SCIENCE & TECHNOLOGY IN SOCIETY

GENERAL GUIDE FOR TEACHERS

SATIS

Science and Technology in Society

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ASSOCIATION FOR SCIENCE EDUCATION

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Contents

Contents

Foreword

Making decisions about the need for change is rarely difficult. Agreeing the direction of change may be more contentious, but implementing change is quite the most taxing step. There is a clear consensus within the science education community about need and direction — students in schools *will* benefit from science courses which are set in the real world, which do relate concepts and content to social, economic and technological contexts. There is agreement too that motivation and learning are influenced for the better by teachers who use a variety of styles and approaches in their day-to-day work. Promoting and supporting, and in this sense enabling, just such shifts in practice is at the heart of the SATIS Project. Given the emphasis evident in the new GCSE syllabuses, its publication could not be more timely.

The Association for Science Education is not unused to success. We have initiated, supported and published a number of influential curriculum projects — some, like the LAMP materials, low cost, in-house publications; others, like Science in Society, produced in cooperation with a commercial publisher. All ventures have had a common feature — they have depended upon the drive, expertise and sheer professionalism of ASE members. SATIS is no exception. Its close sense of the realities of schools and its relevance to existing and emerging syllabuses in the sciences reflect clearly the classroom roots of its writers.

As the Chairman of ASE I count myself fortunate that my year of office coincides with the formal launch of the SATIS materials. I have seen something of the team at work and have been very impressed — but the products speak for themselves. We should not be slow to let the community at large know that science teachers, given even minimum space and resources, can be creative, innovative and, not least, hard working in the interests of their students.

The Association, and I am sure the science teaching profession at large, owe a considerable debt to John Holman, the Project Organizer and his team. If we are looking to change, the SATIS publications are a well judged and readily usable resource supporting change. I commend them to you.

JOHN NELLIST *Chairman ASE, 1986*

About this book

This General Guide for teachers complements the Teachers' Notes published with individual SATIS units. It gives more general information about the project, about some of the teaching methods involved, and about other ways of introducing social and technological aspects into the secondary science curriculum. At various points in this book, we have inserted quotations from teachers and students who took part in trials of SATIS units. These quotations appear in italics.

Many of the SATIS central team contributed to this Guide, and their names are listed at the end. Particular acknowledgement is also due to Peter Borrows for the part on 'Science trails' in Section 3.

Section 1 About SATIS

1 How SATIS started

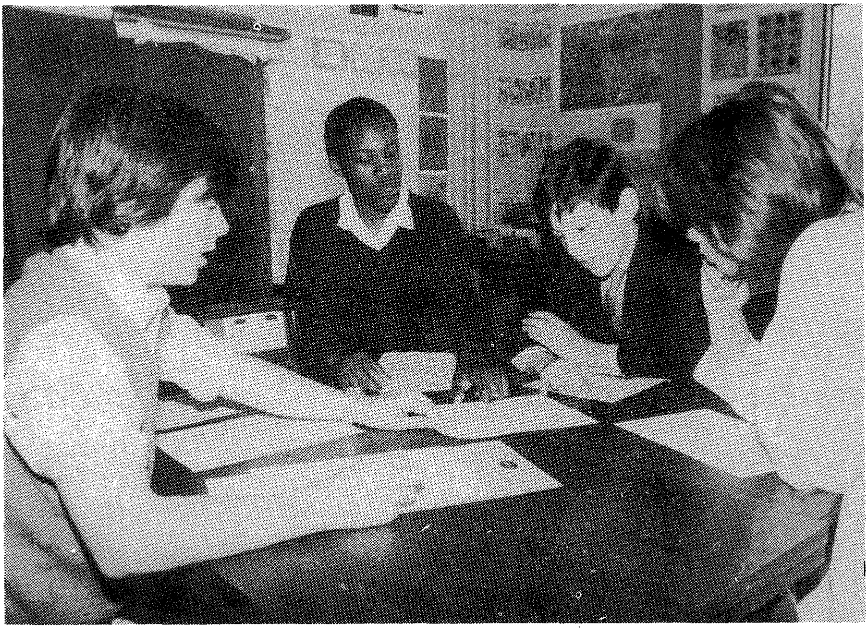
The Association for Science Education set up the SATIS Project in September 1984. The Association had already published two successful sixth-form courses, *Science in Society* and *SISCON in Schools.* Both these General Studies courses looked at the interactions between science, technology and society, but it was difficult to adapt them for use with younger students. The Association set up a working party to consider the needs of the younger group, and it was from the report of this working party that the SATIS Project grew.

There was little doubt of the need for a project of this kind. Policy statements from the Department of Education and Science *(Science 5—16: a Statement of Policy),* the ASE *(Education through Science)* and other authorities agreed on the need to relate science to its social and technological context. The problem was the shortage of resources to enable teachers to do this.

SATIS gets under way

Thanks to generous support from sponsors, the SATIS project team was able to set to work to develop such resources. Writing of students' units began in September 1984, and continued until December 1985. Each unit was written by an experienced teacher, often in association with an expert from industry, the universities or the professions. This draft was then edited and produced in its trial version.

The trial units were circulated for three kinds of comment. First, each unit went for trial in schools. A list giving some of the wide range of SATIS trial schools appears at the end of this book. Trial schools were invited to comment on the level of the unit, with regard to demands made in terms of language, concepts, skills, etc.; the layout and presentation of the students' materials; the general effectiveness of the unit, and students' reactions to it; and the ease of use of the unit and the time it required.



School trials — four students working on the unit, Living with Kidney Failure

Each unit was also circulated to members of the SATIS team for detailed comment on its suitability for students of this age and level. For the third level of comment, each unit was sent to one or more experts in the field concerned: doctors, industrialists, university specialists and so on, as appropriate. As a result, many different people from many walks of life have contributed to the students' units. A list of contributors appears at the end of this book.

The abundant feedback produced by this process of trial and consultation was invaluable when the units came to be revised prior to publication.

By covering origination costs out of project funds, and by publishing and distributing through the ASE, it was possible to keep the price of the final publications low.

2 Why teach about science and technology in society?

We are all born scientsts, with an innate curiosity about the things around us, the materials that make up the world and about other living things. Some retain this curiosity all their lives, but others lose it — perhaps because the science they study is too esoteric, too academic or too far removed from their everyday lives and experience.

Much has been written and said about the lack of relevance of the secondary science curriculum: its dryness, its impersonality and its excessively academic content. Introducing social and technological aspects into the science curriculum helps to make science more relevant in a number of ways.

Relevant to the future citizen

Our students will all be living in a world dominated by the manifestations of science and technology. In the food cupboard, in the car, on clothing labels, in electric lights . . . science is everywhere. But how much understanding of these everyday aspects does today's citizen have? Tomorrow's citizens, like today's, will be surrounded by science-related issues such as nuclear power, food additives and fluoridation of water supplies. Surely, if there is one thing a science education should be doing for these citizens of tomorrow — most of whom will study no science beyond the age of 16 — it is to equip them with the means to consider such issues in a rational, informed way. Yet a traditional, academic science curriculum often has little time for consideration of such matters.

A comprehensive school teacher from the South of England, reporting on *Test-tube Babies:*

> *Well received by all. Some of the group started with a purely emotional response to AI, spare embryos, surrogate motherhood, etc. But after hearing the views of others,*

they tempered their emotional feelings with factual knowledge, to arrive at a more mature point of view.

Relevant to the future worker

For those students who will enter employment, it is likely they will be working in an industry or activity based on science and technology. If the science these children learn in school is to be of help to them in this work, it clearly needs to be closely related to the real-life things of the working world. Abstract concepts will be of little use unless their relation to practical applications is made clear.

A comprehensive school student from the South of England, commenting on *Recycling Aluminium:*

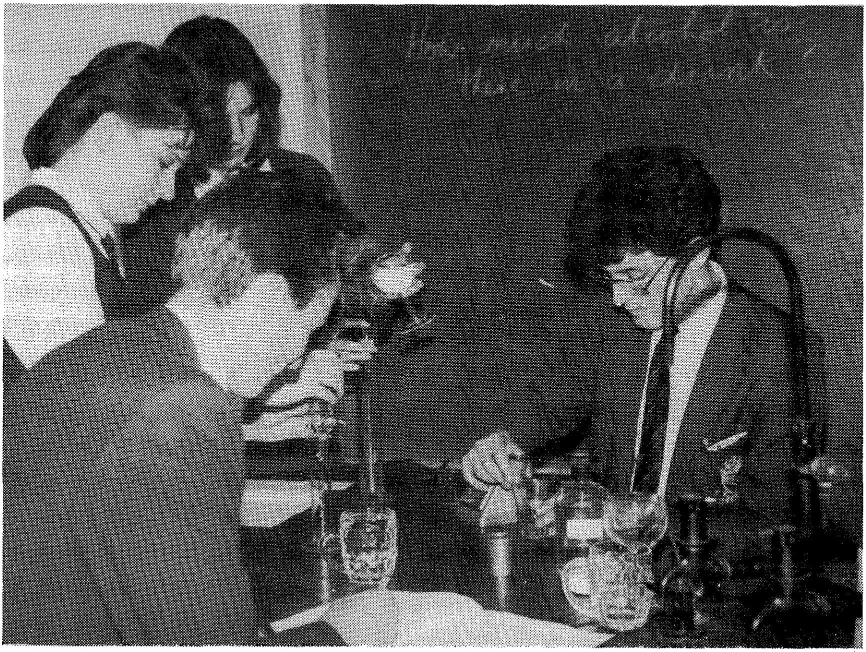
At least we were tackling a real problem in the real world, and not some sort of artificial problem in school.

And another student, on *Making Fertilizers:*

It was interesting because you don't realize what goes on behind the scenes in industry.

Relevant to the students' own lives

Above all, relevant science can be so much more interesting and motivating. Young children begin their study of science full of enthusiasm, yet their turning away from science as they enter adolescence is all too familiar to secondary-school teachers. There is much evidence to suggest that adolescents find the science they are taught dehumanized, and irrelevant to themselves and their lives. Yet science is intrinsically relevant: it is all around, in the lives of every one of us. It does not take a great deal of effort to make these links clear, and so humanize the science and bring it closer to everyday experience.



Making science relevant to students' lives — practical work in Drinking Alcohol

Often science is represented, in school and in the media, as neutral, objective and impersonal. The scientific method may be objective, but the practice of science is certainly not. It is a human activity, carried out by humans and having an impact on the lives of every human. To dehumanize science is to misrepresent it, and perhaps to turn away those students who are interested in people and personal relations. These are the very students, often the imaginative, sociable ones, which the community of professional scientists and engineers needs. There is much evidence to suggest that girls, in particular, are turned away by the impersonal, dehumanized face of science, but attracted to the idea that science can be useful to society.

Relevant to the wider world

We live in a diverse world of many cultures, and it is important that our science curriculum reflects such diversity. A number of SATIS units (for example, *A Medicine to Control Bilharzia, Appropriate Pumps, Energy from Biomass* and *Fibre in your Diet)* are concerned with this wider context. The impact of science and technology is not confined to Britain and the prosperous Western world: it has a profound effect on the developing world, both for good and for bad. Emphasizing the wider context of science draws attention to this diversity, and perhaps may help widen the appeal of science in school.

A teacher in a comprehensive school in a northern city, reporting on *A Medicine to Control Bilharzia:*

> *They were very interested, especially the more disruptive pupils, because they could air their views — and thus contribute positively.*

Getting the facts right

SATIS units have been written by teachers, because these are the people who can best judge what students can and cannot do. But in a field like this it is important to get factual information correct, and for these facts to be presented in a balanced way. It was therefore particularly important to ensure that each SATIS unit was checked by an expert in the field.

