science departments still seems to be in short supply. The results suggest that, certainly in a significant number of schools, what ICT provision there is relies over heavily on outmoded and obsolete equipment. Twenty percent of science departments were still using Acorn BBC machines. Much-loved and useful as they are (were?) most BBC computers should by now have been replaced with more up to date kit.
2. **E-mail and internet:** Similarly, although sixty percent of science teachers had access to E-mail at school only forty-five percent had direct access in the science department itself. Quality and convenience of access is important if teachers are to make the best use of ICT networks. This reinforces our experience with the SSERC website. Of those teachers and technicians who have thus far registered for the Members' section of the site a significant proportion have done so using their home E-mail address.
3. **Datalogging:** The use of datalogging and interfacing remains patchy overall and is conspicuous by its absence in the early years of secondary science. Including in S1/S2. Physicists, as ever, are the most frequent users of interfaces and dataloggers. There is a wide variety of interfacing devices and software in use and some evidence that older devices are gradually being replaced by more up to date equipment from the likes of DJB and PASCO. Philip Harris devices and DCP Developments LogIT and Datameter 1000 are fairly commonly in use for chemistry and biology. The latter devices are more popular with biology departments. There are hints of a kindling of interest in the use of graphing calculators for such applications.
4. **Other science software** in use for learning and teaching is similarly diverse but with a heavy concentration on the use of a fairly small number of packages. Newbyte and New Media seem to be the respective software 'stars' of biology and chemistry with Crocodile Physics and Crocodile Chemistry also popular with the relevant specialists.
5. **Technical support:** This also is diverse in pattern. Central support is available only to about a fifth of the schools surveyed. In most departments the major burden falls on school science technicians and teachers. Just under half of those who undertake this somewhat specialised support work claimed they had been trained.
6. **Professional development:** There remains a strong demand for training in datalogging and interfacing techniques with fairly keen interest also in data analysis (eg spreadsheets) and in presentational software (presumably Powerpoint and the like). There seems also to be a welcome shift in interest away from routine usage toward applications of ICT which, it's hoped, will improve learning and teaching in science. This shift in focus away from technique towards tactics for learning and teaching is welcomed (see also Editorial page one).

References

ICT in Science Education, SSAG Advisory Notes, in Bulletin 196, SSERC, 2000.

Acknowledgements

We are most grateful to the Scottish Science Advisory Group for permission to base this article on their ICT survey report. Particular thanks go to John Sharkey, Science Adviser for Comhairle nan Eilean Siar, (Western Isles Islands Council) and to Christina Macmillan, Secretary, at the Education Development Centre, Stornoway, for her work in collating the information.

Safety

Protective Gloves

The HSE has recently published a leaflet 'Selecting protective gloves for work with chemicals'. The publication contains information on the law, chemical resistance of gloves and selecting suitable gloves. It is aimed primarily at the employer and health and safety specialist but it does provide information that would be useful for both science technicians and teachers.

A free copy can be obtained by mail order from HSE Books, at the address listed on the rear cover. Alternatively, it can be ordered online at the HSE website:

http://www.hsebooks.co.uk/index2.html

Packs of 15 leaflets are also available and are charged at the following rates per pack:

1 pack	£ 5.00	2 - 4 pack rate	£ 4.00 each
5 - 9 packs	£ 3.00	10 - 49 packs	£ 2.00
50 or more packs	£ 1.50		

Reference

Selecting protective gloves for work with chemicals, ISBN 071761827
Order code INDG330 ISBN

Conducting Polymers

Organic polymers with semi-conducting properties are described together with methods suitable for laboratory scale preparations of some examples.

For some time now, plastics have been used commercially as alternatives to natural materials such as wood, metals, ceramics and glass. They are used extensively because they are relatively cheap, lightweight, strong and easy to process. Most polymers are good electrical insulators, a property highlighted in science education and by their extensive use in the home. Over the last 30 years or so, however, there has been increasing interest in a number of plastics found to be electrical conductors. Yet another case of telling students what they were taught in the past wasn't quite the whole truth! Researchers have discovered that conjugated polymers, which have a pathway of alternating double and single bonds, exhibit metallic and semiconductor characteristics. These polymers possess a delocalised pi-electron system along their backbone that confers semiconducting properties to the polymer.

Curricular context

Poly(ethyne) is included as an example of a conducting polymer within:

Higher Grade Chemistry Unit 2: The world of Carbon, section e) Polymers.

Although polymers such as polyethyne have a conjugated system of bonds, this alone does not make them conduct electricity. To make these polymers conduct, electrons must first be removed (oxidation) or added (reduction). In the case of polyethyne, oxidation to create a conducting polymer can be achieved by the addition of iodine. This particular method is called 'doping'.

Applications

Working lifetime is a major concern when considering the commercial applications of these plastics. Considerable research has taken place over the last 50 years to improve the resistance of plastics to photo oxidation. As could be expected, similar problems exist with conjugated polymers. To be commercially viable, storage lifetimes of at least 5 years and operating lifetimes of > 20,000 hours are typically required.

