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INTRODUCTION

Increased confidence in teaching science within the primary curriculum should come with the acquisition of appropriate scientific knowledge and exposure to a range of possible ways of translating that knowledge into the classroom.

However, because of the current climate of major change in education which follows in the wake of the Education Reform Act 1988, you are faced with the challenge of coping with a further range of issues. These must be assimilated into your teaching of science within the curriculum. They are an additional consideration to be addressed alongside acquiring sufficient experience of science on a personal level to face the prospect of teaching primary science with enthusiasm.

By following the programme of work contained within *Science for Primary Teachers*, you will have gained, or be in the process of gaining, a fuller understanding and appreciation of science.

The issues addressed in *Issues in primary science teaching 1: In the classroom* will provide a variety of perspectives on aspects of science teaching within the primary curriculum.

A number of activities are included in the articles. You will derive most benefit from them if you are able to discuss the outcomes either with your colleagues at school or during a tutorial session.

Table 1 gives a brief overview of your main responsibilities as a teacher of primary science; the right-hand column indicates which of the articles will help you to address these responsibilities.

<table>
<thead>
<tr>
<th>Responsibility</th>
<th>Relevant article</th>
</tr>
</thead>
<tbody>
<tr>
<td>To effectively manage the environment in which learning about science can take place</td>
<td>Organization and management of the classroom</td>
</tr>
<tr>
<td>To provide opportunities for science to be integrated into the curriculum and to allow for progression in knowledge and skills</td>
<td>Progression and development in the practical curriculum</td>
</tr>
<tr>
<td>To stimulate children's abilities to solve problems and engage interactively with the practical curriculum</td>
<td>A practical problem-solving approach to education in science and technology</td>
</tr>
<tr>
<td>To assess children's achievement in science</td>
<td>Assessment in primary science</td>
</tr>
</tbody>
</table>
ORGANIZATION AND MANAGEMENT OF THE CLASSROOM

Gloria Davenport

Project Director, National Project: Practical Problem-Solving 5–13

In this article, Gloria Davenport examines some aspects of classroom organization that affect the children's potential for learning through practical activities.

INTRODUCTION

To maximize the potential for learning through practical activities, careful consideration needs to be given to the organization and management of the classroom. Efficient, structured and well-planned organization is the key to providing a stimulating environment that inspires quality learning.

This article examines both the organization of the environment and the organization of resources.

ORGANIZATION OF THE ENVIRONMENT

The national curriculum has shown the importance of a balanced curriculum and has also highlighted the importance of cross-curricular schemes of work and the need to reappraise teaching strategies, allowing the children to work in different ways. Effective contact between the teacher and the child can be categorized into four main types:

- guiding
- questioning
- informing
- interacting.

These types of contact facilitate progression and encourage the development of cooperative work, independence and individuality. It is essential to have a flexible working style in the classroom, and the environment needs to be organized so that the teacher can provide quality learning. In order to promote the efficient delivery and management of the curriculum, the classroom must be well organized. It should allow for different methods of working, including individual, pair, group and whole-class work, and for different types of activity, such as quiet work, discussion, 'messy' work, role-play, and making music.

Areas need to be clearly defined so that the children know what kind of work they are expected to do in each section, and how to care for and tidy each area. Obviously the shape, size and design of the classroom will influence the layout; however, taking the time to reassess the situation will often reveal that better use could be made of the room available.
ACTIVITY 1: PLANNING FOR CLASSROOM REORGANIZATION

Spend some time now compiling a checklist of questions that you would need to consider before reorganizing your classroom to allow for different styles of working.

After you have compiled your list, compare it with ours, shown below.

Your list probably contained some of the following questions:

- What is the overall size of my classroom?
- How many children are in the class?
- What range of activities do I wish to provide for?
- What resources do I need to accommodate and make accessible, particularly as regards science?
- Is there a need for more furniture in the classroom? Or do I need to reduce the amount?
- Does the organization allow for different styles of working—individual/pair/group/whole class?
- Does the organization allow children to move effectively from one activity to another?
- Do I wish to provide a permanent mathematics and/or science area displaying appropriate work, games or information about topics in the news?

With careful management, activities can be planned so that only one or two are teacher-directed at any one time. Note that classrooms quite often contain too much furniture; with improved organization and reduction of furniture, it might be possible to demarcate various working areas. Creative use of bookcase units and tables makes it possible to set out different working areas even in a mobile classroom. If children have access to resources and tools, the teacher no longer has to cope with queues of children asking for permission to use equipment, and can move around the working groups. Queueing is also reduced if rotational activities are set up, so that the children know which activity to move on to next. This gives children ownership, developing independence and a degree of responsibility for their own learning. However, it is a method that requires careful recording, structuring and organization of the activities.

In the next section, we take a few of these ideas that relate especially to teaching science and examine them in more detail.

A PRACTICAL AREA

It is important that there is a specific, well-equipped area for practical activity, where children can work with materials and equipment without feeling guilty if they make a mess.

The clear labelling of resources, with everything having its proper place, is especially important. It helps develop the children's responsibility for their own learning. The resources and tools available should be relevant to the children's age group, and their ability to use them properly and safely. Surfaces should be provided that can be designated for use with different types of material.

Clay work—Clay work is best done on an absorbent surface, such as card, hardboard, or wood. If a non-absorbent surface, such as polythene or vinyl, is used, you will find that as the clay dries it tends to flake off and make a mess.

Art and design—Painting should be done on a surface that can be easily wiped clean, or on an absorbent surface such as newspaper. Easels are not really
appropriate as young children find it awkward to paint at arm’s length. Also, thin paint is likely to run down and frustrate the child’s efforts. Charcoal, pastels and pencil drawings can all be made on a flat, dry surface.