An expert on risk assessment, commenting on *Risks:*

> *May I say how valuable I think your unit is — just the sort of thing that science education ought to be about. I have only a few criticisms or suggestions to make. Clearly one could add innumerable qualifications to the answers proposed, but you cannot hope to be as exact at the level you are teaching as at the level of a PhD and yet continue to arouse interest and communicate the central ideas.*

A note on technology

Technology — the enabling process by which science is applied to satisfy our needs — has been the subject of considerable discussion, in particular concerning its place in the school curriculum. In the same way that SATIS is not a science course in its own right, it is not a technology course either. Instead, SATIS looks at the ways technology interacts with society, influencing and in turn being influenced by it.

3 Aims of the project

The aims of the individual SATIS units are indicated in the Teachers' Notes for the unit concerned. The overall aims of the project are listed below. Clearly, how many of these aims can be achieved must depend among other things on which units are selected for use.

- To show that science is not confined to the school laboratory, but is manifest in all aspects of the world, both local and distant.
- To show that science has a human face.
- To encourage interest in the interactions between science, technology and society.
- To develop awareness of the contributions, both good and bad, made by science and technology to society.
- To develop awareness of industry, its economic basis, how it operates and its role in wealth creation.
- To show the need to consider the impact of technological activity on the environment, and the need to minimize environmental damage.
- To develop awareness of the need for careful use of natural resources.
- To show that science is not an isolated field of enquiry, but interacts with other disciplines, such as geography, economics and history.

- To show that real-life decisions often have to be based on conflicting or inadequate information, that decisions involve compromise, and that there is not always a 'right' answer.

- To encourage students to argue on the basis of facts, and to listen to and judge the arguments of others.

- To encourage students to discuss their ideas with others, within a scientific context.

- To provide opportunities to practise certain skills, including reading and comprehension, data collection and analysis, retrieval of information, problem-solving, role-play and communication skills.

4 About SATIS units

The SATIS students' materials are presented as a large number of individual units. Each unit comprises Teachers' Notes (printed on blue paper) and Students' Worksheets (white). Copyright is waived so that schools may print the sheets they need for the use of their students.*

Each unit has links to major science topics as well as exploring important social and technological applications and issues. The units are thus designed to be used in conjunction with **existing** science courses: they do **not** comprise a complete course, but a varied set of resource materials. The units generally require a minimum of two periods (about 75 minutes) of classroom time, or more, depending on the number of parts attempted. They are meant to be used flexibly and selectively, and it is expected that teachers will often want to adapt them to their own particular purposes.

*The permission of the publishers must be obtained before reproducing the material for any other purpose.

The interactive approach

SATIS units are intended to involve students as actively as possible. Instead of simply reading or listening, the units are designed to get students involved, in comprehension questions, discussion, simulations, role-play, decision-making, problem-solving, surveys and so on. Experience has shown that interactive techniques such as these can be very effective, particularly where students are interacting with one another in small groups. However, these approaches are relatively novel for many science teachers, and some guidance on their use is offered in Section 2.

SATIS units are designed for use with GCSE science classes. Naturally, there is considerable variation between units concerning the most suitable ability range or age range. In some units, parts of the unit are intended for use only with students of higher ability. Some guidance is given in the Teachers' Notes, but in general it is left for teachers themselves to decide which units or parts of units will be most appropriate.

A list of titles of SATIS units is given in each book of ten. A detailed index appears in SATIS 7 and will be updated in subsequent books.

5 Using SATIS units

Tear them out and cut them up

SATIS units are meant to be used flexibly. No teacher will want to use all the units, or even the majority of them. It is hoped that teachers will select those units or parts of units that fit in best with their course and their students' needs.

The books containing the students' units are designed so that the units can be easily torn out for duplication and filing. Furthermore, it is expected that teachers will cut the units up, adapt them, use the parts they feel are appropriate, and leave out other parts.

In school trials, units were used in a variety of ways. Some were felt to be a useful way of revising a science topic, and at the same time showing its social relevance. For example, *Industrial Gases* was used when revising the properties of gases in chemistry. *Test-tube Babies* was useful during the revision of reproduction. Most trial teachers waited until an appropriate linkage point arose in the course, but inevitably there were times when units were used as 'fillers' when teachers were absent. Often, trial teachers used only part of a unit, and some schools cut out parts of units and included them in their own workbooks.

Adapting to suit less academic students

Where teachers felt the level of units was too high for their students, they sometimes simplified and adapted the unit.

A teacher in a London comprehensive school, reporting on *What's in our Food? — a Look at Food Labels:*

> *It sparked off much debate and got all children involved. But for non-exam groups it was too complex and had to be considerably adapted.*

Adaptation may involve cutting out some parts of the unit and rewriting others. But even without any rewriting, units can be made more accessible to less academic students simply by increasing the level of teacher intervention: the teacher can bring out key points by presenting them verbally instead of relying simply on students reading them. Where students are taught in mixed-ability sets, small-group work can provide opportunities for more able students to help the less academic ones.

A teacher in a Midlands comprehensive, commenting on *The Label at the Back — a Look at Clothing Fibres:*

> *There is a good range of material appropriate for a range of different abilities. The data handling towards the end is complicated for the less able but we spent more time*

on the presentation of data with these pupils, e.g. samples of fabric were stuck to pupils' copies of Table 2, and to the bar chart they had drawn in Q.1.

And the same teacher describing adaptations made to *The Pesticide Problem:*

Pupils put their major conclusions on a series of posters rather than having a plenary session. Less able pupils had a go at designing posters to advertise the slug-killing pesticides, giving evidence to back up the effectiveness of each pesticide.

SATIS beyond GCSE

There is of course no reason why SATIS units should be confined to GCSE science courses. In school trials they were used in Certificate of Pre-vocational Education (CPVE) courses, and sixth-form A-level, General Studies and non-examined courses. Other uses which suggest themselves include adult education and technology courses.

But is it science?

SATIS units are meant to be used in conjunction with mainstream science, not separate from it. Because they extend science, many of the units have a considerable cross-curriculur character, and it has been found that non-science departments such as Geography and Personal and Social Education often show considerable interest. At least one trial school took the wise precaution of meeting with other departments to coordinate the presentation of related subject matter, with the aim of avoiding duplication.

A related problem is that some students, particularly the more examination-conscious ones, may see the subject matter as peripheral to their studies. The following quotations illustrate this point.

A student from a comprehensive school near London, commenting on *Chemicals from Salt:*

It tended to get away from the chemistry aspect and some of the questions wandered

> *onto more geographical problems than scientific . . . Personally I'm more worried about my exams.*

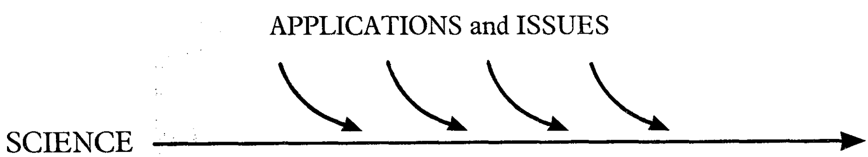
And a teacher from a comprehensive school on the South Coast, reporting on *Drinking Alcohol:*

> *Some found it difficult to accept the relevance of this to their chemistry exam, and were harder to switch on. This was more true of O-level than CSE pupils.*

With the greater emphasis on social applications in the new GCSE courses, this attitude should become less common. In any case, comments such as these were relatively rare, and most students welcomed the change of activity and the emphasis on real-life things.

6 SATIS isn't the only way

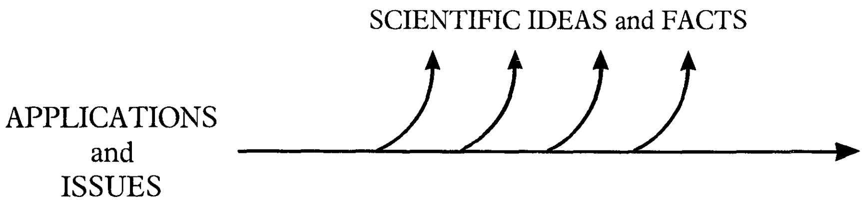
The approach adopted by SATIS is to insert the relevant applications and issues at appropriate points in the science curriculum — the 'science first' approach illustrated in the diagram below.



But, of course, SATIS units are not the only materials suitable for insertion in this way. Good teachers have long adopted this approach, and have built up a stock of resource materials, from anecdotes and videos to newspapers and visits. Section 3 offers some ideas for this kind of enrichment. Section 5 suggests some useful sources of resource material.

Why not applications first?

Some teachers, impatient for change, may find the gradual, pragmatic 'science first' approach too slow. They may prefer to reverse it, to abandon existing ideas about science curricula, and adopt an 'applications and issues first' approach, as in the second diagram.



In this approach, everyday applications and issues are used as starting-points from which scientific ideas are developed as they arise. This 'bottoms up' approach has the advantage that it is rooted in students' experience.

A good example is *Salters Chemistry*, a GCSE chemistry course which takes as its starting-points such topics as Food, Clothing, Warmth, Drink and Buildings (see Section 5 for further details of *Salters Chemistry*).

But the applications-first approach does not have to be in the form of nationally planned and published courses: one of its strengths is that it can use local and topical issues as starting-points. The following quotation, from a comprehensive school which designed a science curriculum based on these principles, illustrates the approach.

> *We decided that the traditional methods of presenting the science first and then throwing in a quick word on applications was too pure and unsuitable as a motivator of 14—16 year olds. We pledged to study everyday issues, the uses to which we put science and our dependence upon it, as the major subject content of each lesson. The pure science could then follow but only in as much detail as was needed to understand the original stimulus to the lesson. A discussion on the energy crisis can lead to questions about the need for nuclear power and the work of the CEGB. Eventually you end up at the generator! Information technology works back to the electronics that runs it; thrombosis and obesity lead us to the heart but only via the heart-lung machine.*
>
> (From *Rethinking Science?*, an ASE Occasional Paper)

Section 2 Guidance on some of the SATIS teaching methods

Some of the teaching methods in SATIS are likely to be unfamiliar to science teachers. This section offers guidance on some of the techniques.

1 There isn't always a right answer

Real-life decisions usually involve compromise, imperfection, and no single 'right' answer. Several SATIS units try to reflect this fact, but their open-ended nature can present problems at first for students who are used to the security of the more closed, single-answer problems often presented in school science. The following quotations illustrate the point.

A teacher in a secondary-modern school in the Midlands, commenting on *Fluoridation of Water Supplies:*

> *The main problem seemed to be their difficulty in realizing the difference between facts and opinions, and in seeing that it was possible to have differing opinions and that there was not necessarily a 'right' answer.*

And from a comprehensive school teacher in the West of England, commenting on *Chemicals from Salt:*

> *Pupils dutifully answered, but did not respond to the open-ended nature of the work. They needed to be reminded that there is no one answer to this type of work.*

More positively, again from a comprehensive school teacher in the West, this time commenting on *The Design Game:*

> *It was very effective in encouraging pupils to work in a way in which there can be many 'correct' answers — often in science we have only one.*

Controversial issues

A number of SATIS units are concerned with controversial issues, where the 'right' answer depends on one's point of view, values and beliefs. Some teachers may argue that science lessons are not the place to air such issues. But there are several strong arguments in favour of allowing controversial issues to be considered where they arise naturally from science.

- Many of the issues of the day — for example, pollution, nuclear power, genetic engineering — are rooted in science and technology. To suggest that science is free from controversy is to misrepresent science.

- Consideration of controversial issues benefits from the rational, informed approach which a study of science encourages.

- Social issues such as alcohol abuse may well be discussed in other parts of the school curriculum, but students can benefit from discussing them in the context of a science lesson. Science has a particular way of looking at the world which can give students a useful perspective on an issue.

- Controversial issues can be stimulating, and can motivate students — in particular those who find little to interest them in the traditional content of science lessons.