Poly(pyrrole) and poly(aniline) are commonly used conducting polymers in industry because they are relatively stable. Polypyrrole is not directly processable and is deposi-ted in film form by electrochemical means. Commercial applications of these plastics currently include battery electrodes, conductive coatings for electrostatic speakers, capacitor electrolytes, transparent conductive coatings, through-hole plating of double sided printed circuit boards and electrostatic discharge coatings.

In the future, conducting plastics will be used because the material and manufacturing costs are low, they can be used to cover large areas, form thin films and are flexible. As such, it seems that conducting polymers will not be a general replacement for metals but will be used where these advantages can be exploited for medium conductivity applications.

Making polypyrrole

Polypyrrole can be easily made in the school laboratory using the following method adapted from The Salters' A Level Chemistry 1991 Trial material [1].

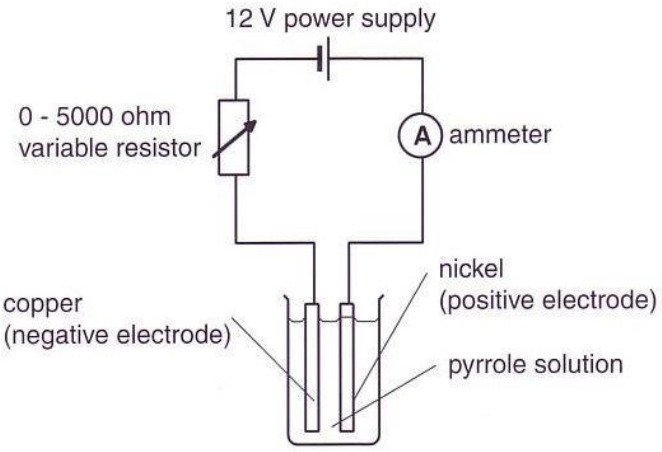


Figure 1 *Setup for making polypyrrole.*

1. For the positive electrode, use the flat end of a cleaned nickel spatula. The polypyrrole will be deposited on this so it is important that it is clean and smooth.
2. Use Brasso (not an abrasive material like steel wool as this will scratch the surface) to clean the spatula, rinse with distilled water then propanone (Highly Flammable) and finally dry in air.
3. The negative electrode can be made from a strip of cleaned copper sheet approximately 1 cm wide and about 14 cm long (it should be long enough to bend over the rim and reach the bottom of a 250 cm^3 beaker). This can be cleaned using an abrasive such as steel wool after which it should be rinsed with distilled water. cont./

4. To make the pyrrole solution, prepare 200 cm^3 of 0.1 M sodium 4-methylbenzenesulphonate solution (dissolve 3.9 g of sodium 4-methylbenzenesulphonate (Irritant) in 200 cm^3 of distilled water). In a fume cupboard, pipette 0.68 cm^3 of pyrrole (Flammable and Toxic) into a 250 cm^3 conical flask and add the sodium 4-methylbenzene-sulphonate solution. Carefully swirl the contents until the pyrrole has dissolved.

Procedure

1. Pour the pyrrole solution into a 250 cm^3 beaker and set up the circuit shown in Figure 1. Before switching the power on ensure that the variable resistor is set at its maximum resistance (usually fully clockwise).
2. Slowly reduce the resistance until the ammeter reads approximately 40 mA. The nickel electrode will quickly get a black coating of polypyrrole and bubbles of hydrogen will form at the copper electrode (Fig. 2).

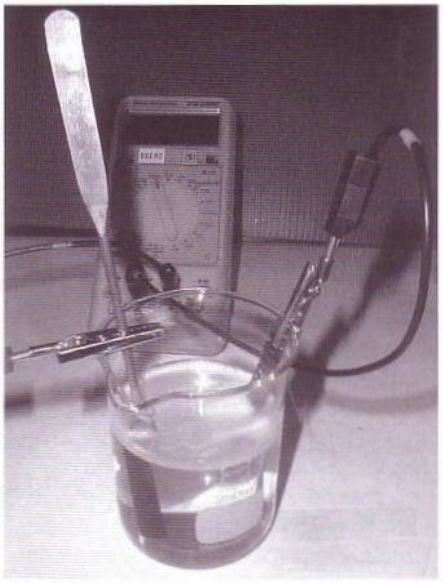


Figure 2 *Making polypyrrole.*

3. It will take approximately 40 minutes to form a film of polypyrrole thick enough to work with. After this time, switch off the power and remove the nickel electrode from the solution. Wash with distilled water and using a scalpel or razor carefully slice along one edge of the deposit and peel off the polypyrrole film (Fig. 3).

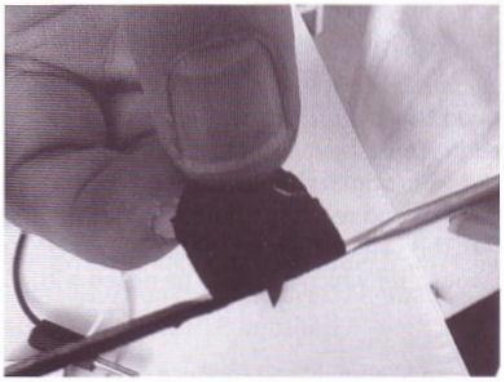


Figure 3 *Removing polypyrrole from the nickel electrode.*

Testing the electrical conductivity

For this, the polypyrrole film should be placed on a flat non-conducting surface. A glass microscope slide is ideal. Set up the circuit illustrated in Fig. 4