Construction—Construction exercises using wood, card or glue, require a workbench, preferably with a vice attached to hold the material safely for sawing, hammering and drilling. An old table could be used instead of a workbench; however, it must be sturdy enough to allow activities to take place safely.

Fabrics—Work with fabrics will usually require a clean, flat surface. It can be integrated with work using other materials, and the children could explore a number of applications, together with ways in which fabrics can be woven, coloured, and joined together or assembled into collages etc.

Food—Food surfaces must be kept clean and hygienic, and be stored well away from other materials. Thorough preparation of work surfaces should take place before working with food. It may be desirable for schools to provide a central site which is kept for this activity.

If possible, create a space where incomplete work can be placed. It could perhaps be labelled as a working display, for example: ‘Teresa and Lucy are making a model of a space rocket.’

Consider using the checklist given in Table 1 to assess your practical area.

TABLE 1 Practical area: a checklist

<table>
<thead>
<tr>
<th>Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Is the floor-covering suitable?</td>
</tr>
<tr>
<td>Do the tables have a protective covering?</td>
</tr>
<tr>
<td>Is there a supply of protective clothing for the children?</td>
</tr>
<tr>
<td>Is there an adequate water supply and sink?</td>
</tr>
<tr>
<td>Are the sand and water trays near the water source?</td>
</tr>
<tr>
<td>Is the equipment suitable for the two trays?</td>
</tr>
<tr>
<td>Is there adequate room for movement?</td>
</tr>
<tr>
<td>Is the equipment:</td>
</tr>
<tr>
<td>• clean</td>
</tr>
<tr>
<td>• tidy</td>
</tr>
<tr>
<td>• labelled for the correct age group</td>
</tr>
<tr>
<td>• accessible?</td>
</tr>
<tr>
<td>Do the children know how to use the materials and the tools safely and correctly?</td>
</tr>
<tr>
<td>Are the tools, paintbrushes, scissors, junior hacksaws, etc., stored in suitable containers?</td>
</tr>
<tr>
<td>Are the fixatives, glues, sticky tape, nails, etc., stored carefully?</td>
</tr>
<tr>
<td>Is the accessibility and availability of tools and resources linked to a progressive framework?</td>
</tr>
<tr>
<td>Do the resources present equal opportunities for all?</td>
</tr>
<tr>
<td>Are the construction kits suitable for the children’s:</td>
</tr>
<tr>
<td>• age group</td>
</tr>
<tr>
<td>• level of ability</td>
</tr>
<tr>
<td>• interest?</td>
</tr>
<tr>
<td>Is the equipment for role-play suitable for the children’s age group?</td>
</tr>
</tbody>
</table>
Could you make any changes to the way your classroom is currently organized to provide better for practical work?

A QUIET AREA

Even if there is not enough room to have a ‘book corner’ in the class, it is advisable to have a quiet area, to which children can retreat if they want to read, either for relaxation or research, or if they need a quiet break during the day.

A quiet area needs to be:

- inviting
- attractive
- comfortable
- stimulating
- conducive to relaxed reading.

The area can be made inviting, attractive and comfortable with cushions and toys, either that the children have made or that have been purchased. To create interest and stimulate investigation there could be a weekly display of books on a particular theme or relevant topic, together with questions such as: ‘Can you find out who . . .?’ ‘Can you find out where . . .?’ ‘Can you find out how . . .?’ or ‘Have you read . . .?’

Try to ensure that the books in this area support the children in factual discovery linked to class projects. There are many books available that build on and extend children’s knowledge in science.

Book displays should also include books that children have made: for example their own dictionaries, investigation books, story books, etc. If a tape recorder and headphones can be made available in a nearby area then story tapes and factual tapes can be utilized, providing an opportunity for children to develop their listening skills. You could also have a changing display of reviews of children’s books. In addition, you may wish to explore the authority’s library service. An area of uncluttered desks or tables where children can concentrate quietly on finishing items of written or illustrative work can also be a valuable feature.

AN AESTHETIC ENVIRONMENT

It is important to provide the children with a rich learning environment. An atmosphere conducive to learning can be promoted by the thoughtful use of displays. Displays of children’s work together with purchased posters can be punctuated with questions. For example, the question ‘How do you think this works?’ could be pasted beneath a Heath Robinson poster.

A display of interesting or unusual objects, again with pertinent questions in the vicinity, can stimulate an enquiring mind. For example, to a display of plant life could be added a magnifying glass and a card containing questions such as: ‘Can you make a drawing to show how the leaves join the stem?’ or ‘What patterns can you see?’ This helps to bring about an understanding of shape, form and structure, all of which are concepts vital to science, art, design, technology and mathematics.

Encourage the children to bring in objects from home so that they take an active role in the design, display and resourcing of their classroom.

OUTSIDE THE CLASSROOM

Are you maximizing the use that can be made of your school grounds, and in particular the area immediately outside your classroom?
ACTIVITY 2: OUTDOOR ACTIVITIES

Spend some time now jotting down a list of the types of outdoor activity in which you might engage in the course of a school year.

When you have compiled your list, compare it with ours, shown below.

Opportunities in science for working outside are numerous and varied. Some activities you might have thought of are:

- creating a garden for flowers, vegetables, herbs and fruits
- developing a 'natural' area, where grass is left unmown and natural communities of plants and insects can be observed
- creating a rockery with specialized rockery plants
- building a bird table, and collecting data on the species that visit it at different times of the year
- building a weather station
- surveying building styles and materials that have been used to build the school
- examining the speed with which food items and packaging materials decay when buried in soil
- work on camouflage in the natural environment
- work on shadows and the Sun's position in the sky at various times of the year
- late afternoon/early evening observational work on the stars, the Moon, etc.
- work on the seasons, looking at the colours that predominate at various times of the year.