A teacher in a comprehensive school in East Anglia, reporting on *Fluoridation of Water Supplies:*

> *It was effective because the idea of controversy was introduced and they could argue about statements among themselves, and justify their own ideas.*

And a teacher in a London girls' comprehensive, reporting on *The Limestone Inquiry:*

> *It effectively involved all of the class. Even the most inhibited joined in. The class looked forward to the lesson, and went out of the room still debating.*

Of course, it is not proposed that the science curriculum should suddenly be taken over by controversy. The amount of such material introduced may well be quite small, but it is suggested that the teacher should not shrink from it.

Controversial issues of course place the teacher in a difficult and challenging position. It is generally accepted that the authority position of a teacher is strong, and it is difficult for the teacher to express a personal point of view without this view carrying disproportionate weight. Like the Humanities Curriculum Project before it, the SATIS Project has assumed that the most appropriate role for the teacher is that of a neutral chairperson, ensuring that all students can have their say and avoiding the assertion of his or her own views. This idea is developed further below, where discussion work is looked at more closely.

2 Discussion

Discussion is an activity central to the SATIS Project. Discussion is felt to be valuable and important for a number of reasons:

- SATIS often involves matters of opinion, not fact. Discussion encourages students to express their own opinions.
- Discussion helps students develop an awareness of the strengths and weaknesses of their own ideas, and appreciate that different people can have different views about the same thing.
- Discussion work can help the learning of science concepts. Talking about scientific ideas with each other, and applying them in new contexts, helps students gain confidence in handling the ideas.

A teacher in a London comprehensive, commenting on *Chemicals from Salt:*

> *They enjoyed the change to small discussion groups and I was pleased with what they did discuss. They liked the feeling that they were in charge. Some who never*

> *contribute did in this context. Even the most rebellious boy in the class, who initially would not even sit with his group, eventually moved closer to them.*

And a teacher in a West Country girls' grammar school commenting on *Nuclear Power:*

> *Good for getting otherwise quiet girls to talk . . . It made some of the very quiet girls speak out.*

Running a good discussion

Teachers of science are sometimes wary of discussion, since the nature of their subject limits their experience of this kind of activity. Running a good discussion needs skill, enthusiasm and sensitivity, and above all good organization. A number of SATIS units (for example, *Living with Kidney Failure* and *Nuclear Power*) have a structured format for generating discussion; others are less specific. The following general tips may be of help to teachers in organizing discussion in any context. Some of them are very obvious and will be familiar to many teachers.

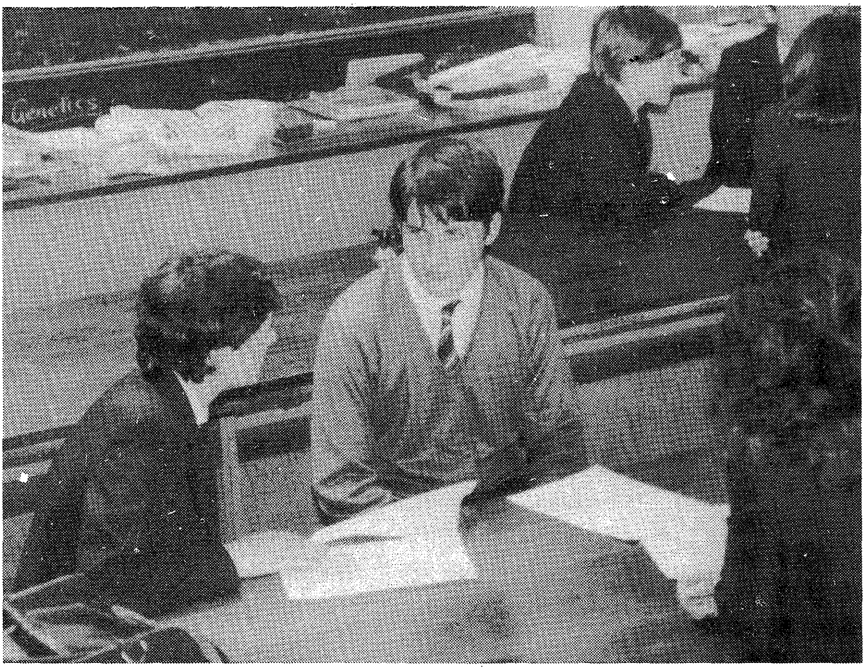
- Working in small groups is often the most effective way of getting discussion started. A useful technique is to start off discussion in small groups, then widen it to the whole class by getting groups to share their ideas. (See Section 2 for more on group work.)

- Seating is important. The usual classroom arrangement, with the teacher at the front facing the students, encourages a flow of discussion from teachers to students and back again, but discourages communication *between* students. Wherever possible, discussion groups should be arranged so everyone can see everyone else. The best arrangement is a circle. In a conventional laboratory with fixed benches, this may be difficult to arrange for the whole class, though with small groups it is easier.

- Discussion rarely goes well without an initial stimulus. SATIS units include many discussion questions and stimuli, but there are plenty of other sources of stimulus — newspaper cuttings, pictures from magazines, a recent TV programme, a provocative statement by the teacher and so on.

- It is difficult to launch a discussion straight into abstract generalities. Start with specific, simple, concrete points, then widen to the more general.

- It may help to ask students to write down their views on one or two specific questions at the start. This gives them time to think, and is helpful to the more shy and less articulate ones.



Group discussion. Fixed laboratory benches can be a problem, but less so if discussion is in small groups.

- The teacher's role is very important. He or she needs to avoid dominating the discussion: remember that the teacher's views will carry disproportionate weight. Try to give support and encouragement, and to draw out the quieter students.

- It is important to get the right atmosphere at the start. The teacher needs to be enthusiastic, lively and well organized. Students need to know the topic for discussion, but the agenda should not be so rigid that it cannot be adapted as the discussion develops.

- The teacher needs to be sensitive to students' feelings, particularly cultural differences and religious beliefs. Try to protect minority opinions, and make allowances for shy students. Some researchers have suggested that girls may not get a fair hearing in mixed discussion groups unless the discussion is carefully chaired.

A teacher in a Northern city comprehensive, commenting on *Paying for National Health:*

> *Arguing a case proved difficult — they were too shy or could not think deeply enough in the given time.*

And a teacher in a comprehensive school on the South Coast, reporting on *Test-tube Babies:*

> *Excellent for group discussion and making class aware of the social implications. They concluded there were many complex problems which previously they hadn't considered. One or two were reluctant to participate because they have a strong religious background.*

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3 Working in groups

Small-group work is a technique often suggested in SATIS units. Small groups encourage cooperative working, and they have the advantage that they are less threatening, and communication is more effective. There follows a list of questions which may be usefully considered before starting group work.

- Are the students familiar with group work? If not, they may find it strange at first.

- What is the best group size? Groups of five, four, three, or even pairs?
- How can the seating be arranged for most effective communication within groups, and least distraction of one group by another?
- Who goes in which group? Should friends work together?
- Is the group task quite clear? Will a worksheet be needed?
- Will each group tackle the same task? Or will there be different tasks for different groups?
- Does each group need an appointed chairperson? An appointed secretary? Are any other specific roles needed?
- To what extent should the teacher intervene in the work of a group?
- Will the groups report their findings to the whole class? If so, how?

Reporting-back sessions are sometimes unsatisfactory because students are not always good at making a concise summary, and often they tend to address their remarks to the teacher, rather than the class a whole. There are a number of alternatives to formal reporting-back. For example, groups can summarize their findings on a poster. Or the discussion can be developed by bringing small groups together into progressively larger units until finally two large groups present their ideas in front of the teacher.

A teacher in a comprehensive school in Northern England, reporting on *The Limestone Inquiry:*

> *Their reaction varied from great enthusiasm, to worry at having to speak in front of others, to disinterest in a few cases.*

And a teacher in an independent school in Southern England, reporting on *Nuclear Power:*

They appeared to enjoy it, though at first a little unnerved by the group work — and this in itself made the exercise worthwhile.

4 Role-play

Why use role play?

A number of SATIS units (for example, *Dam Problems, The Coal Mine Project, The Limestone Inquiry, Should we Build a Fallout Shelter?)* are role-plays. This technique is relatively uncommon in science, but teachers in other areas have found it has a number of advantages:

- It is a useful way of simulating real-life decisions and situations.
- It can be used to make sure that differing, and sometimes conflicting, points of view are presented in a balanced way.
- It is effective because it involves active, not passive, learning.
- It provides an opportunity to practise oral skills and to develop qualities not normally recognized in science lessons.
- It can help improve students' confidence, and encourage cooperative working.
- It increases students' involvement and interest, and can be great fun.

A teacher in a Northern comprehensive, commenting on *The Limestone Inquiry:*

The class are all sure they will remember the uses and issues concerning limestone. 'We'll always remember this lesson 'cos we could shout at each other!'

Points to consider when using role-plays

SATIS role-plays are fairly tightly structured, with suggested procedure in the Teachers' Notes. The following points may be of more general use when using role-play, and they may be useful for teachers who decide to create their own role-plays:

- The procedure should be clearly explained before the exercise begins. Make sure the class are familiar with the scientific background to the topic.
- The layout of the room is crucial. In particular, everyone should be able to see everyone else.
- The roles should be carefully balanced to represent the different opinions. Role cards should be used to outline the roles (SATIS role-plays have ready-produced role details).
- Students need to be carefully selected for the role they will play, depending on personality, ability and social groupings. If there is to be a chairperson or other leading role, this will need to be played by a strong personality. In some cases it may be necessary for the teacher to play the chairing role.
- It is often a good idea to have at least two students per role. This helps their confidence and is an insurance against absenteeism. The students can divide the speech between them.
- Make sure students have enough time to prepare and rehearse their roles.
- Allow students to elaborate their roles. Encourage them to do research.
- Props can be used — students can wear hats, etc. Name-tags can be useful.

- There should be a maximum time for each speech. Two or three minutes is usually plenty. Many students perform better if they write out their speech beforehand.

- It is useful if participants are questioned straight after their speech. The teacher may have to prompt questions, but should take care to avoid dominating.

- **Follow-up work is essential.** Let the class discuss the issue out of role, and say how they felt the exercise went. A summary by the teacher at the end is useful.

A teacher in a comprehensive school in Southern England, reporting on *Should we Build a Fallout Shelter?*:

> *I was not able to anticipate their reaction to a role-play exercise, as 'physics' has not included such exercises before. It was very easy and successful, largely I believe because of careful choice of expert witnesses. I gave the roles to pairs of students, who were also close friends. This seemed to give them confidence, and the class enjoyed the empathy and interaction between them. We benefited from an excellent Mayoress, played by a girl who tends to be apathetic in physics lessons, but revelled in the opportunity to use her talents. She kept things moving and allowed each expert witness to be questioned for five minutes.*

Where can role-plays go wrong?

Teachers using role-plays for the first time are sometimes alarmed that things seem to be getting out of control, particularly where a student is chairing and the teacher is trying to play a spectator role. Try not to intervene if possible: the noisiest role-plays often prove to be surprisingly productive. Nevertheless, intervention may be unavoidable with some groups: quite apart from control, less able students may need help with preparing their role and thinking of questions to ask.

Difficulties can arise when students run out of information. The notes on role cards are necessarily limited, and students' lack of background knowledge can easily be exposed by a probing question. Having two students per role can help in this connection.

A related problem is that students may have difficulty assimilating all the information on the role card and other briefing sheets. This underlines the importance of allowing plenty of preparation time.

A head of science in a selective school near London, commenting on *The Coal Mine Project:*

> *Despite a good Chairperson it got pretty noisy, and one or two colleagues looked round the door to see what was happening. Nevertheless, it was clear from follow-up work several days later that they had learned a lot from the exercise. 'It helped you to see both sides'.*

And a teacher in a girls' comprehensive school in London, commenting on *The Limestone Inquiry,* used with class of 13-year-olds:

> *At the level used, students found it hard to conceptualize large amounts of information. They were able to pick out isolated points but found it hard to develop them into reasoned arguments. They tended to concentrate on one piece of information and bring their own experiences to bear on it.*

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5 Problem-solving activities

There is some debate and uncertainty about what problem-solving actually means. Solving problems is a common activity in science: textbooks and examination papers are full of problems which students are expected to solve. But these are usually 'closed problems', in which the goal of the problem, and the route to that goal, are made clear. In 'open' problem-solving the general *goal* of the problem is clear, but there is no single, right answer, and the path to the answer is not clear.