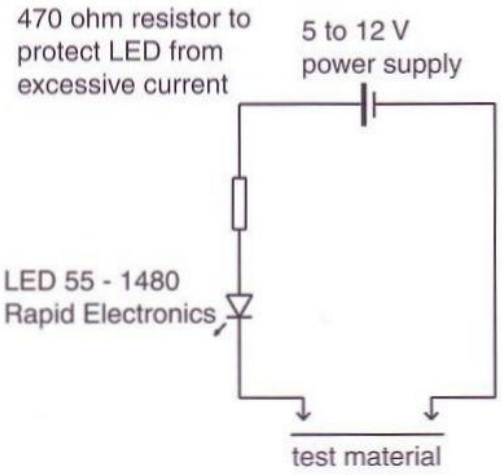


Figure 4 *Setup for testing the electrical conductivity of polypyrrole.*

We suggest using an LED to indicate whether electricity is being conducted because we feel it gives a good visual impact. It is possible to use a 6 V bulb if you are into a dull orange ' is it on or is it off?' type of effect!

The polypyrrole is fairly easily torn, so use 4 mm plugs, placed flat, and gently pressed down to connect the plastic into the test circuit. You should be able to get the LED to light when the plugs are about 1 to 2 cm apart (Fig. 5).

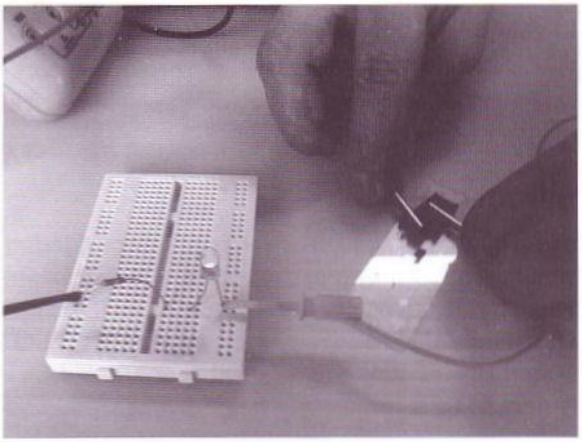


Figure 5 *Using an LED to test the electrical conductivity of polypyrrole.*

Safety considerations

Wear eye protection throughout and work in a well ventilated laboratory away from sources of ignition and hot surfaces.

Propanone is highly flammable. Its vapour is an irritant to eyes, skin and lungs and it is a narcotic in high concentrations.

Safety cont./

Sodium 4-methylbenzenesulphonate. Avoid contact with eyes, skin and clothing. It is an irritant to eyes, skin and lungs.

Pyrrole. Avoid contact with eyes, skin and clothing. It is a flammable liquid, which is light, air and moisture sensitive (it will deteriorate slowly – buy small quantities). The vapour may travel a considerable distance to a source of ignition and flash back (it forms an explosive mixture in air). It is toxic if swallowed, harmful by inhalation and skin absorption and is an irritant to eyes and lungs. Use in a fume cupboard.

Source of chemicals

Acros Organics via Griffin Education Tel. 01509 233344 (see Address List).

Sodium 4-methylbenzenesulfonate (sodium p-toluene sulfonate)	*Order code*	*Quantity*	*Cost*
	25947-1000	100 g	£13.30
Pyrrole	15771-0250	25 g	£7.64

References:

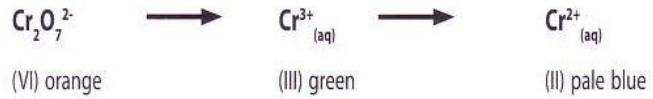
1. *Poly(pyrrole) – a conducting polymer*: Salters' A Level Chemistry 1991 Course Trial Edition PR5, 17 - 19
2. *Electrically Conductive Polymers:* Prize Winning Chemistry: CHEM NZ February 2001 Number 82, 7 – 15.

Air-free, small-scale, reduction

An alternative method, not requiring a Bunsen valve, is suggested to provide air-free atmospheres for the reduction of transition metal salts.

In the past this was often done on a fairly large scale in a conical flask with a *Bunsen* valve fitted to exclude the air. For test tube scale, *Bunsen* valves are unsuitable; a simple alternative technique is to cover the few cm^3 of the solution with a thin layer of a water immiscible solvent such as butyl ethanoate or kerosene.

It is fun to go up and down the oxidation states of some of the transition metals as each state is easily identified by its own colour. Chromium, manganese and vanadium salts are old favourites for this exercise. The technique is illustrated by the example of the chromium "redox ladder". It is fairly easy to reduce dichromate(VI) to the $^{(3+)}$ state, but further reduction to chromium(II) can only be achieved if air is excluded. Chromium(II) and vanadium(II) are both powerful reducing agents.



By using a variety of reducing and oxidising agents of the suitable redox potential it is possible to stop at intermediate oxidation states or to go on to the highest or lowest state. Fe^{2+}, H_2S, Br^-, I^-, and SO_2 are suitable for the first stage to Cr(III) and Zn for the last step to Cr(II).