Several of these suggestions are included in the Study Commentaries for Science for Primary Teachers. Your list probably contained many other ideas.

DISPLAYING CHILDREN'S WORK

Look carefully at the current displays in your classroom. Do you make good use of the display areas? The checklist in Table 2 may suggest some ideas that you may not have thought of.

<table>
<thead>
<tr>
<th>TABLE 2 Displays: a checklist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do you use the tops of tables, units or bookcases for displays?</td>
</tr>
<tr>
<td>Do your displays stimulate the children’s imagination and creativity?</td>
</tr>
<tr>
<td>Do they extend their use of language?</td>
</tr>
<tr>
<td>Do they extend the children’s knowledge of other cultures?</td>
</tr>
<tr>
<td>Do the objects displayed have historical, scientific or technological interest?</td>
</tr>
<tr>
<td>Have you explored the authority’s museum/resource service?</td>
</tr>
<tr>
<td>Do you keep records of whose work has been displayed so that no one is left out?</td>
</tr>
<tr>
<td>Do the children have opportunities to take an active role in the classroom displays?</td>
</tr>
</tbody>
</table>
ACTIVITY 3: IMPROVING CLASSROOM DISPLAYS
Having surveyed your current classroom displays against the checklist in Table 2, note down whether there are any changes you could make to your organization of classroom displays.

Can you suggest any ways in which displays of scientific interest could be made interactive? Using one of the current displays in your classroom, try to develop an interactive theme for it. Discuss this with your tutor group next time you meet.

ACTIVITY 4: BUILDING PROGRESSION INTO DISPLAYS
Write down how you think the role of scientific display should change as the intended audience increases in age from 5 to 11 years. Compare your notes with those of your colleagues at a tutorial and discuss how you can build progression into your scientific displays.

ORGANIZATION OF RESOURCES
The organization, storage and maintenance of materials, tools and equipment is vital; it is through their use that the important skills and concepts of science and technology are developed. A wide variety of resources is essential for providing quality learning experiences. Materials, tools and equipment should be readily available to support children’s progressional needs in construction, textile work, art and design, and food studies.

Care needs to be taken when planning the availability and accessibility of these resources. Strategies really need to be discussed by all the members of staff, as it is essential that there is a coherent resourcing policy.

ACTIVITY 5: PLANNING FOR RESOURCES
Write down your school’s resourcing policy for science. Would it be possible for you to borrow items of scientific equipment from a neighbouring secondary school? Could you set up a reciprocal arrangement whereby resources could be loaned between schools? Note down some ideas on how you might go about organizing such a scheme.

The school’s resources should be appraised in terms of: the children’s age group, ability, skills and knowledge; you must also consider health, safety and hygiene factors. A decision should be made as to which items belong in a central resource area. For example, precious items, such as cameras; dangerous items, such as junior hacksaws; and materials required to be stored in a controlled environment, such as food items, all need to be centrally located. Alternatively each classroom needs to be allocated a supply of basic materials such as wood, clay, card, fabrics, paints, etc. You need to think about how these materials are best stored in the classroom, giving due consideration to questions of accessibility, availability and labelling.

An investigative approach to learning will founder if it is not supported by the necessary learning resources. Books and pictures are, of course, extremely important, but the term learning resources should be seen as encompassing a much wider range of things.
**BOOKS**

The activity of reading can be undertaken for different reasons, each needing a different reading skill. For example, we read for:

- pleasure
- research
- information
- reference.

It is essential that the range and quality of books is such that many different reading skills are stimulated, and equal opportunities are presented for all the children to derive benefit from them. The books should, of course, be suitable for the children's age group and ability.

**INTERESTING AND RELEVANT OBJECTS**

A classroom should be a stimulating, exciting environment for the children; to this end it may be useful to have a collection of interesting objects that encourage an enquiring mind.

The objects chosen could be linked to any area of the curriculum. However, it is essential, particularly when working in a cross-curricular way, that a balance is achieved between objects from the natural world and those illustrating human constructions and artefacts. One week, for example, there could be a display of shells for the children to observe closely and make drawings of. This would encourage an understanding of natural structures; the observations could support a project on a particular aspect of the made world, and show the dependence of the one upon the other. The following week, a piece of machinery or a tool could be displayed, together with the questions: 'What do you think this is for?' and 'What do you think this does?' The artefact could be compared with similar mechanisms in nature, such as a crab’s claws, or the pincers on an earwig.

**CONSTRUCTION KITS**

Construction kits play an important role in a child’s conceptual and manipulative development. Construction equipment needs to be wide-ranging in order to cater for the different needs, abilities and interests of the children, and also to provide a variety of experience.

**TOOLS**

Quality tools are vital for practical learning activities. They should be assessed in terms of their suitability for the age group and ability of the children, as well as their appropriateness for the intended task and health and safety factors.