Open problem-solving can be a valuable and rewarding activity in science. It reflects the way real-life problems are solved, and it can be very motivating.

SATIS includes a number of problem-solving activities, some closed and some open. For example, in *How would you Survive?*, the goal is survival in the Arctic. The boundary conditions are defined by listing the resources available, but there are any number of possible solutions. Only outline guidance is given on how to tackle the problem.

Most of the open problems in SATIS are of the pencil-and-paper type, though one or two practical problems are included (for example, designing a bridge in *Bridges*, building a biogas digestor in *Energy from Biomass*). Teachers of technology will be familiar with practical problem-solving work: it is after all the essence of the technological process. (See part 7 for more on this type of work.)

Problems with problem-solving

A major difficulty is that open problems, particularly the practical type, can be time-consuming, though the time is usually well spent in terms of the motivation generated. Time is needed for students to plan and discuss solutions and put them into practice. Once again, working in groups is a very effective approach, reflecting the team approach of real-life design tasks.

Students who are unused to the problem-solving approach may find it a little difficult to come to terms with at first. They may tend to demand more information and help, and may need reminding that there is no single, right answer. This difficulty is less likely to arise in schools where students are introduced to open problems from an early stage.

6 Reading activities

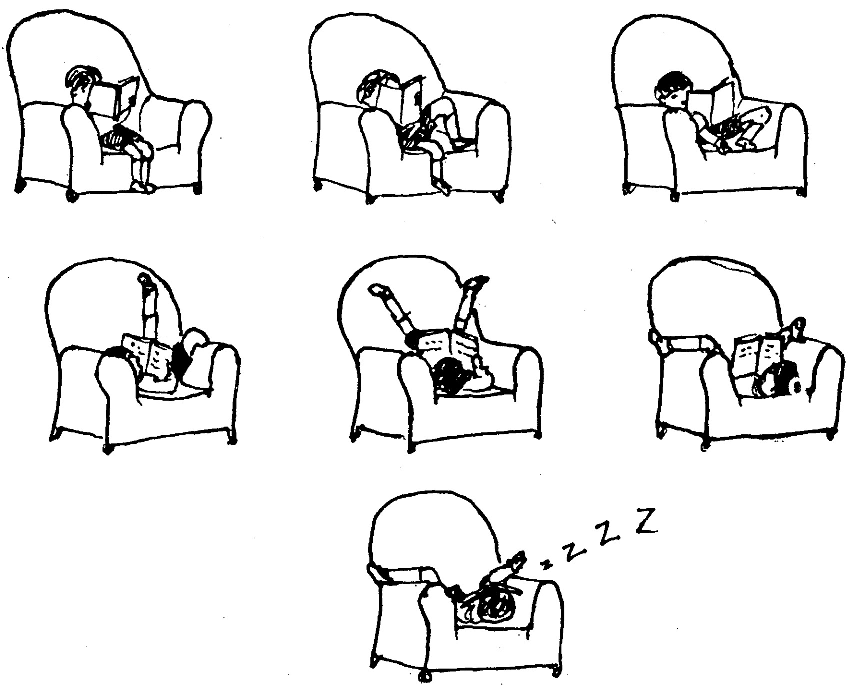
Science is a practical subject, and for this and other reasons, reading is not such a common activity as it is in other subjects. Reading in science lessons tends to be in fairly short bursts, and when more sustained reading is required it is often set for homework.

Teaching the social aspects of science tends to increase the emphasis on reading. Written material is needed to establish the social context even when the material involved is of an active rather than a passive type. For example, a role-play requires a certain amount of preparatory reading.

SATIS trial teachers sometimes commented on the problems caused by the reading requirements, particularly with less able students. In some cases, teachers felt it necessary to rewrite certain passages in a simpler way for the benefit of such students.

Activity-based reading

One way round reading difficulties is to build some kind of activity into the reading, to aid concentration and understanding. The idea of active



reading and DARTS (Directed Activity Related to Text) is developed extensively in *Reading for Learning in the Sciences* (see Section 5), from which many of the ideas in this part are taken.

Some suggested activities

- Underlining the text

While they are reading, students try to pick out the most important parts of a text and underline them. An interesting extension of this is for students to underline on an overhead projector transparency placed over the text. The results of different groups of students can then be compared.

- Completing a diagram or table

This activity involves summarizing information in the form of a table or diagram. The headings to the columns of the table, or a partially completed diagram, should be provided by the teacher. For example, in *Perkin's Mauve* students could draw up a time chart showing the development of dyes.

- Glossary of terms or words

Students are given a list of terms or words that arise in the text, and are asked to write down a brief summary of what they mean.

Alternatively the students can be asked to read the text and write down the terms which they see as being the most important.

For example, *Fibre Optics and Telecommunications* includes a number of technical terms: students could be asked to write down these terms, with an explanation of each.

- Sequencing

This activity takes up more preparation time than the others, but it can be particularly useful where a number of logical sequences need to be understood. It involves preparing a photocopy of the text, with sentences or paragraphs jumbled in the wrong order. Each part is labelled with a letter. Students are asked to reassemble the text into what they think is the best sequence.

The box below shows an example taken from *Looking at Motor Oil.*

These sentences describe the problem of designing a good motor oil. The sentences have been jumbled up. Rearrange them in the right order.

A Any change in viscosity affects the way oil behaves and how it lubricates the engine's moving parts.

B To overcome the problem of the wide range of temperatures in which oil has to work, scientists have developed special oils called multigrade oils.

C One of the main jobs of motor oil is to *lubricate* the pistons so they move smoothly.

D For good lubrication, the oil must have the right *viscosity* (thickness).

E Motor oil gets thinner (less viscous) at higher temperatures but oil must work at a wide range of temperatures.

F In a car engine, pistons move up and down inside cylinders.

(The sequence in the unit is F C D E A B)

• Editing the text for a different readership

Students sum up the text using ideas and language that would appeal to a particular type of audience.

For example, when using the *Noise* unit, they could prepare an information sheet with ten questions and answers, suitable to give to concerned parents. Or, when using *Fluoridation of Water Supplies*, they could write a short illustrated leaflet for 7-year-olds, explaining why they should use fluoride toothpaste.

- Making a flow chart

Some sections of reading put forward a series of ideas which students can identify by underlining or text marking. The development of ideas can then be represented by drawing up a flow chart. For example, in *Robots at Work*, students could draw up a flow diagram to summarize the way robots function.

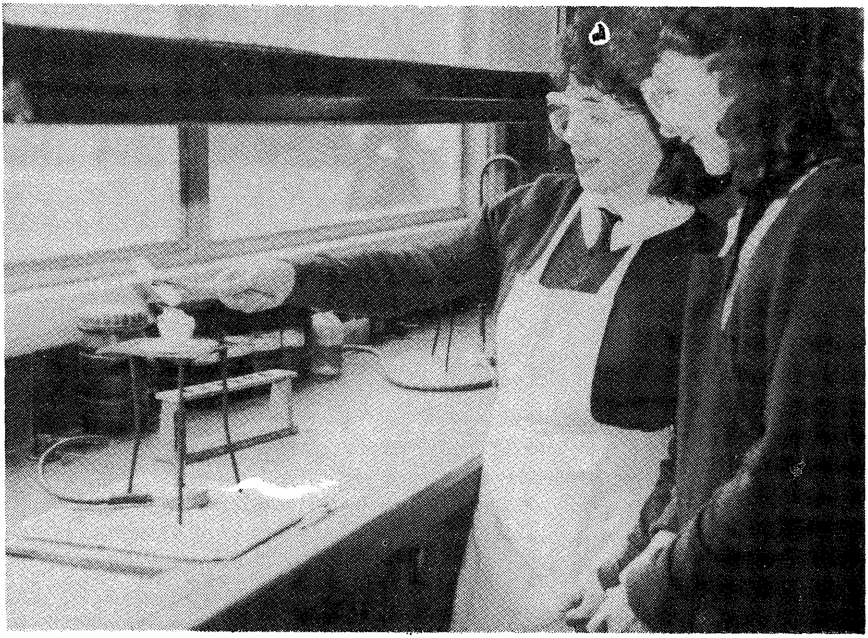
- Analysing the argument

Students attempt to list the pros and cons relating to a particular issue as they read the text. This type of activity is perhaps less necessary for SATIS units, where the cases for and against tend to be presented in a fairly structured fashion anyway. But it is a useful technique to use with other printed material such as newspaper extracts.

7 Practical work in SATIS

Practical work is of course central to science, but it is not necessarily appropriate to achieving all the aims of science education, and this is particularly true of a number of the aims of SATIS. Understanding of the interactions between science, technology and society is often best achieved by talking, listening and discussing as much as by experimenting. It was always felt that one of the important contributions that SATIS could make was to widen the range of activities involved in science lessons beyond the commonly encountered practical-based lesson.

Nevertheless, many of the everyday aspects of science lend themselves well to practical work, and a number of SATIS units do include experiments. In



Making Sulphurcrete

a number of cases there are suggestions for extension practical work in the Teachers' Notes. The investigational, open-ended, problem-solving type of practical work is particularly appropriate in this area: looking for practical solutions to real-life problems.

Devise your own investigations

There is plenty of scope for teachers to develop their own practical work of the SATIS type. The table below gives a few suggestions for investigations linked to specific SATIS units.

SATIS Unit	*Related investigation*
Controlling Rust	Comparing the effectiveness of different rust prevention methods
How Safe is your Car?	Investigating the most suitable material for brake pads
Physics and Cooking	Investigating the best ingredients and conditions for making good gravy (or custard, or soup)
Sulphurcrete	Investigating the factors affecting the strength of ordinary concrete
The Label at the Back	Comparing the strength, water absorption, etc., of different fibres
Noise	Finding out which types of sound are considered most unpleasant by human subjects
What is Biotechnology?	Comparing the effectiveness of enzyme washing powders and ordinary powders
Which Anti-acid?	Investigating 'sparkling' anti-acid products

There are also, of course, many opportunities for developing practical investigations in areas not covered by SATIS. Ideas for starting-points can be found in *Ideas for Egg Races* and a number of publications of the Secondary Science Curriculum Review (see Section 5).

The whole question of practical work is covered well in *Practical Work in Science* (see Section 5).

Science and the consumer

There are opportunities in science lessons to develop both consumer awareness and appreciation of the problems of manufacturers. Manufacturers provide a vast range of products, but are we, as consumers, always given good value? Why do apparently similar articles have different prices? Do the products justify the claims of their advertisers?

Science education should encourage attitudes of open-mindedness, rational thinking and willingness to put things to the test. This principle is certainly needed in a market-economy, where consumers have choice and face competitive advertising. It should also help us appreciate that manufacturing and retailing do incur costs and perhaps give some indication of what may be a 'fair price'.

The SATIS unit *Which Anti-acid?* illustrates some of these ideas. It involves comparisons of anti-acid formulations based on their prices and packaging, and practical work to compare their effectiveness. The same approach could be used with many familiar products — for example, toothpastes, margarines, electric plugs, paper towels, batteries, iron tablets. Students can undertake comparisons and practical tests of 'value-for-money' and of the claims of advertising. An interesting follow-up could be the task of making their own versions of the product, costing their process and comparing with the commercial variety.

Section 3 Beyond SATIS: Further ways of making the science curriculum more relevant

1 Write your own units

By nature, a nationally-published project like SATIS has considerable limitations. Its coverage of the many applications of science and technology must inevitably be restricted. Science and technology develop fast: interesting new applications and issues constantly arise, and what is already written can quickly become out of date. In any case, what is of interest in one part of Britain may be less so elsewhere.