Alternatively zinc added to chromium(VI) in acid solution carries out both steps with the colour changing from orange through green and onto to pale blue. Note that a mixture of orange and green appears brown and at a point where half of the chromium(VI) is reduced to chromium(III) some pupils might report another oxidation state!

Method

To 2 cm^3 of potassium dichromate(VI) solution (0.5M in 2M sulphuric acid) in a test tube add a piece of granulated zinc (about 1 g) and add a few drops of butyl ethanoate. Note the colour changes from orange through green and on to pale blue. To show the aerial oxidation of the Cr^{2+} ion withdraw, with the aid of a Pasteur pipette, some of the solution from below the solvent barrier and transfer to a small open vessel. The pale blue colour soon turns to the typical green of $Cr^{3+}_{(aq)}$.

Safety considerations

Wear eye protection and carry out in a well ventilated laboratory as a small amount of hydrogen is evolved.

Solvent: Both butyl ethanoate (Flammable) and kerosene have highish flash points (23°C and 65°C to 85°C) and though not likely to be capable of igniting at room temperature will because of the reaction be at temperatures well above 60°C and sources of ignition should not be near. Both solvents have a very low acute toxicity, but will irritate skin and especially eyes. Kerosene has been reported to be an experimental carcinogen; hence butyl ethanoate is preferred.

Chromium compounds. Avoid skin contact. Chromium(VI) is a carcinogen by inhalation. However it is easy to make up the solution without creating an aerosol. The lower oxidation states of chromium are of much lower toxicity and are not carcinogenic.

Notes : 1. The colour of the hydrated $[Cr(H_2O)_6]^{3+}$ cation is violet in crystalline solids and usually should also so appear in solution. Often in solution, however, it appears green because some of aquo ligands have been replaced by halide or sulphide ones.

2. *Good technique will avoid re-aerating the lower aqueous layer; take care to partly depress the pipette bulb before inserting its tip into the lower layer.*
3. *A similar sequence of stepwise reductions and re-oxidations can be achieved for vanadium salts (details on SSERC Members' website).*

Galileo's inclined plane experiment

On getting a pattern of odd integer numbers while experimenting with a rolling ball on an inclined plane Galileo realised that the laws of nature are universal. With the help of new technology, this historical experiment is now feasible in a school lab.

This is one of the most significant experiments of all time. We tend to overlook one form of this experiment nowadays. It was expressed in the *Dialogue* by Salviati (representing Galileo) thus:

> "- the distance traversed during equal intervals of time by a body falling from rest stand to one another in the same ratio as the odd numbers beginning with unity."

Normally we consider the total distance travelled from rest. Its value varies for journey times of 1, 2, 3 and 4 time units by the ratio of 1, 4, 9 and 16 units of distance.

Galileo saw that the differences in distance travelled relate to each other in the ratio of odd numbers starting with unity: 1, 3, 5, 7, 9, etc.

Here for the first time ever was a physical experiment that produced results with integer numbers. And such a commonplace phenomenon, gravitational acceleration! The implications were immense. When Galileo conducted this experiment he already knew that astronomy was a mathem-atical science. That was not too surprising. Astronomy was about heavenly bodies and mathematics was understood to be the purest of disciplines. In ancient Greek times it was the science of the gods. What inferences was he able to draw? Firstly, that the Earth, too, must also be a heavenly body. And secondly, that the laws of nature are universal.

Getting his result was difficult in Galileo's time. It is still quite difficult, even with the PASCO *Motion Sensor*. Try it for yourself.

Method

A low friction cart or trolley is allowed to run freely from rest down a uniform inclined plane. The distance travelled in each successive unit of time is measured.

For apparatus, I used a *PAScar Dynamics Cart* (PASCO ME-6950) and 1.2 m *Dynamics Track* (PASCO ME-9493) at an inclination of about five degrees. Other PASCO carts would be suitable. Traditional trolleys and runways might also do, but would probably give inferior results. Critical factors are the uniformity of the runway and low friction. Any non-uniformity in the acceleration will prevent you getting the desired results.

Several distance sensors were tried, but only one found suitable. The sensor must be able to measure distance, or range, at uniform periods of time. For this reason the *Smart Pulley* (PASCO, now obsolete) and *Photogate/Pulley System* (PASCO ME-6838) were rejected because they log whenever the light gate makes and breaks - at ever diminishing intervals of time. Also the *Rotary Motion Sensor* (PASCO CI-

COLUMN A	COLUMN B	COLUMN C	COLUMN D	COLUMN E
Time (s)	Position (m)	Difference in positions (mm)	Values in Column C divided by ascending odd integers	Values in Column C divided by 3.9
0.1060	1.043			
0.2061	1.043			
0.3062	1.043			
0.4063	1.043			
0.5064	1.043			
0.6065	1.039	4	4.0	1
0.7065	1.027	12	4.0	3
0.8065	1.008	19	3.8	5
0.9064	0.980	28	4.0	7
1.0063	0.944	36	4.0	9
1.1062	0.901	43	3.9	11
1.2060	0.852	49	3.8	13
1.3058	0.793	59	3.9	15
1.4055	0.726	67	3.9	17
1.5051	0.650	76	4.0	19
1.6048	0.568	82	3.9	21
1.7043	0.478	90	3.9	23
1.8039	0.381	97	3.9	25