It is essential that the children respect the tools, know how to use them safely and correctly, and are fully aware of the dangers of misuse. Storage and accessibility require careful thought. Any school policy regarding tools must take into account health and safety aspects. Consistency in the application of this policy is essential. If tools are locked in a cupboard in one classroom, and readily available in the adjoining one, the children will, understandably, be confused. Although, in the main, tools should be available and accessible to children, some may need to be kept by the teacher, for example glue guns and craft knives. All tools should be clearly labelled, and stored carefully.
CONCLUSION

Classroom management for effective learning is one of the most difficult aspects of a teacher's job. If the teacher is able to involve the children actively in any decision-making about the ordering of their classroom, it will not only encourage them to take responsibility for the care of the classroom, but it will also foster attitudes of cooperation and independence.
PROGRESSION AND DEVELOPMENT IN THE PRACTICAL CURRICULUM

Peter Sellwood
Director, National Project: Practical Problem-Solving 5–13

As Director of the National Project: Practical Problem-Solving 5–13 group, Peter Sellwood worked with a large number of case-study schools and established a scheme for progression within the practical curriculum. He considers how the development of skills can be promoted through practical activities. Examples have been selected to show a range of cross-curricular approaches.

Much of the research used topics with a technology focus. However, the ideas are readily transferable to science, and the examples cited demonstrate the close links between science and technology.

INTRODUCTION

Primary teaching functions most effectively when it works across the whole curriculum, linking broad subject areas together through a carefully constructed theme or topic.

In the light of the national curriculum requirements, topics that are intended to be relevant and meaningful across the primary curriculum need to be carefully balanced. All topics will have a bias and it is vital that each is planned to complement previous and future work, in order to meet the demands of attainment targets and levels of achievement.

Accurate recording, assessment and evaluation procedures are essential to make sure that children achieve progression in learning. Consideration also needs to be given to the children's social and personal development, to ensure that boys and girls from various cultures and backgrounds are given suitable incentives to learn, and that the experience is equally stimulating for all the different groups.

In order to facilitate progression, teachers need to develop strategies to assist in the children’s learning process. A properly organized environment for practical activities is thought to be an effective way of providing such help.

One of the criticisms of a topic-based approach has been that some teachers have planned work around their own special interests or teaching strengths while neglecting others. The balance necessary to meet national curriculum requirements should remedy this weakness and at the same time provide a richer learning experience for the children.

PROGRESSION THROUGH PRACTICAL WORK

Research has shown the importance of including practical activity in the curriculum, and it is recognized to be a potent learning medium. Children’s understanding and recall of what they have learnt is increased if they have done a related practical activity.

During 1987–90, the project team worked with teachers planning a framework for progression in design and technology using a cross-curricular approach. They have matched the development of children to a problem-solving philosophy.
using three broad stages. We can equate these stages with national curriculum levels of attainment:

- structured play—equivalent to levels 1 to 3
- guided discovery—equivalent to levels 2 to 5
- project design—equivalent to levels 3 to 7.

Although these stages correspond to age-related development, they should be familiar to all of us as natural reactions to something new. When, for example, we unpack a new micro-computer, the first stage is to ‘play’ with it—pressing various keys to see what happens, and moving the cursor across the screen. Guided by the instruction manual, we gradually learn what the machine can do. As our confidence increases we learn how to produce sophisticated documents without continually looking at the instruction manual.

Let us now consider each of these stages in detail.

**STRUCTURED PLAY**

On encountering something new, children will engage in free play. This can be structured by the teacher asking challenging questions; the children consequently become more familiar with the new object or idea, and their confidence increases.

Children should be encouraged to play with a variety of materials, and be provided with stimuli with the aim of achieving specific objectives. At this stage they will think of materials as being simply 'hard', 'soft', 'bendy' or 'floppy'. They will readily build with kits and wrap, shape and join fabrics to make clothes for their toys. Through structured play they will come to understand that energy is needed to make things move, for example ourselves, toys and models. They will also begin to understand that they can control things; they can make objects go in certain directions by pushing and pulling, and they can guide them by means of tunnels, paths and slopes.

The development of practical skills will involve arranging, sticking and joining things, and building with cardboard boxes, softwood and plastic containers. Children should be provided with the opportunity to form, bend and mould malleable materials, such as clay and Plasticine, and also develop their ability to shape easily worked materials using simple tools such as scissors and junior hacksaws.

Language plays a crucial role in the development of the young child’s thinking. Conceptual understanding is developed through verbal description and the acquisition of a relevant vocabulary. It is essential that scientific and technological understanding is fostered as children’s language is developed alongside practical activity. Their language is extended and enriched by a creative and questioning approach, and they will gain in confidence and understanding when encouraged to experiment with words and descriptions.

**Teddy bear topics**

To illustrate activities at this stage, a ‘teddy bear’ (our collective name for any one of an assortment of cuddly toys) topic was used by the teacher of a reception infant class. The children, who had only recently started at school, were encouraged and reassured when allowed to share this new experience with a ‘friend’—their favourite cuddly toy. Many learning experiences were related to their toys, such as constructing somewhere for Teddy to live, and this provided the initial reason, or stimulus, for each of them.

Language skills were developed through descriptions and ideas presented by the children about their toys. They told and wrote stories about their Teddy’s adventures. Specific skills were developed through considered questions, such as ‘How many Teddies do you think this box will hold?’, which encouraged them to think about the size and capacity of the box, and how these related to the size...
of the Teddy. The question ‘Can you design a house for your Teddy?’ encompassed designing and thinking about what a house looks like, and things that it might need, for example windows. Specific questions might be: ‘What are windows for?’ ‘Where do windows need to be?’ ‘How does Teddy get in and out?’

These considerations can lead on to questions involving practical skills, such as ‘How do you make a door?’ ‘Can you make the door open and close?’ Making a house for Teddy involved using appropriate materials; learning where to bend and where to cut; estimating size, and then measuring Teddy against the house. If Teddy was the wrong size to fit into it, the children were asked to think about how the house could be made bigger—for example by adding on rooms. They were also encouraged to consider aesthetics, with the questions: ‘What colour house would Teddy like?’ ‘What colour would Teddy paint the door?’ ‘What colour would Teddy paint the surrounds of the windows?’ ‘Do you think Teddy would have a garden in front of his house?’ ‘What sort of garden would Teddy have?’