It is individual teachers in individual schools who are in the strongest position to judge what is appropriate for their class, and to take advantage of local applications and topical issues. SATIS units are intended to be adapted and modified to individual needs, and of course there are many opportunities for writing one's own, home-produced units. A role-play based on a local news story; data analysis using local statistics; a simulation based on a local industry: there are many possibilities. And home-produced materials do not have to be extensive: there is much to recommend short activities occupying a single period or less.

The approach does not have to involve the SATIS format. There are many other ways of bringing science closer to the outside world, and in the following parts of this section some of these are considered.

2 Visits

Outside visits can be a very successful way of showing students the applications of science in the real world.

Remember science is everywhere

Visits do not have to be restricted to the obvious, spectacular places like steelworks and power stations. The applications of science are to be found in all sorts of apparently unpromising places. Of course, if you are fortunate enough to a have a steelworks or a power station nearby, do not miss the opportunity of visiting it. But there is plenty of science to be seen in ordinary places. For example, why not visit:

- The local fire station — to link with work on fuels and combustion.
- The local sewage works — to link with work on micro-organisms.
- A supermarket — go behind the scenes and see how they package the food — to fit in with work on food and food preservation.
- A hospital, when doing work on disease.
- A quarry — to link with work on limestone or other minerals.
- A farm — to link with all sorts of work in biology.
- An MOT testing station — to link with work on motion.
- Practically any local factory or works — there is bound to be some interesting application of science to see. For example, a bakery gives a good illustration of yeast, fermentation, hygiene and food in general.

The following quotation illustrates how a middle school teacher in the Midlands used a visit to a local tannery to link with science work with 11- and 12-year-olds.

> *I chose to link the work they had covered on acids and alkalis, and the following section on purity (dyeing with natural vegetable dyes), with a visit to the tannery.*
>
> *The children were allowed into the tannery laboratory where they made a list of the various indicators used and compared them with ones they had used at school. Then*

they saw the application of the preservative properties of sodium chloride (curing), and acids (pickling), of alkalis (liming) and of chromium salts (tanning) within the main works. They could 'see' neutralisation taking place when the hides were transferred from alkali to acid. Other important concepts were safety awareness — the revolving drums of acid and alkali were locked in cages — and the economics of stretching leather to sell by area.

On returning to school the children followed up the visit by dyeing small pieces of cotton with extracts of bark, moss, onion, coffee, etc. Perhaps we might have been more ambitious and tried dyeing a sheepskin, or tanning a chicken or fish skin. Display work included a flow-chart of the process, with samples of leather collected and samples from dyeing experiments.

(From *Rethinking Science,* an ASE Occasional Paper)

Successful visits: be prepared!

The following points are intended to help teachers make the most of visits.

- **Make preparations well in advance.**

- Brief the students carefully. Wherever possible, the teacher should have made a prior visit, so that he or she is familiar with the layout of the place to be visited. A prior visit also enables the teacher to structure the visit, draw up worksheets and identify those features which will be relevant to work being covered. Students need to have a general idea of what the company does, how the place is arranged and what to look out for. This kind of briefing needs to be given in class, well ahead of the visit, even though a briefing will probably be given at the beginning of the visit itself. Worksheets can be very useful, but try to leave students plenty of scope for framing and asking their own questions.

- Brief the company carefully. Unless they are very experienced, the people acting as guides will have little idea of the appropriate level at which to pitch their information. In any case, they will need to know how the visit fits in with the rest of the students' work, how much prior knowledge to assume and so on.

- Be prepared for a certain amount of disruption. A visit can rarely be fitted conveniently into a science lesson, so negotiations with colleagues may be necessary. Some companies may not be able to accommodate an entire class, so it may be necessary to split the group.

- The visit should not be an isolated event, but should be integrated with preceding and following work in school.

- It helps if the subject of the visit is already familiar to students. Thus a factory making clothes, food or bicycles may be more interesting, particularly to young students, than a large, complex chemical works.

- Many factories are noisy and in any case the guide may present information at too high a level, or give too much technical detail. In such situations it may be necessary for the teacher to make tactful interjections or ask well-chosen questions.

- Follow-up work greatly enhances the value of the visit. This might consist of discussion, worksheets, or perhaps a visit by someone from the company to talk to the students.

- If, following all this, the visit is not a success, review the arrangements to see if they could be improved the following year.

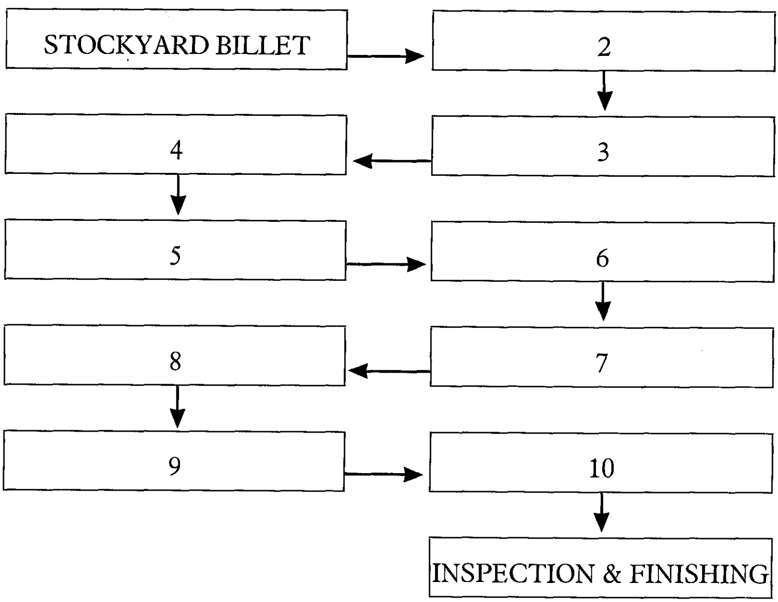
The worksheet below was produced by a teacher in a Midlands comprehensive school, for use in conjunction with a visit to a metal tube manufacturer. Note its potential for enabling students across the ability range to make sense of a complex industrial process.

Metal tube making at Seamless Tubes Ltd

Flowchart to show how the billet is turned into a steel tube by the hot stretching process

Here is a list of the different operations carried out during this process. The list is *not* in the right order. PIERCING; REHEATING (walking beam furnace); CUTTING; COOLING; STRETCHING (reducing mill); BILLET CENTRING; HYDRAULIC DESCALING; STRETCHING (mandrel mill); HEATING (rotary hearth furnace).

Write down each of the operations in the correct order on the flowchart.



3 Linking with industry

A permanent link between a school and a local industry can be of great value. The opportunities offered are much wider than visits alone. A local industry can provide visiting speakers and can cooperate in the development of curriculum materials such as case studies, simulations and practical exercises. Contact with industry enables teachers to familiarize and update themselves on industrial practices. In many cases, local industries may be able to make donations of equipment and materials. Beyond the science curriculum, there are also the wider benefits which stem from contact with a local employer.

Forging the initial link is of course the most difficult part. Most science teachers have found that a direct approach is best, but it is important to approach the right person in the right manner. *Go to the top: approach the person who is responsible for running the site you are interested in.* You can find out who this person is by telephoning the company switchboard. Make your initial approach by letter and be specific in the letter about what you want, and the commitment this will involve on the part of the company. It is a good idea to follow up your letter with a phone call, to show you mean business.

If the direct approach proves difficult, your local education authority may be able to help. The LEA may have a Schools-Industry Liaison Officer (SILO) who can advise you. Or you could try your local Science and Technology Regional Organization (SATRO) — the LEA will be able to tell you where this is.

These direct and local approaches are likely to be most effective, but a number of central organizations do exist to encourage schools–industry links. A directory to these organizations can be obtained from the Department of Education and Science (see Section 5 for details).

The following quotation, from a chemistry teacher in a West Midlands comprehensive, is an example of an initial contact leading to fruitful liaison.

> *At our school we are fortunate to have a metallurgical company close by. Local residents do not have quite the same enthusiasm for the company, which they normally associate with atmospheric pollution and unpleasant smells. In fact, it was through a project on environmental pollution around the school by a sixth-form biology group that the initial contact with the company was made. The biologists were invited to look round the plant, and the Company were very willing to discuss the problem openly with students.*
>
> *Following this initial contact, my own contact was with the Company's Technical Director — in my experience it is best to make initial contact at the top: a director has a great deal of influence and can open many doors. A colleague and I were shown round the plant, and we soon realized that there was the basis for an excellent curriculum development project involving a wide range of our chemistry courses. We invited the Technical Director to join our project — this turned out to be a wise move as it provided expertise and ensured the company's commitment.*
>
> *From this initial partnership developed a project which culminated in a programme of industry-related practical work for O level and CSE Chemistry courses. We were fortunate in that I obtained secondment to work for ten days in the plant, and this enabled us to achieve a great deal. There were problems — for example, getting the company chemists to come down to the level of 14- to 16-year-old pupils. But the benefits, in terms of the materials developed and the liaison made, were very considerable.*

4 Visitors

Bringing in outside visitors to speak to the class is another excellent way of helping show the place of science in the real world. Some companies and institutions of higher education offer a visiting speaker service. But visitors do not need to be particularly distinguished — in fact, the more the students can relate to the visitor, the better. For example, you could invite:

- A nurse or doctor, to link with many aspects of work in biology (for example, the heart or lungs, treatment of disease, etc.)
- A hospital radiographer, to link with work on radiation.
- A police officer, to talk about scientific methods of detection.
- Other members of staff, to talk about their hobbies or interests: for example, a keen home wine-maker to link with work on fermentation, or a beekeeper, or an ornithologist.
- The school canteen supervisor, to link with work on food and nutrition.
- A manager, trade union representative or other worker from a local industrial company, perhaps to precede or follow up a visit.
- An electrician, to link with work on domestic electricity.
- A local Environmental Health Officer, for example, to talk about hygiene in catering establishments.
- A local farmer, to link with work on agriculture.
- A civil engineer, for example, to talk about bridges to link with work on forces.
- A public analyst, to link with work on analytical chemistry.
- A family planning adviser, to link with work on reproduction.
- A photographer, to link with work on optics.

There are many more possibilities. The visitor will of course need to be carefully briefed on what is required, and especially on the appropriate level. The main danger is that the level will be pitched too high, and that excessively technical language will be used. If necessary, the teacher may need to make tactful interjections.

Involve the students

The more involved the class is in planning and running the occasion, the better. Ask students for ideas on whom to invite — it is surprising how many contacts there are in the families of a class. Where possible, involve students in meeting the visitor, introducing the visitor at the beginning and thanking him or her afterwards. This can be an occasion when otherwise unexceptional students show surprising social skills.

Try to keep the occasion informal, with a minimum of lecturing and lots of questions from the students. Talk to the class about it beforehand. What do we want to know from the visitor? What questions can we ask? Remember to build in follow-up work to make full use of the occasion.

5 Using the media — television, newspapers and magazines

Media coverage of science-related news is often thin and sometimes inaccurate. Nevertheless, the media can be fruitful for the alert science teacher.

Television

Keep an eye on the programme schedules, particularly for the science programmes. Watching the programme can be a homework assignment, with discussion in class the following day. Be opportunistic too: encourage students to talk about programmes with scientific content they have seen the night before. Even if the subject matter is a bit off the syllabus, it is worth spending a few minutes on it to encourage interest.

Newspapers and magazines

Once again, there is plenty of scope for the opportunistic teacher. If there is a science-based story in the headlines, encourage students to bring in newspaper cuttings.

Some other interesting and stimulating activities:

- Compare the coverage of the same science-based story in different newspapers.

Radiation cloud reaches Britain

By David Fairhall and from Michael White and Mark Tran in Washington

The radioactive cloud from the Soviet nuclear disaster reached Britain yesterday. But the National Radiological Protection Board described the contamination level as very low and the Department of Health said it posed no health risk to the public.