Table 1 *Analysis of values of position versus time recorded by a* Motion Sensor. *The relative distances travelled each 0.1 s are shown in Column E.*

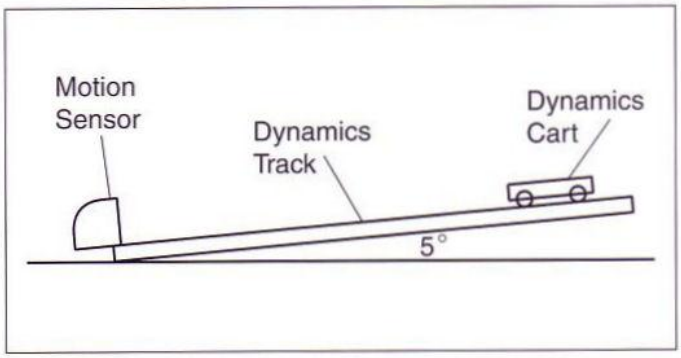


Figure 1 *Apparatus for Galileo's inclined plane experiment.*

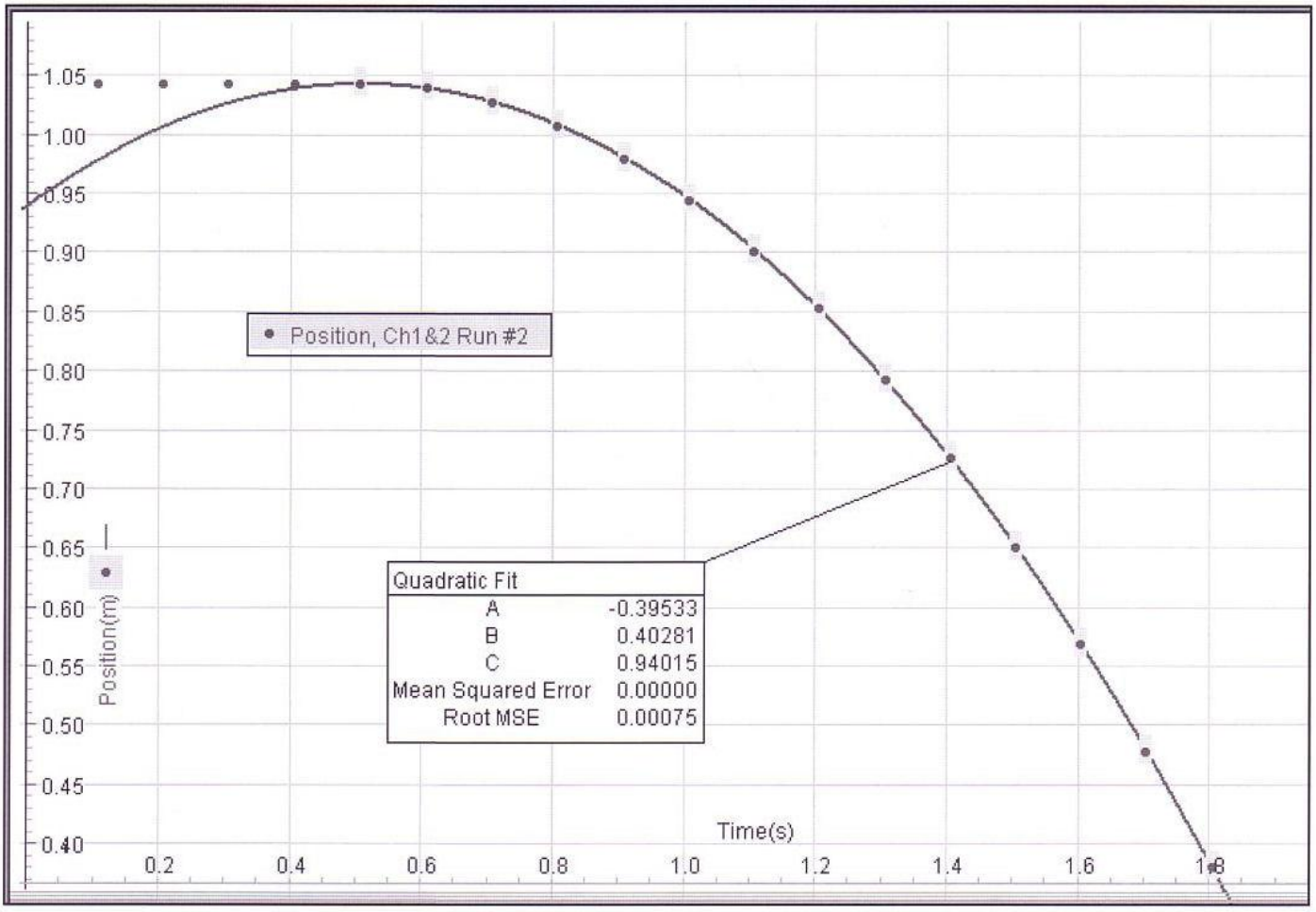


Figure 2 *Graph of values of distance versus time showing a parabola fitted through the points. The turning point coincides with the point at 0.5064 s indicating that the cart's release had been synchronised with the data capture events.*

6538) was rejected because it was found to cause too much friction. The *Motion Sensor* (PASCO CI-6742) is perhaps the only sensor suitable. It uses ultrasonic echolocation to measure range to an uncertainty of ± 5 mm.