The children’s skills of designing, constructing and technical understanding were developed through the teacher’s questioning approach, whereby they were led to think through their ideas and come to reasoned decisions about what they thought Teddy would like.

Breakfast time at Teddy’s house provided an opportunity to cook—an obvious choice being porridge. It also constituted an ideal time for social interaction around a table, with the children tasting their porridge, discussing their meal and measuring out portions for each other. A picnic presented similar opportunities, but also allowed the children to make decisions about where and when it was going to take place. The children prepared food, made clothes and dressed their Teddies for the occasion.

GUIDED DISCOVERY

At this stage the teacher can supply starting-points for investigations, and guide the children, again through open-ended questioning, towards a range of possible solutions. The period of guided discovery is most effective during the late infant and junior phase, as this is the time children benefit most from an investigative approach to learning. They usually enjoy the responsibility of working in groups in which they can plan and discuss the direction of their investigations and possible solutions, and this type of activity encourages them to become more independent. Their conceptual understanding is greater because it is largely self-motivated. The best tasks are those that expand concepts previously introduced and extend and build on the skills acquired through structured play. During this broad stage of development, children should be provided with tasks that develop their understanding that different materials have different properties; for example, they can be malleable, flexible or brittle; can be of varying degrees of hardness; can be porous or non-porous; can be conductors or non-conductors. They must also be able to apply their understanding of these properties.

They will, through guided discovery, learn that energy can be stored in the form of a battery, a spring or an elastic band. Their developing skills will include the ability to build structures that stand, support, protect and move. They will need to be competent in the safe use of a variety of tools, such as: a junior hacksaw; a pair of scissors; a hand drill; a mallet; a hammer; a pair of pliers; sewing needles; and knitting needles.

Practical problem-solving activities at this level are illustrated by the following case study, which involved upper junior children.

The post office

Many different themes relating to the post office were considered by the children. We present a summary of some of them here.
Parcels and packaging—The children chose a variety of articles that they would like to post, such as chocolates; various toys; a pair of spectacles; a plant; and 'surprise parcels' (out of which something popped when the parcels were opened). The children then designed suitable packaging for the articles that would enable them to be sent through the post. This involved testing different things to discover their suitability as packaging materials. Which material would be the strongest? Which would be most suitable as decorative wrapping paper? Which would provide most protection for fragile items?

Different-shaped packages were constructed (for example, an oblong box, a triangular prism, a cylinder) to see which shape provided the best protection. From their results, the children then packaged their articles in the most appropriate way. After making their individual parcels, they made comparisons about each of them as regards strength, attractiveness and capacity.

To see how effective the individual parcels and packages were, the children posted them back to themselves at school. The results were carefully noted.

The children also designed a bag to hold the post, for use on a round that was by foot. They tested different materials for strength, ease of carrying, protective ability in different weather conditions, etc. Different designs of bag were tested for comfort, capacity, strength, ease of fastening, and ease of removing the post.

Transport—The children looked at the different ways of transporting the post and considered the questions:

- Why are there different forms of transport?
- Which form of transport (for example, a van, a bicycle or a trolley on wheels) is most suitable for a particular round, such as a rural round; a round in a small village; or a round in a town?
- Which form of transport holds the most items?

The children made small postal vans using a variety of materials, such as balsa wood, card and corrugate, and tested the suitability of the different materials for making the vans. They experimented with various ways of joining the materials together, and the effect of using wheels of different materials and sizes. The children had already discussed why the wheels on bicycles were different from those on motor bikes, and why different cars had wheels of different types, etc. They put items of different mass inside their vans, and examined the effect that these would have on the speed and the distance that their vans would travel. They also experimented with ways of making their van move: some used batteries; some used string to pull their van along; some used the stored energy of an elastic band to make it move, etc. Some children put lights on the front of their van so that the driver could see in the dark, and some put lights inside the van so that the addresses could be easily read.

Clothing—Children tested fabrics for their different properties, for example how good they were at keeping a person warm, cool, dry, etc., and then designed outfits for post office employees. They had to take into account not only the suitability of the fabric, but also the appropriateness of the design for a particular activity; for example, a person delivering post using a motor van will not need such protective clothing as one who delivers it on foot or by bicycle. The children designed and cut out paper patterns, and then made clothes from them to fit dolls (male and female) that they had brought into school. A fashion show was held, and they put together a catalogue to advertise the various outfits.

PROJECT DESIGN

The results of a well-planned and consistent investigative programme of learning needs to progress from structured play in early infancy, through guided discovery at junior school, to project design at middle and early secondary school levels. This is the stage at which the child will have matured into an independent
thinker, with his or her own ideas, and should be capable of following a project through from its initial concept to final conclusion.

At this stage the children will be able to discuss with the teacher how to turn their ideas into action. Group work will still be successful, particularly when it is properly planned. Work should stem from open-ended design briefs, drawing not only on previous experience, but also on the strengths and interests of the children. Projects involving a few subject areas will be a more common feature of integrated learning than topics across the whole curriculum.

Children will be involved in:
- planning, designing, testing and making prototypes
- choosing materials for a specific purpose, for example economy, ease of manufacture or appropriateness for intended use
- working in groups
- exploring energy, mechanisms and control
- coming to understand processes of manufacture, marketing and cost.

The following case study, although not directly applicable to primary teaching, illustrates the application of the skills that you are encouraging the children to develop throughout their primary schooling.