The Guardian, 3 May 1986

Red nuke dust is here

By LESLIE TOULSON

THE CLOUD of radio-activity released by the Russian nuclear plant disaster at Chernobyl hit Britain yesterday.

Scientists have detected traces of radioactive iodine in the air and expect readings to increase—but not to danger level.

The Sun, 3 May 1986

- Bring in a selection of newspapers on any day and ask the students to look for stories and articles with a science content.
- Ask students to rewrite a particular news story to make it suitable for young children (a particularly good activity with scientific magazines like *New Scientist*).
- Get students to take home science-based newspaper articles and talk about them with their family.

But it isn't on the syllabus!

Discussion of topical news stories can be interesting and motivating, and is usually worth the time spent, even if the content is a little unrelated to work presently being covered. But even so, some teachers may feel they cannot spare the time for these kind of activities unless the subject matter relates to the syllabus they are following. In this case, you can always get students to make collections of newspaper and magazine cuttings relating to the subject area being studied. For example, they could collect:

- Cuttings about energy saving — advertisements and news stories.
- Articles about smoking, to link with work on respiration.
- Stories about air pollution or acid rain, to link with work on air or acids.
- Advertisements for electrical appliances, which can then be classified into categories (heating, lighting, motors, etc.)
- Advertisements which appeal to different senses (sight, smell, hearing, etc.), to link with work on senses in biology.

6 Making the most of audio-visual material

There is abundant material available on film and video which helps relate science to the world outside. Much of this material is commercially sponsored (for example, films on energy topics from oil companies, films on electricity generation from the Central Electricity Generating Board), and is available on free loan. The quality and age of the films varies widely: some of the ones found useful by teachers are identified in the Teachers' Notes accompanying some of the relevant SATIS units.

Moving pictures in darkened rooms

Sitting and watching a film or video is a very passive business. Its educational value can be small unless some steps are taken to make the occasion more active on the part of the students. The following points suggest some ways students can be encouraged to interact with the film:

- Stop the film at key points and ask students questions.
- Give students a worksheet or list of questions beforehand, to answer during or after the film. This of course requires the teacher to have viewed the film first.
- Tell the students they are to write a review of the film straight after it has finished. They could be asked to comment on its effectiveness, whether its presentation is biased, and so on.

Home-made slide sets

A useful technique is to produce your own set of slides based on the immediate locality, thus bringing the outside world into the classroom. It can also encourage boys and girls to take a fresh look at things they take for granted day by day. Slide sets of this kind are particularly useful when introducing a new topic. This technique is incorporated in the SATIS unit *Bridges,* but it is widely applicable. The following are examples of slide sets that could be usefully put together:

- *Plastics in use:* a slide set to show uses in buildings, homes, schools, etc. The examples could be chosen to illustrate advantages and disadvantages. The table below gives some examples.
- *Corrosion in action:* rusty cars, railings, bike sheds, etc. 'Corrosion' could be extended to include stonework.
- *Magnets in use* (compass, door catch, motor, magnetic blackboard, etc.).
- *Simple machines* (wheelbarrow, scissors, crowbar, tin opener, screwdriver, nutcrackers, etc., being used by people known to the class).
- *Gardeners' world,* showing aspects of horticulture which relate to scientific principles (use of fertilizer, pesticides, irrigation, etc.).
- *The variety of life:* pictures of plants and animals around the school.

The following table could be used in conjunction with a home-made slide set on 'Plastics in use'. The table could be filled in by the students themselves.

Subject illustrated on slide	*Name of plastic (if known)*	*Useful properties shown*	*Limitations/ problems shown*
1 Washing-up bottle in prep. room or canteen	Low density polythene	Flexible, waterproof, not attacked by chemicals	

	Subject illustrated on slide	*Name of plastic (if known)*	*Useful properties shown*	*Limitations/ problems shown*
2	Plastic drainpipe	Rigid pvc	No corrosion, strong in relation to weight	May slowly become brittle in sunlight
3	Table tennis balls in action	Cellulose nitrate	Light and strong	Easily crushed, highly flammable
4	Insulated wires, e.g. in physics lab.	Plasticized pvc	Electrical insulator, flexible, easily coloured	Insulation melts if overheated
5	Yoghurt pots and disposable cups	Polystyrene	Cheap, strong in relation to weight, easily formed, heat insulator	Disposable, wastefulness of non-reusable products
6a	Plastic bucket used by caretaker or cleaner	Polypropene	Light and strong, does not dent	May become brittle with age
6b	Galvanized steel bucket			
7	Car rear light in staff car park, e.g. notorious old banger	Acrylic (perspex)	Transparent, non-brittle	Easily scratched
8	Clothing, e.g. school tie on unusually smart young pupil	Polyester	Easily coloured, can be spun into fibres	Feels less appealing than natural fibres

Slides may be more interesting if they include people well known to the class. The production of a slide set can be an interesting project for a keen photographer or for members of a photography club.

It is a good idea to provide some simple activity for the pupils, to focus their attention and hold their interest while viewing the slides. In the *Plastics in use* example, this could consist of filling in an empty version of the table above.

7 Science trails

Many families happily spend Sunday afternoons tramping around a Nature Trail: a delineated route through the countryside, usually with an accompanying written guide. The approach is readily extended beyond nature study to science education in general, using the school's immediate environment, whether urban or rural. Science trails are effective because they use students' own local environment as a teaching aid: the chemistry of the street where they live, or the physics of the building where they learn.

A school science trail can have an accompanying leaflet or worksheet, like a public nature trail. This could be a fairly ambitious affair, with a page on each point of interest, or a more modest list of points and questions. Its production could be a collaborative exercise involving several members of the science department: a quick brainstorming session can generate plenty of initial ideas. Another possibility is to get students to create their own science trail as a project.

The trail can of course be made specific to a particular subject area: chemistry trails (see below), physics trails and biology trails are all possible.

One example: a chemistry trail

The following points are taken from a chemistry trail developed at Pimlico School, London. The trail is more extensively documented in the December 1984 edition of *The School Science Review*. It illustrates very well the scope of chemical change that can be observed in most environments.

• Concrete

Most schools should be able to find examples of concrete or cement nearby. Although the chemistry of cement is complex, some interesting simple chemistry can be developed from it. For example, rain water tends to leach calcium hydroxide out of concrete, resulting in an alkaline solution (pH 10 at Pimlico School). Exposed to air, this solution reacts with carbon dioxide, forming calcium carbonate stalactites. It is not difficult to spot these small stalactites growing down below concrete bridges and archways. Because of its basic nature, concrete is able to neutralize acid rain and thus provide a good environment for the growth of algae and lichens which might not otherwise survive. Such growth on concrete surfaces can be contrasted with the lack of growth on non-basic building materials like brick.

• Other building materials

Limestone, *marble* and *chalk* are quite common building materials, and on older buildings you can sometimes see the effect of acid rain, in the form of erosion and a dirty surface deposit of calcium sulphate. *Sandstone* consists of grains of silica cemented together with calcium carbonate, and is particularly susceptible to attack by acid rain. The familiar red colour of *brick* is due to iron(III) oxide, but blue-grey engineering bricks are fired under reducing conditions, resulting in iron(II) instead of iron(III). Porous brick often shows signs of frost damage, caused by water which penetrates into the pores and expands on freezing. Non-porous materials like *granite* show no evidence of such damage.

• Pollution

Air pollution is regularly monitored in many places by local authorities, who will often supply the figures to schools. These figures are given impact when they are related to the visible effects of pollution: blackened buildings, perhaps partly washed clean by an overflowing gutter, or the crumbling limestone or sandstone of a church attacked by acid rain.

• Corrosion

There are plenty of examples of corrosion, particularly rusting, in the environment of any school. Look out for places where corrosion is

Looking for corrosion — just one aspect of a science trail

particularly bad: scratched paintwork, say, or partially-buried pipes. Look out for corrosion prevention too: galvanizing, painting, plastic coating and sacrificial anodes. Non-ferrous metals also corrode: observe the familiar green patina of corroded copper on roofs, lightning conductors and even the pipework in public conveniences.

- Swimming pools

There is a surprising amount of chemistry involved in swimming pools. The presence of chlorine in the water lowers the pH, and this is compensated for by adding sodium carbonate. The pH is monitored using a suitable indicator such as phenol red, having first added a little sodium thiosulphate to the water to remove free chlorine.

- Other points on the trail

Look out for different types of plastics: what are they used for, and why? Paints and pigments are another useful theme. Apart from their obvious use on walls and doors, what about the yellow lines on roads (lead(II) chromate(VI))? And there are the materials from which streets themselves are constructed. What is asphalt? Where does the cinder used in the car park come from? Then there are the stained glass windows in the local church, and the Bottle Bank skips for different colour bottles. Not to mention sodium, mercury and neon lights, and the changing colour of leaf pigments in autumn . . .

Trails in other sciences

The idea of trails originated in the biological field, and their value in ecological studies is obvious. Once again, urban environments have much to show as well as rural ones. Physics trails may appear more difficult, but what about noise and reverberation times in different parts of the school, and the greenhouse effect of large classroom windows? Look for the lightning conductors on local churches, the application of optics in the cat's eyes down the road — and do not forget the local playground or fairground.

Using science trails

Once the trail has been established, there are several ways it can be used. The whole class can follow the trail from beginning to end, though this can be time-consuming and perhaps disruptive. Another possibility is to go round in pairs. Alternatively, just take the class out briefly at an appropriate time, to visit points on the trail directly relevant to work being covered. For example, when talking about crystals, why not go out and look at the giant crystals to be found in granite kerbstones?

8 More ideas

There are many other techniques and activities that can be very effective in getting students to participate actively. These alternative approaches have the advantage that they give students opportunities to practise skills and show qualities that are not always encouraged by conventional science lessons — for example, debating skills, acting ability, creative thinking and draughtsmanship. In this way, a greater proportion of students can feel they are contributing and achieving something positive in their science lessons.

A number of the techniques described will be familiar to teachers of other subjects, but may be less well known to science teachers. There is only space here to give a brief outline of each technique.

Brainstorming

The value of brainstorming is that it can generate a large number of ideas about a topic in a short time. The ideas can then form the starting-point for discussion. For example, a brainstorm could be used to generate ideas for 'Uses of levers in the home' or 'How can we solve the problem of world food supply?'.

The most important principle of brainstorming is **never to reject any contribution**, no matter how wild. In this way the least confident members of the group are encouraged to participate. Under the stimulus of brainstorming, students may have the most surprising and imaginative ideas. Each idea contributed must be recorded, preferably as a single key word. For this purpose it is important to have an empty board or large sheet of paper available.

Brainstorms may be followed up by **rounds**. Rounds give everyone an opportunity to express their opinion. Go round the class, to each person in turn, asking their opinion on the most important word generated in the brainstorm. Anyone may pass if they do not wish to express an opinion, and no one is allowed to criticize anyone else's opinion until the round is finished. Tick or underline the word each time it gets a 'vote'. In this way the most popular word can be identified, then perhaps discussed further.

Lecturettes

A lecturette is a short talk on a specific topic prepared and presented by students. The lecturette can be given by a single student, but it is probably better done in pairs or threes. For example, when covering air pollution, each lecturette could feature a specific pollutant gas, such as sulphur dioxide or carbon monoxide, its origin and effects. Similarly, in the treatment of alternative energy sources, each lecturette could describe a different alternative source, its advantages and limitations.

Give students plenty of time to prepare their lecturettes. Make it clear how long they will be expected to speak for (most students will find it difficult to manage more than five minutes). Do not allow interruptions while the lecturettes are being given, but invite questions at the end.

Debates

Formal debates can be an effective way of approaching some topics, especially where controversy is involved. This is particularly true in schools where students are familiar with the formalities of debating. Examples of questions for debate might include:

- Should spare embryos be used for research?
- Is money spent on heart transplant research wasted?
- Should Britain spend more money on alternative energy projects?