The *Motion Sensor* was clipped to the foot of the track as shown (Fig. 1) and calibrated. The cart was held very steady by hand at the top of the track. The logging program *Data Studio* was set to log at 10 readings a second. About a second after logging began the cart was released and allowed to accelerate towards the Motion Sensor. Unfortunately the method does not allow for the release of the cart to be synchronised with the moment of logging. I had to chance my luck that the cart was released at the right instant. For a logging rate of 10 a second, this chance is about 1 in 5.

To check whether the release was synchronised with measurements, you need to look at a graph of distance versus time. I highlighted the data between the first point after release and the first point after a range of 0.4 m, and fitted a quadratic curve to the data. This fitted a parabola through the points, the turning point of which showed me the time of release. In the example given (Fig. 2), the parabola's turning point coincides with the data point at a time of 0.5 s. I was therefore able to analyse this data set to look for Galileo's number pattern.

If the turning point had not coincided with a data point, your simplest option would be to reject your data and obtain a fresh set, hoping that it is synchronised. Otherwise you could place the *Smart Tool* on the turning point and read off the point coordinates. The *delta function* on the *Smart Tool* should then be used to obtain the difference between points on the parabola for equal intervals of time.

I analysed the results with a spreadsheet by copying data from the *Data Studio* table and pasting it into an *Excel* spreadsheet (see Table 1). The starting position was 1.043 m. The starting instant was 0.5064 s. Both of these are arbitrary values arrived at by chance in where the cart was positioned and when it was released. The third column (*C*) contains successive distances travelled per 0.1 s time interval. These are shown in millimetre units to avoid working with decimals. Anticipating the result, I divided these successive distances by ascending odd integers beginning with unity. These quotients are listed in column *D*. They range in value between 3.8 and 4.0 with a mean of 3.9, confirming that there is a pattern of numbers. I was now able to go back to the values in column *C* and divide each by 3.9, showing the results in Column *E*. Hey presto! I had the series of odd integers beginning with unity - just as old Galileo had got all those centuries ago.

Two simple aids for microbiology

Designs for a Petri dish carrier and a Universal or McCartney bottle holder are described.

Commercial plate carriers and bottle trays are extremely useful but relatively expensive items for most school biology budgets. Two DIY designs by Kirsty Menzies of the SAPS Scotland Biotechnology Education Project are described here. These have been much admired on SAPS/SSERC microbiology courses and they've no doubt been much copied since, and well-deservedly so.

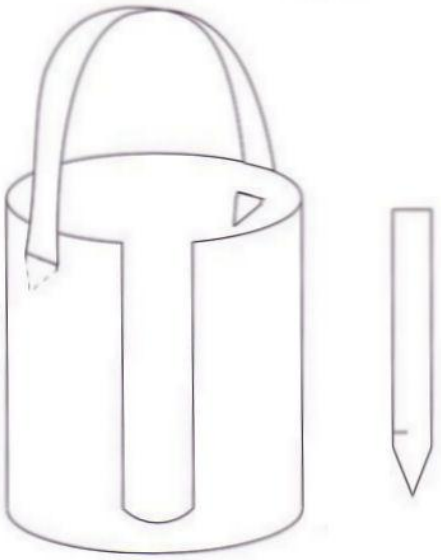


Figure 2 *Sketch of Petri dish carrier made from the base of a plastic juice bottle (not to scale). The inset shows one end of a plastic strip with a slot cut for its insertion into the sides of the bottle to become one end of a handle.*

Making a 'Buggy Bottle'

A 'Buggy Bottle' is a carrier for up to 10 petri dishes made from a plastic juice bottle. You want to use a bottle which is quite sturdy and has an internal diameter just over 9 cm. These instructions are for a Robinsons 2 litre diluting juice bottle (Figures 1 and 2).

Instructions

1. Mark a line around the circumference of the bottle just underneath the handle. Cut around the line and neaten to give a smooth edge.
2. Mark another line 1.5 cm below this edge and cut out to make a strip for a handle. Neaten the edges and cut a notch at each end of the strip as shown in Figure 2.
3. Mark 2 lines 2 cm apart from the top to the base of the bottle. Cut out this strip and neaten the edges.
4. On either side of this opening, so they are diametrically opposite, mark 1.5 cm slits around the circumference 1cm below the top edge of the bottle.
5. Insert each end of the handle in the strip and lock in position.

Figure 1 *Photograph of a Petri dish carrier made from the base of a plastic juice bottle.*

Making a 'Buggy Box'

A carrier for up to 6 universals or McCartney bottles is made from 1 pint or 2 pint plastic (HDPE) milk cartons (see Figure 3). Simply mark a line 7 cm from the base of the carton and cut round it to give a smooth edge. If you wish a handle for this, one can be made following the same method as that used for the Petri dish carrier or 'Buggy Bottle'.

Figure 3 *A SAPS 'Buggy Box' - a holder and carrier for Universal containers or McCartney bottles made from the base of a plastic (high density polyethylene or HDPE) milk container.*

Water rockets : *Rokit* type

An appraisal of the hazards of this popular rocket indicate that there is a slight risk of an impact injury, but that other risks are negligible.