**Designing a package for the topic of 'Flight'**

A group of students in the third year at secondary school were set the task of designing and making an educational package about flight for children in the developing world. The task of providing a kit that would encourage investigations into the principles of flight required the team to think of themselves as real 'designers'.

The pack had to be easily transportable and its costs kept to a minimum. The students experimented with gliders, powered models, rockets, parachutes and hot-air balloons. They developed their ideas through the technique of brainstorming, and came to decisions as a result of discussion and negotiation. Graphic symbols were invented and printed on the package to make its assembly and use clear to children throughout the world.

The final product was a marketable package that called upon their acquired skills of science and technology in relationship to materials, manufacture, production, product design and retailing—a logical step in their progression as knowledgeable and comprehensively schooled young students.

**CONCLUSION**

An investigative or problem-solving approach to learning is most successful when children work in cooperative learning groups. These are particularly effective when engineered by a teacher who has a sound knowledge of the qualities of each individual within the class, and is able to balance skills, knowledge, temperaments and personalities. The benefits of the approach are manifold: it develops positive attitudes towards others and appreciation of their skills, which in turn fosters increased cooperation and respect for the opinions of others. It also helps to exercise and develop important learning skills, such as verbalizing, discussing, brainstorming, interacting, etc. Both the teacher and the children come to appreciate that each and every member of the class is an important learning resource.

This recognition is highlighted by the way in which group or cooperative working will be assessed, recorded and evaluated. It will become necessary for children to play an important role in assessing their own contribution to a group project.
Teachers will need to construct groups carefully, so that there is an even distribution of talents and skills. Members of the group, depending on their age and ability, should be able to record their own achievements and be encouraged to make honest assessments of each others' contributions.

In conclusion, it is important to note that when seeking to build on the qualities of an investigative learning approach, it is vital that the resources for learning are readily accessible to the children. An investigative approach will founder if not supported by a wide range of the necessary resources.
A PRACTICAL PROBLEM-SOLVING APPROACH TO EDUCATION IN SCIENCE AND TECHNOLOGY

Peter Sellwood
Director, National Project: Practical Problem-Solving 5–13

Arguing that problem-solving is the basis of all good teaching practice, Peter Sellwood examines the need for a problem-solving approach to be consistently developed throughout schooling.

He examines the role of problem-solving in the development of thinking and language in schools, and looks in particular at how techniques of questioning used by the teacher can assist children’s learning.

The work was developed as part of the National Project: Practical Problem-Solving 5–13, 1987–90.

WHAT IS ‘PROBLEM-SOLVING’?

Problem-solving is a well-worn term representing a wide range of activities that take place in school. Definitions vary and it can be all things to all people. ‘Problem-solving’ is neither a separate subject within the school curriculum, nor solely part of the process of science and technology. One often hears the phrase ‘In the afternoon we did some problem-solving’. Problem-solving is not something to be switched on and off; it should be consistently developed throughout schooling, and is the basis of all good teaching practice. There is no mystique about a genuine problem-solving approach, neither should it be represented as a binding and restrictive methodology.

While children are exploring, discovering and investigating the world around them, they will inevitably be involved in problem-solving of various kinds. The ability to recognize, analyse and then solve problems is a fundamental part of their intellectual development and is becoming increasingly important as a life skill.

For the purposes of this article, problem-solving is seen as an important component in an investigative approach to learning—an approach that requires both the teacher and the child to ask searching questions of one another, in order to identify their objectives. When properly controlled and monitored, it provides the opportunity to develop the important skills of ‘learning how to learn’. According to Nisbet and Shucksmith (1986), ‘a successful learner is one who has learnt how to learn’, a skill they say comes through developing the ability to reflect on one’s own learning. This skill can be developed through teaching.

THE NEED FOR A PROBLEM-SOLVING APPROACH

Rapid scientific and technological development in recent years has made it impossible to teach content merely by providing facts. Knowledge has doubled in the past decade and is likely to treble in the next. The development of the national curriculum, in which the broad curriculum needs of children have been reviewed, reflects this; this major overhaul of the system does not restrict itself to what is to be taught in schools, but also indicates ways in which it should be
taught. Consider the attainment targets of the national curriculum document for technology:

1. Identifying needs and opportunities.
2. Developing a design.
3. Planning and making.
4. Evaluating.

They are themselves a good illustration of the problem-solving approach to learning, and closely resemble more formal methodology.

The value of using such a methodology is that it structures and organizes 'thinking' skills in the process of arriving at a solution. Ideally, through consistent and progressive development in the use of investigative skills from their first years at school, it will become second nature to children to organize a means of successfully achieving their objectives. The early years of schooling are particularly important, as this is when children develop learning patterns and form attitudes. A learning strategy can operate at all levels and in all situations when an objective needs to be reached, and it applies equally to teachers in their work as it does to children in theirs.

A MODEL FOR PRACTICAL PROBLEM-SOLVING

The following is a model used by the National Project team in its work with schools.

The thinking, sharing and interacting stages

1. What is the problem? A definition will include the setting of criteria for judging the success or otherwise of the solutions.
2. What possible solutions are there? Explore the full range of solutions, for example by brainstorming. Record all ideas suggested, even those that initially seem unlikely to be taken up.
3. Choose 'possible' solutions. (Can they be achieved? Take account of time, resources, skills, knowledge, etc.)
4. What solution is the most appropriate?

The making and doing stages

5. Try out your chosen solution.
6. Test your solution.
7. Evaluate the results—by reference to criteria established at 1.
8. Modify if necessary.