Allow plenty of time for students to prepare their cases. Encourage students in the 'audience' to prepare questions which they can ask from the 'floor'.

Mini-plays

A number of science topics lend themselves to setting in a short play. This technique can enliven the topic and give students a chance to show their acting skills. There are two good examples of mini-plays in Biology for the

Individual, Book 7, *War against Disease*, by Donald Reid and Philip Booth (Heinemann Educational Books). *The Plague at Eyam* re-enacts the true story of the bubonic plague in the village of Eyam, Derbyshire in 1665. *The Discovery of Vaccines* re-enacts Pasteur's discovery of a vaccine against anthrax.

The writing of a mini-play could be an activity for the whole class. Plays might be linked to the topics of SATIS units — for example, *the Tristan da Cunha Dental Surveys, Perkin's Mauve, Materials for Life* or *Test-tube Babies.*

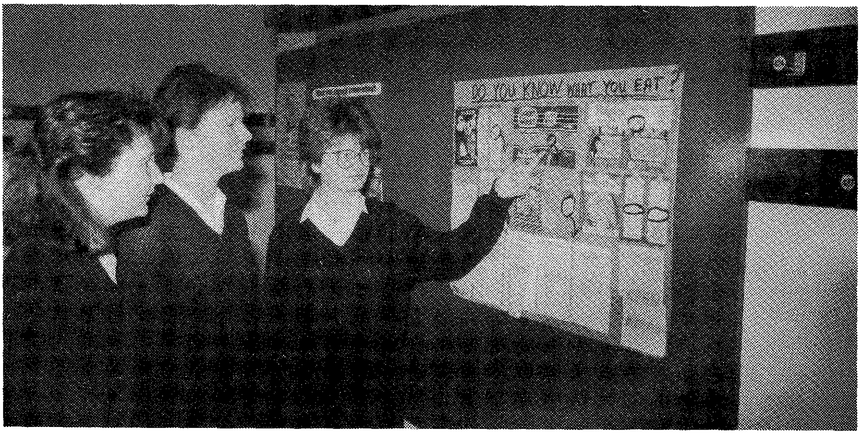
A variation on this approach is to record a 'radio programme'. Students imagine they are reporting or re-enacting an event for the local radio station. Writing the script, rehearsing, and recording the programme on cassette can be an absorbing and rewarding activity. More ambitiously, a video recording might be made.

Projects and in-depth studies

Projects are a fairly well-established activity in science. A written project assignment is a good way of getting students to look in detail at a particular scientific application or issue, and it also has the advantage that it encourages independence and resourcefulness on the part of the student. Give students plenty of time for the assignment, so they can collect newspaper and magazine articles, use libraries, write away to companies, and so on. Students will need regular advice, guidance and monitoring if they are to avoid the common pitfalls of leaving the assignment to the last minute, or copying out large passages from books.

Art work

Science students are commonly expected to present their ideas and findings in writing. Art work presentations make a change from this and provide an opportunity for students to practise artistic skills in the context of science.



Students working on What's in our Food? *produced this poster display*

An effective approach that has been used in conjunction with some SATIS units is to present ideas on a poster. For example, in *Food from Fungus,* students could design a poster advertising a novel food product. In the *Great Chunnel Debate,* they could design posters making the cases for and against building the Channel Tunnel. The approach can be extended beyond SATIS. For example, in chemistry, students could be asked to design posters explaining the causes and effects of hard water. In physics they could design a poster showing how to wire a 3-pin plug.

Opinion polls

Students could conduct interviews, within school or elsewhere, to assess people's opinions on an issue. This approach lends itself to a whole range of science-related issues, from nuclear power and traffic noise to acid rain and alternative medicine.

It is best if students design their own questionnaires, working in small groups. Before conducting the poll, the questions should be checked to ensure they are unbiased, and it is a good idea to have a practice run first. During the survey, information can be recorded on paper or using a cassette recorder. Once collected, the raw data could be converted into a visual form (bar charts, etc.) which could be the basis of discussion.

Section 4 Assessment

This section is mainly concerned with assessment of social and technological aspects at the end of a course, particularly in public examinations. However, many of the remarks also apply to assessment carried out by teachers at different stages while the science course is in progress. It is particularly concerned with the assessment of *social* aspects, since this is the more novel, and possibly problematical, area.

1 Why assess social and technological aspects?

There has been much debate over how appropriate, and indeed possible, it is to assess the social and technological areas of GCSE science curricula. On one hand we have the arguments in favour:

- If social and technological aspects are considered worthy of inclusion in the syllabus, they should also be considered worthy of assessment as part of the syllabus.

- If these aspects are not assessed, there is a real chance that they will not be taught at all, particularly when teachers find themselves hard-pressed for time.

- Assessing these aspects broadens the range of skills and qualities assessed in science. For example, it provides an opportunity to assess the ability to evaluate an argument, and a wide range of communication skills.

On the other hand there are a number of problems. Some would say it is inappropriate to assess knowledge and understanding of the social issues of science, pointing to the danger of science courses becoming politicized, and the possibility that candidates might be able to gain credit in a science examination by showing knowledge and understanding of society, but not of science.

Another problem concerns content: should the assessable syllabus include specific, defined social and technological content? If it does, it may remove from teachers the freedom to cover local and topical issues. If it does not, the assessment of these aspects becomes more difficult because it cannot be based on specifics: it has to relate to more generalized attitudes and awareness.

A third problem relates to assessment techniques: what are the most effective assessment techniques for this relatively new area? This question is addressed further below.

Despite these problems, the desirability of assessing social and technological aspects in public examinations has been recognized in the National Criteria for GCSE sciences, which specify that substantial proportions of GCSE science syllabuses should deal with this area.

2 What are the appropriate assessment techniques?

How can we test students' attitudes and critical awareness of the interactions of science with society? Recall of knowledge is not enough: we are also interested in students' ability to understand, explain, evaluate and show awareness of these aspects. This is a relatively new field, in which science teachers have little experience: much imaginative work needs to be done on assessment techniques.

Despite these reservations, some suggestions follow for assessment techniques that may be appropriate.

Written assessment — examination questions

The following types of questions lend themselves to the assessment of this area.

- Structured questions

Structured questions may be based on a brief introductory passage setting the social or technological context for the question. This type of question was developed to a valuable extent in the examinations of the Schools Council Integrated Science Project (SCISP). Such questions have the advantage that some parts can assess knowledge and understanding of 'pure' science, while other parts can assess the social aspects. An example of such a question appears in the box below.

> This question is about a chemical called metaldehyde — META for short. META is a white solid. It contains carbon, hydrogen and oxygen. Its formula is $C_8H_{16}O_4$.
>
> META has two uses:
>
> 1 As a solid fuel for camping stoves. META burns steadily with a clean flame.
>
> 2 For killing slugs. Some species of slugs are pests because they eat food crops. META can be used to poison these slugs.
>
> (a) What substances will be formed when META burns in a plentiful supply of air?
>
> (b) Write a balanced equation for the reaction in (a).
>
> (c) Suppose you were supplied with pieces of META and pieces of ordinary white firelighter. What tests would you do to decide which was the better fuel for camping stoves?
>
> (d) Give two pieces of information you would want before you used META to poison slugs in your own garden.

• Comprehension questions

Comprehension questions share common ground with structured questions. They have an introductory passage on which subsequent parts of the question are based. Such questions have the advantage that they can assess candidates' ability to apply existing knowledge and concepts to an unfamiliar situation, and their ability to evaluate social and technological aspects. An example appears in the box below. An extension of comprehension questions is to use a picture or newspaper article as the stimulus from which to develop the question.

Read the following passage, then answer the questions which follow it.

Typhus is a serious disease. The symptoms of typhus are a severe fever, muscle pains and a rash. If it is not treated, typhus can be fatal.

Typhus is caused by a microorganism called a *rickettsia*. This microorganism is spread by human parasites such as lice and fleas, which pass the microorganism into the blood when they bite. These parasites are themselves carried by rats. Typhus can spread particularly quickly when people are living in very crowded conditions and in dirty surroundings. Typhus outbreaks were very common in concentration camps in the Second World War. During and after the War the insecticide DDT was used to prevent typhus outbreaks among refugees and soldiers.

(a) Explain why DDT is effective in controlling typhus.

(b) Suggest a reason why typhus spreads rapidly when people live in crowded conditions.

(c) Suggest a reason why typhus spreads rapidly when people live in dirty surroundings.

In the 1960s DDT was banned from use in many countries for environmental reasons. It was found that the insecticide was responsible for the death of many species of animals, particularly frogs and birds.

(d) Explain how DDT can get into the bodies of animals such as frogs and birds even if they have not been treated with the insecticide.

(e) No insecticide can be completely safe. Even the safest insecticide is bound to cause some environmental problems. How can we decide whether or not a particular insecticide should be banned?

Data-analysis questions

Data-analysis questions are based on data which candidates are asked to analyse and evaluate. As well as assessing data-handling skills, this type of question can assess ability to apply knowledge to, and evaluate, unfamiliar situations. An example is given in the box below.

The three primary energy sources used in Britain are coal, oil and natural gas. The table below compares the amounts of energy obtained from each source for different purposes. The figures are in billions of megajoules per year (1 billion megajoules = 10^{15}J). They are for the year 1983.

Use	*Coal*	*Oil*	*Natural gas*
Generating electricity	2150	210	—
Industry	190	870	600
Road transport	—	1160	—
Domestic (homes)	210	90	940
Other	390	560	240

(a) What is meant by a *primary* energy source?

(b) Coal, oil and natural gas are all known as fossil fuels. Why?

(c) (i) Which energy source had the biggest domestic use in 1983?

(ii) Explain why the domestic use of this energy source is so large.

(d) Most electricity is generated by burning coal in power stations. Yet the cost of electricity per energy unit is over three times the cost of coal. Give *two* reasons for this.

(e) Why was so much more coal than oil used to generate electricity in 1983?

(f) (i) What was the biggest single use of oil in 1983?

(ii) Why is oil particularly suitable for this use?

• Free-response questions

The free-response or 'essay' type of question has the advantage that it allows candidates to demonstrate the breadth of their knowledge and awareness, and their ability to communicate in writing. Such questions do, however, place candidates with writing difficulties at a particular disadvantage. An example of a free-response question is given below.

In recent years, plastics have been replacing traditional materials like wood, leather, bone and metal. Give *two* examples of articles which are now usually made from plastics instead of a traditional material. Using these examples, discuss the advantages and disadvantages which plastics have compared with traditional materials.

Clearly, for questions of this type it is difficult to devise a structured marking scheme, and a certain amount of impression marking will inevitably be involved. Indeed, wherever the evaluation of the social implications of science is being assessed, it is likely that impression marking will be involved to some extent.

School-based assessment

In many ways, written questions are a somewhat restrictive means of assessing the broad and discursive field of the social aspects of science. There is much scope for the development of school-based assessment in this area.

An obvious possibility, already familiar in some schools, is the school-based assessment of project work. But there are plenty of other possibilities: many of the activities involved in SATIS lend themselves well to school-based assessment. For example, the ability to work with others and to contribute to discussion are important skills which are not assessed by conventional examinations. Teachers, on the other hand, are in an excellent position to assess such skills.

There is scope for basing assessment around a specific SATIS unit. For example, by assessing students' performance when using the *Dam Problems* unit, teachers would be able to assess their ability to analyse information, prepare and present an argument and contribute to negotiation.

The value of this kind of approach in the preparation of student profiles is evident. Nevertheless, this type of school-based assessment is relatively new to science teachers, and the experience of colleagues in other subject areas may be helpful.

Section 5 Other useful sources

This section gives details of other publications that will be useful to teachers wishing to bring everyday applications and issues into the science curriculum. The lists are inevitably selective and we apologize for omissions.

Many of the publications are available from the Bookselling Department of the Association for Science Education (ASE). Address: ASE, College Lane, Hatfield, Herts AL10 9AA.