Information on water rockets published in a US physics journal [1] shows that a 2 litre bottle with a tank of 0.7 litres of water pressurized to 120 p.s.i. can attain a speed of 60 m s^{-1} and an acceleration of more than 10 g. Hazards related to this operation include:

- rupture of the bottle due to over-pressurization, or
- impact injury to the experimenter or onlookers due to the rocket going out of control, or to a premature launch.

Subsequently, but unconnected to this American story, there was an enquiry asking whether the water rocket had been banned. Here is information about the *Rokit* and advice on its use:

1. We understand from the maker, Hinterland, that *Rokit* has been investigated by Trading Standards and has been given their approval as a product that complies with the safety provisions of consumer protection legislation.

   40 000 *Rokits* are sold every year. There have been two complaints about its safety following misuse, both incidents with unsupervised children.

   The self-release pressure is 25 p.s.i. This is many times lower than the burst strength of a PET bottle, which Hinterland informs us is 300 p.s.i. Therefore the *Rokit* pressure has a large safety margin. By comparison, Coke has a bottled pressure of about 45 p.s.i. at room temperature, but may reach 100 p.s.i. on a hot, sunny day.

2. No accidents or incidents with *Rokit* have been reported to either SSERC or CLEAPSS. The product has been on the market for nearly 20 years – the safety record is good!

3. We understand from the Institute of Materials and several plastic bottle manufacturers that it is standard practice to test pressurize samples of bottle at 150 p.s.i. Few bottles fail this test. If a bottle fails, there are two types of explosion :

   - across the base, resulting in the base cone being projected as a single piece, or
   - a tear in the side wall, in which case no fragments are projected.

   PET bottles never rupture at the neck; only in the two ways indicated.

   The explosion of a PET bottle does not produce high velocity fragments, unlike the explosion of a glass bottle. In view of this and because the *Rokit's* maximum pressure is six times lower than the pressure to which PET bottles are tested, the risk of harm from a bottle rupturing is negligible.

4. An enquiry to the Institute of Physics Internet user group produced one reply only, indicating a failed launch as the main snag.

   "The major hazard we experience is the depressuring of a failed launch. Normally we have secured a needle football inflator in a rubber bung/cork and attached pressure tubing by fitting it over the screw thread and then wiring it in place. Occasionally the pressure has been such that the bung has remained in place but the tube blows off leaving the rocket on the launch stand (a retort stand fitted with a ring clamp). We then either knock the rocket off with a well-aimed ball or approach it in a crouched position and carefully pull the bung out - waterproof gear is needed here!!"

5. Recommendations on bottle type :

   - The bottle material must be polyethylene terephthalate (PET), as used in carbonated drinks, because it is designed to withstand pressurization.
   - Do not use PVC bottles, which may be used to contain uncarbonated drinks. PVC bottles should not be pressurized.
   - The base should be rounded with a large radius of curvature such that a direct blow on the face could not injure the eye.
   - The most suitable basal type is ellipsoidal. A champagne-type base with a recess may also be suitable provided that the eye cannot be touched. Petaloid bases with five feet are not suitable.
   - The capacity should be either 1 litre or 1.5 litres. Do not use bottles with a bigger capacity because they can cause greater impact injuries.

6. Impact injuries : This would seem to be the one significant risk of harm. For reasons explained above, eye injuries are unlikely. Therefore eye protection need not be worn by spectators, but perhaps should be worn by the person pumping air.

Misfires seem to cause problems. Because the pressure is limited to 25 p.s.i., which is less than the pressure within a bottle of Coke, the risk of harm from an impact injury on following the manufacturer's instructions to unscrew the bottle from the tail unit would seem to be very slight.

This information supplements the manufacturer's instructions [2], which should be followed. We hope that it encourages rocketry and would welcome further information or comment from teachers on this subject.

Reference

1 Kagan D, Buchholz L and Klein L *Soda-bottle water rockets* The Physics Teacher 1995 33 150-157

2 *Rokit Instructions* Hinterland Limited

Trade News

Marlec Engineering is a firm weel kent to boat owners and caravanners. It makes and sells small-scale renewable energy systems. They have now introduced a range of educational kits named *Green PowerEd* Systems. There are three kits in the range, the *Junior*, *Senior* and *Graduate*. The Junior kit could well be of interest to schools. It consists of a Rutland 503 Windcharger, generating 25W at wind speeds of 22mph and up to 80W at higher wind speeds. A 30w solar panel (60x50x5cm), a power monitor, 70Ah 12V battery, cables and mounting kits are included with the pack. However at a cost of £749.95 it may be a wee bit dear? The Senior with a more powerful Windcharger and solar panel costs £1149.95. The Graduate should be left to colleges and universities.

Novara plc was the overall holding company and 'parent' of Philip Harris and Unilab until the early Summer when it accepted an offer for its assets from *Findel plc*, a UK based mail order company. Findel is a supplier of educational materials through its Premier Educational Supplies subsidiary which trades under the Hope Education, Galt, Step by Step and Philip Green brands.

The management of Findel plc apparently believe that opportunities within Novara have been under-exploited and claim that they are committed to maximising the potential of the Company's brands (which, we understand, would include Harris and Unilab). Novara's relationships, both with its suppliers and its customers, have been severely strained in recent times by operational difficulties arising from major infrastructure projects within, and the consequent cash constraints placed on, the business.