As mentioned earlier, the use of a method such as this structures thinking at all levels; at each stage during the process there will always be (a) the problem of the moment (constructing, modifying, changing, etc.) and (b) the overall problem, or the objective. However, it is not essential slavishly to follow this order of working. To do so would be to replace one set of didactic principles for another. During the process of problem-solving, it may be necessary to engage in further brainstorming or even to redefine the problem.

THINKING SKILLS INVOLVED IN PROBLEM-SOLVING

At each stage different thinking skills are exercised.
1 What is the problem?—The problem must be defined; this stage involves coming to a clear understanding of the final objective, or analysing the true nature of what is required.

2 What possible solutions are there?—Problem-solvers must resort to ‘creative’ or ‘lateral’ thinking, extending their thoughts to all ways in which a solution might be found. There are no wrong solutions. In the process of choosing those ideas most likely to achieve the desired result, brainstorming, particularly in groups of young children, generates frenzied interaction, noisily suggested ideas and much hilarity when humorous suggestions are put forward. Thinking is active and quick. It is a stage the teacher must prolong, so as to draw out all possible ideas. It is important that all ideas are recorded.

3 Choose ‘possible’ solutions—Analytical thinking is employed at this stage, breaking down each idea and discussing its feasibility. The number of ideas advanced during the brainstorming session must be reduced to the ones that could be achieved with the resources available. Are there sufficient materials? What time is available? Have we the expertise, skills and knowledge?

4 What solution is the most appropriate?—This stage involves decision-making, negotiation and comparison, employing a thinking process that is judgemental; it consists of weighing up one idea against the others, discussing its merits and drawbacks, until one solution is agreed upon.

5 Try out your chosen solution—We now arrive at an active, ‘making’ stage. It employs the type of thinking associated with structuring, predicting, measuring, estimating, assembling, trial and error until the solution has been carried out.

6 Test your solution—This stage necessitates accurate observation, recording and fair testing, to decide whether the solution meets the specification.

7 Evaluate the results—The problem-solvers should ask themselves the following questions: Have we been successful? Could we have done better? Have we all played an equal part? What have we learned?

8 Modify if necessary—Does the solution need to be modified? Does it need to be changed to meet the specified criteria?

The process is iterative—in other words, it keeps going back to previous stages. It employs many forms of thinking. Communication, both verbal and visual, is important: words and diagrams can be used in explaining the problem to others, and in discussing solutions and trying them out.

The traditional method of learning—that is, teachers supplying facts and information in a didactic way—has always been a secure approach. In the past, teachers have felt confident in knowing that they have had a sufficient fund of knowledge to meet the requirements of the curriculum. An investigative approach requires a greater consideration on the part of the teacher about how to create an environment in which children develop the skills of enquiry and learn how to apply them effectively.

**ACTIVITY 1: TRYING OUT STRUCTURED PROBLEM-SOLVING**

Apply the model described above to an activity of your choice in school. If possible, invite a colleague into the lesson to participate in this and to help you record what happens. Make a note of your findings and discuss the outcomes at a tutorial session.
THE VITAL ROLE OF QUESTIONING IN PROBLEM-SOLVING

An ability to stimulate thinking through questioning is an important aspect of this approach. Research shows that classroom teachers receive little instruction in this approach, either in their initial training or in INSET.

In a study of class interactions, the Oracle Report (1986) found that during a school day, 45.8% of teachers' communications with the class took the form of statements. Only 11% of the communications took the form of questions, and of these only 0.6% were sufficiently open-ended to require considered answers. Our own observations of teachers in classrooms in the initial stages of a project on problem-solving (in 1987) confirmed these findings.

ACTIVITY 2: IMPROVING COMMUNICATIONS

For a science activity you are engaged in with your class, analyse the time spent on different forms of communication. Discuss the outcome with your colleagues either at school or in a tutorial.

What positive steps could you take to increase the percentage of time spent on using a questioning and problem-solving approach?

We found that most teachers in the schools involved in the problem-solving project were anxious to have guidance and information on how to formulate questions for a particular purpose; for example, questions that are asked or problems that are set in order to develop and assist learning.

LANGUAGE AND PROBLEM-SOLVING

The ability to ask the right questions, using suitable language, is a skill that needs constant practice and review. The language used by the teacher can, if inappropriate, be counter-productive and destroy a child's confidence. For example, try not to use terminology that a child is unlikely to understand; the wording of the instruction 'Construct a mechanism that will ...' is appropriate at one level, but inappropriate at another. Words can, in themselves, either limit or extend the scope of a question or problem. For example, instructing the children to 'Make a vehicle that will ...' is likely to limit their thinking because the word 'vehicle' will be interpreted by most children as something that has wheels, such as a car or a lorry. The instruction 'Make "something" that will ...' is more open-ended and is likely to lead to a wider range of solutions. Some caution is also necessary in devising open-ended challenges. The challenges must not be so open-ended that they have no boundaries—there is no useful purpose in saying, for example, 'Make anything you like!' It is important to define the task so that just enough guidance is given to help the children, but without unduly limiting their ideas. The language used in practical problem-solving can easily become gender-biased, particularly if the teacher sees 'constructing things' as a masculine activity. A careful balancing of tasks will help to develop a broad and comprehensive view on the part of the children.

QUESTIONS IN THE LEARNING PROCESS

The way a question is asked, its structure and emphasis, indicates to a recipient the kind of response that is required. The simple question 'What are you doing?' can be a reprimand, or alternatively, show interest. A changed structure can place a stronger emphasis. The question 'And what do you think you are doing?' demonstrates strong disapproval, whereas 'Tell me, what are you doing?' indicates approval and interest. Most questions asked by teachers are closed questions, to which there is only one correct answer, for instance: 'What is 30 divided by 5?' or 'Who can tell me the name of the capital city of Italy?' This type of questioning often accompanies a didactic approach.
Some questions have no real answer; they are judgemental and represent a form of discipline. The question ‘And what time do you call this?’ is demanded of a child arriving late for a lesson and clearly demonstrates disapproval.