1 A list of lists: a directory of where to find sources

A number of publications provide lists of sources of teaching materials, contacts, useful addresses, and so on. There is not enough space in this guide to produce another such directory; instead, the following is a list of published lists which may be helpful in the SATIS field.

1 *Addresses for Science Teachers* (Centre for Studies in Science and Mathematics Education, University of Leeds). From Bookselling Department, ASE. A comprehensive address list of publishers, examining bodies and other organizations concerned with science education.

2 *A Directory of Physics Resource Material* (ASE). From Bookselling Department, ASE. A directory to sources of support material produced by industrial companies and professional bodies.

3 *Environmental Education: Sources of Information 1981* (Department of Education and Science). From HMSO, Publications Centre, PO Box 276, London SW8 5DT.

4 *Goldmine* (Epistemology). From Epistemology, 62 Newland Road, Worthing, Sussex BN11 1JX. A list of resource materials on scientific and technological topics which are available cheaply or free. Mainly intended for the primary- and middle-school age range, but useful elsewhere.

5 *NERIS* (National Educational Resources Information Service). A computerized data-base including the *Overture* data-file of industry-related science and maths teaching materials, and the directory to industry-related science practical work compiled for SCSST by Bath SATRO. Details from: NERIS, Maryland College, Leighton Street, Woburn, Bedfordshire MK17 9JD.

6 *School—Industry Links: a Directory of Organizations* (Department of Education and Science). A guide to organizations involved in promoting school—industry links. Available free from: DES Publications Dispatch Centre, Honeypot Lane, Canons Park, Stanmore, Middlesex HA7 1AZ.

7 *Secondary Science Curriculum Review — Better Science: a Directory of Resources* (Heinemann/ASE, to be published 1987). From Bookselling Department, ASE. A directory to the comprehensive range of products of the SSCR, a good number of which are concerned with the science-technology-society field.

8 *Teaching Materials available from Industry and Commerce* (Understanding British Industry). From UBI Resource Centre, Sun Alliance House, New Inn Hall Street, Oxford OX1 2QE. An extensive list of companies providing resource material, with summaries of the materials available in each case.

2 Published courses and textbooks

A large number of published courses and textbooks emphasize the applications and issues of science. What appears below is a selective list.

Once again, we apologize for omissions. Most of the publications are available from the Bookselling Department, ASE.

Published courses

1 *Nuffield Home Economics* (Hutchinson Educational, 1982). A series of course books, worksheets and Teachers' Guides. Includes many ideas for relating science to domestic applications.

2 *PLON Physics* (State University of Utrecht, The Netherlands). A modular physics course based on everyday topics. Several of the modules have been translated into English and are available from: NIB Publishers, PO Box 144, 3700 AC Zeist, The Netherlands. A modified English version of the course is being prepared. Information from Dr Robin Millar, Education Department, University of York.

3 *Salters Chemistry* (to be published 1987). A GCSE chemistry course based on everyday topics. Trial version available from Science Education Group, Department of Chemistry, University of York.

4 *Science in Society* (Heinemann Educational Books/ASE, London and Hatfield, 1981). A sixth-form general studies course comprising Student Readers, Teachers' Guide, simulation games, audio cassette programmes, etc.

5 *Science at Work* (Longman, 1981). A modular course for less motivated 14- to 16-year-olds. The modules are all related to everyday topics.

6 *SISCON-in-Schools* (Basil Blackwell/ASE, Oxford and Hatfield, 1983). A sixth-form general studies course comprising Student Books and Teachers' Guide.

Texts and readers

7 *Chemistry in Use* by Roland Jackson (Longman, 1984). A GCSE Chemistry text with strong emphasis on applications and issues.

8 *Extending Science* series (Stanley Thornes, Cheltenham, 1983-). Short background books on topics such as energy, sounds, diseases and disorders.

9 *Looking at Science* (for 10- to 14-year-olds) (1982-) and *Science in Today's World* (for 12- to 16-year-olds) (1983-84), Batsford. Two series of short background books looking at science in an everyday context.

10 *Reading about Science* (Heinemann Educational Books, 1982). A series of topic books with short passages, well illustrated and designed to encourage reluctant readers as well as more motivated students.

11 *Studies in Industrial Chemistry* by W. Harrison and D. Wright (Edward Arnold, 1982). A series of case studies of industrial chemistry processes.

Other publications for students

12 *Experimenting with Industry* (SCSST/ASE, London and Hatfield, 1985). A series of titles providing industry-related practical work. From Bookselling Department, ASE.

13 *Interactive Chemistry Packages* (Scottish Council for Educational Technology, Glasgow, 1978-). A set of teaching materials relating chemistry to historical, social and industrial issues. All involve interactive group learning methods. From Scottish Council for Educational Technology, 74 Victoria Crescent Road, Dowanhill, Glasgow G12 9JN.

14 *Keep Britain Tidy Group Schools Research Project* A series of units relating environmental issues concerning waste disposal to the science curriculum. Titles include *Glass* (1981), *Metals* (1984), *Plastics* (1984) and *Waste Management and Resources* (1985). From Keep Britain Tidy Group, Bostel House, 37 West Street, Brighton BN1 2RE.

15 *Physics Plus* (Hobsons/SCSST, Cambridge and London, 1985). A series of study sheets, each describing a real-life application of physics principles.

16 *Third World Science* (University College of North Wales, 1983-). A series of units relating science to topics of concern in developing countries. Titles include *Methane Digestors, Distillation, Energy Converters,* etc. From Centre for World Development Education, 128 Buckingham Palace Road, London SW1W 9SH.

3 Useful references for teachers

This highly selective list gives some sources of information and ideas which are of particular relevance to the SATIS field. Most are available from the Bookselling Department, ASE.

Useful information about science applications

1 *ASMIT* (Applications of Science and Mathematics in Industry and Technology) (ASE, Hatfield, 1981). A collection of notes for teachers on examples of technological applications of science principles.

2 *The Gass Book* (British Gas/ASE, London and Hatfield, 1982). Resource materials relating the applications of gas to school science.

3 *Geofile* (Mary Glasgow Publications, Warwick). An information service for geography teachers. Regular briefing sheets which include much of interest to science teachers. Details from: Mary Glasgow Publications, FREEPOST, Brookhampton Lane, Kineton, Warwick CV35 0BR.

4 *STEAM* (ICI). An occasional magazine for science teachers containing information about the chemical industry. One copy distributed free to every secondary school.

5 *Technology Made Simple* by Don McCloy (Heinemann, 1984). A helpful summary of many aspects of technology.

6 *Telecommunications in Practice* (British Telecom/ASE, London and Hatfield, 1985). Resource materials relating telecommunications to school science.

Useful information about the teaching of science

7 *ASE Science Teacher's Handbook* (ASE, Hatfield, 1986). A comprehensive general source, with much information relevant to the SATIS field.

8 *Children's Learning in Science Project* (CLISP, Centre for Studies in Science and Mathematics Education, Leeds University, 1983-85). Summary reports of papers concerned with important aspects of learning in science.

9 *Girl-friendly Science: Avoiding Sex Bias in the Curriculum* by Barbara Smail (Longman, York, for School Curriculum Development Committee, 1985). Addresses the problem of how to involve girls more fully in science lessons by making the subject more relevant to their interests. (See (14) below.)

10 *Ideas for Egg Races* and *More Ideas for Egg Races* (British Association for the Advancement of Science, 1983 and 1985). Ideas for practical problem-solving activities.

11 *Reading for Learning in the Sciences* by Florence Davies and Terry Green (Oliver & Boyd, Edinburgh, 1984). A book with many useful ideas for increasing the effectiveness of reading activities.

12 *Rethinking Science* (ASE, Hatfield, 1984). An ASE Occasional Paper concerned with the teaching of science to 11- to 16-year-olds within a social context.

13 *Secondary Science Curriculum Review — Better Science: Curriculum Guides* (SSCR, to be published 1987). A set of resource documents designed to support science teachers at classroom and department level.

14 *Switched-off: the Science Education of Girls* by Jan Harding (Longman, York, for Schools Council (now School Curriculum Development Committee), 1983). Another publication which addresses the problem of how to involve girls more fully in science lessons. (See (9) above.)

15 *Practical Work in Science* by Brian Woolnough and Terry Allsop (Cambridge Science Education Series, 1985). An overview of the role of practical work.

4 Sources of statistics

Statistics can be a valuable source of information and can form the basis of assessment items and data analysis exercises.

References 1 to 7 below give sources of statistical summaries that can be obtained free of charge or at low cost by teachers. References 8 and 9 are to larger statistical sources that may be referred to in libraries.

1 *British Economy in Figures* (Lloyds Bank). A handy annual summary card giving key economic statistics. Available free from: Corporate Communications Division, Lloyd Bank plc, Princess House, 152–156 Upper Thames Street, London EC4R 3UJ.

2 *Handbook of Electricity Supply Statistics* (The Electricity Council). Detailed statistics on electricity generation and supply. Available free from The Electricity Council, 30 Millbank, London SW1P 4RD.

3 *OPCS Monitor* (Office of Population Censuses and Surveys). Detailed figures, regional and national, on population and health in the United Kingdom. Each *Monitor* gives statistics for a different topic (population estimates, causes of death, etc.). Available free from: Information Branch, OPCS, St Catherines House, 10 Kingsway, London WC2B 6JP.

4 *Science in Society Data Project* (GlosCAT). An annual update on data in the Science in Society publications. Available at modest cost from: Science in Society Data Project, School of Environmental Studies, GlosCAT, Oxtalls Lane, Gloucester GL2 9HW.

5 *Statistical Review of World Energy* (BP). Attractively presented annual statistics concerning consumption of different energy sources worldwide. Available free (one copy per school) from: BP Educational Service, PO Box 5, Wetherby, West Yorkshire LS23 7EH. BP Educational Service also provide a *World Energy Statistics Resources Pack* based on the Statistical Review.

6 *United Kingdom Energy Statistics* (Government Statistical Service). A handy annual summary card giving key statistics about consumption of different energy sources. Available free from Department of Energy, Information Division, Room 1314, Thames House South, Millbank, London SW1P 4QJ.

7 *United Kingdom in Figures* (Government Statistical Service). A handy annual summary of the most important statistics on population, employment, the economy, the environment, agriculture, climate, etc. Free from: The Press Office, Room 58/G, Government Offices, Great George Street, London SW1P 3AL.

Larger statistical sources

To use these sources it will probably be necessary to visit a library.

8 *Annual Abstract of Statistics* (HMSO). A wide variety of statistics relating to the United Kingdom.

9 *United Nations Statistical Yearbook.* A major reference for worldwide statistical information.

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Many people have made contributions and given advice and help to the SATIS Project. The names of some of them appear below: our apologies to the many others we have been unable to mention.

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Benfield School, Newcastle upon Tyne
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Bishop Hedley High School, Merthyr Tydfil
Blackheath High School, London
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Brynteg Comprehensive School, Bridgend
Cheadle Hulme School, Cheshire
Churchdown Comprehensive School, Gloucestershire
Cowes High School, Isle of Wight
Crookhorn Comprehensive School, Portsmouth
Didcot Girls' School, Oxfordshire
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Guthlaxton College, Wigston
Harrytown High School, Stockport
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Heaton Manor School, Newcastle upon Tyne
Henry Court Community School
Herts and Essex High School, Bishops Stortford
Huntcliff School, Saltburn
John Kelly Girls' High School, Brent
King's Langley School, Hertfordshire
Lady Mary High School, Cardiff
Langleybury School, Watford
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SATIS is a set of resource units and teaching ideas designed to link major science topics to important social and technological applications and issues. SATIS units are intended to be used in conjunction with conventional science courses, particularly those leading to GCSE examinations.

This General Guide for Teachers accompanies the series of SATIS units. It gives guidance on the use of SATIS materials as well as ideas for further activities and other resources.

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