We at SSERC wish Findel and the established staff at what was Novara, every success in their efforts to turn things round and restore the high level of service which, until recent times, we had all came to expect from Philip Harris and Unilab.

NCBE (the National Biotechnology Education Centre) has launched a 'Transformer Protocol' kit for demonstrating genetic transformation. This is keenly priced at £47. Details from NCBE, see the last column for address details.

Biology tips

We've had recent enquiries about some minor but vital details in Higher Still Biology material issued by HSDU late last session:

Zippette: Apparently some of the biochemical exercises specify the use of a *Zippette* dispenser. This is a proprietary bottle top variable volume dispenser (see thumbnail photo on the right) and its use isn't critical. Pipettes or other dispensers will suffice.

Barfoed's reagent is listed as a requirement for one Unit but without a recipe or source. The recipe is as follows:

Dissolve 13 g of copper(II) ethanoate (acetate) in 200 cm^3 of a 1% v:v solution of glacial ethanoic (acetic) acid (i.e. 2 cm^3 of the glacial acid in 198 cm^3 deionised or distilled water). For Hazard information see entries in SSERC Hazardous Chemicals Manual.

Catalase, similarly, is specified without a type or source and the use of 'live' enzyme extracts from tissues is ruled out because of variable activity levels.

We would recommend Fluka as a source (UK agents Sigma-Aldrich). Most of their cheaper catalase preparations are extracted from bovine liver, which you may wish to avoid. In which case go for:

Product code 60631 catalase from *Aspergillus niger* 100 mg for £7.90 or

Product code 60634 catalase from *Micrococcus lysodeikticus* £28.80 for 100 cm^3.

Biology equipment offer

The University of Edinburgh are to refurbish one of the biological sciences departments. They have surplus incubators, ovens, water-baths and shaking water-baths (with 250 cm^3 to 25 cm^3 flask holders) available for distribution to schools. We have a copy of the list of equipment (Excel file) or you can contact Lynn Kennedy of the University technician staff directly by E-mail :

lkennedy@srv0.bio.ed.ac.uk

Please contact Lynn by E-mail rather than by phone.

Addresses

Acros Organics - see Griffin & George

djb microtech, Delfie House, 1 Delfie Drive, Greenock, PA16 9EN. Tel/Fax: 01475 786540, www.djb.co.uk

Griffin & George, Bishop Meadow Road, Loughborough, Leicestershire, LE11 5RG. Tel: 01509 233344, Fax: 01509 231893, Email: griffin@fisher.co.uk

Philip Harris Education:

E6 North Caldeen Road, Calder Street, Coatbridge, Lanarkshire, ML5 4EF. Tel: 01236 437716, Fax: 01236 435183 and also at:

Novara House, Excelsior Road, Ashby Business Park, Ashby-de-la-Zouch, Leicestershire, LE65 1NG. Tel: 0870 6000193, Fax: 0800 7310003, www.philipharris.co.uk/education

Hinterland Limited, Rokit Dept., Unit 2, Hertford House, Stanstead Road, Hertford, SG13 7AY.

HSE Books, PO Box 1999, Sudbury, Suffolk, CO10 2WA. Tel: 01787 881165, Fax: 01787 313995.

Instruments Direct Limited, Unit 14, Worton Road, Isleworth, Middlesex, TW7 6ER. Tel: 0208 560 5678, Fax: 0208 232 8669, www.InstrumentsDirect.co.uk/pasco

Marlec Engineering Co Ltd. Rutland House Trevithick Road Northants NN17 5XY Tel. 01536 201588 www.marlec.co.uk

National Centre: Education for Work and Enterprise, University of Strathclyde, Jordanhill Campus, 76 Southbrae Drive, Glasgow G13 1PP Tel: 0141 950 3141 W:www.natcentre.org.uk

NCBE, Whiteknights, PO Box 228, Reading RG6 6AJ Tel: 0118 987 3743 Fax: 0118 975 0140 E: NCBE@reading.ac.uk W:www.reading.ac.uk/NCBE

PASCO - see Instruments Direct

SAPS Biotechnology Scotland Project, ICMB, University of Edinburgh, Darwin Building, King's Buildings, Mayfield Road, Edinburgh, EH9 3JR

Tel. 0131 650 7124 Fax 0131 650 8650 and at:

Quest Biotech Laboratory, Dollar Academy, Dollar, FK14 7DU Tel. 01259 743753 Fax 01259 742867.

Scottish Colleges Biotechnology Consortium: Dr John Porter, Falkirk College of Further and Higher Education, Grangemouth Road, Falkirk, FK2 9AD. Tel: 01324 403000.

Sigma-Aldrich Co.Ltd, The Old Brickyard, New Road, Gillingham, Dorset SP8 4XT Tel. (Freephone) 0800 7171 81 Fax 0800 378538 Email ukorders@eurnotes.sial.com www.sigma-aldrich.com

Unilab - see Philip Harris

3M United Kingdom plc, Visual Systems Group, 3M House, PO Box 1, Market Place, Bracknell, Berkshire, RG12 1JU. Tel. 01344 858000.