Open-ended questions are the most productive when learning is required, but should not be seen as exclusive. They require the recipient to weigh alternatives against each other and make a considered response.

A number of different types of question may be asked in order to reach an objective.

- **To draw out information**—Teachers use a particular form of questioning to patiently draw out information from a child or group of children. It often consists of a number of sequential questions that help children to reach an understanding. The teacher needs carefully to listen to the children’s own ideas so that they can be guided towards their goal. The danger is that teachers sometimes make assumptions about what a child has understood and force a premature outcome.

- **To analyse a problem**—Questioning of oneself or others is a valuable thinking skill. It is vital that children acquire the ability to break down a problem into parts, exclude irrelevancies and recognize its true nature.

- **To develop creative thinking**—Most children rush into early decisions as to what they are going to do. They treat a project as if it were a competition and want to be the first ones to start making and doing. They need to learn that exploring the fullest range of outcomes is a necessary stage; it provides a wider choice of alternatives, and is a discipline essential to the problem-solving process. The question ‘What other ways can you think of?’, in whatever form it takes, is important in extending children’s ideas.

### ASSESSMENT

Assessment of what a child has learned can be made by conducting an interactive dialogue—one of the most reliable methods. Through considered questions, a teacher can help children to form understandings and crystallize their thinking, which helps them to develop skills of self-assessment.

### ACTIVITY 3: CONSTRUCTIVE QUESTIONING

For a science activity or investigation of your choice, list a set of questions you could pose that would help your class to develop their experience and understanding in that area of science.

### CONCEPT DEVELOPMENT

It is said that problem-solving is important in the development of children’s understanding of certain concepts. This is true, but only when the teacher identifies the concepts and plans strategies by which the children can come to terms with them. Practical problem-solving is a most effective tool in developing those concepts best understood through physical proof. It is difficult for a child who has calculated the volume of a container mathematically to understand how this volume relates to the number or amount of different things that will fit inside it. Only by trial and error will he or she come to see that the same volume will hold, say, 40 marbles, 3 cotton reels, 1 tennis ball or 250 g of sand.
SET PROBLEMS

For many teachers, giving the children set problems, such as appear in publications like The Great Egg Race Book (British Association for the Advancement of Science, 1986) represents problem-solving. Teachers find them useful because children enjoy doing them—but how often do they ask themselves the questions:

- Why am I setting this problem?
- What are my objectives?
- How am I going to build on the experience?
- Does the problem fit into the topic we are currently investigating?

Most of the publications containing a selection of problems do not give any guidance as to their appropriateness and value. If teachers set problems that do not meet an identifiable learning need, they are wasting a valuable learning resource.

Example 1

Setting a problem can be an ideal means by which the teacher can develop the child’s understanding, and this can be built on in follow-up work. The child is encouraged to think of and explore a number of possible outcomes or solutions yet is also guided in a positive direction. A common set problem is to ask children to make a marble roll from the top left-hand corner of a sloping board (of approximately 75 x 75 cm) to the bottom right-hand corner. Very young children may be asked to make it take a 'long time'; older children will be given a specified time, say 12 seconds.

This problem will result in children exploring:

- the conversion of gravitational energy into kinetic energy
- the way in which the gradient of the board affects the time taken for the marble to cross it, and the final speed of the marble
- the fact that the time taken for a given gradient is independent of the mass of the marble.

There are many possible solutions, yet the problem concentrates on these main concepts. An advantage of this type of problem is that it will prove equally stimulating and rewarding for children of a wide range of abilities. Careful measurement and calculation of the angle of descent, the distance travelled, and the mass of the marble will be demanded at one end of the range, and simple trial and error leading to a successful conclusion at the other.

Careful planning is essential to ensure that activities meet children’s specific learning needs. It is also important that exercises are linked to progression in understanding. Ideally teachers should construct their own problems, lead into the exercise with questions that identify the purpose of the activity, and also use questions to evaluate what has been achieved in the process.

Example 2

This example demonstrates how a child can come to understand the properties of one type of material in a constructional activity.

The aim of the exercise is to get children to understand that different types of bridges have different strengths, and to explore making weak materials strong, and turning weaknesses into strengths, for example by folding.
A suitable teaching strategy is suggested below.

- Using open-ended questions, encourage the children to think of the different ways in which they could make a paper bridge strong enough to hold a weight. Ask them what they think will make the paper strong.

- Give the children the opportunity to try out their ideas. Draw their attention to any folds that they may have made in the paper. Have they used folds to give the paper strength? If so, ask them what the folds are doing.

- Encourage the children to think about the similarities and differences between bridges that they have made. Ask them comparative questions, such as: How are the bridges different? Do they think that one bridge is better than the others? If so, why, and in what way? Do their different shapes remind the children of bridges that they have come across elsewhere? If so, in what way are they similar?

- After testing the properties of the bridges, discuss with the children what conclusions they have come to, asking them questions such as: Which bridge do they think was the strongest and why? What do they think caused one bridge to collapse before the others?

- Get the children to make comparisons between card and paper as bridge-building materials. Encourage them to discuss the different ways of folding paper and card, and to predict what they think will happen to each of the bridges. Ask the children questions to make them think about what they are doing, such as: What do they think will happen? In what ways do they think that a card bridge will be different from a paper one? Which do they think will be the strongest and why?

- Allow the children to try out different ways of making bridges with paper and card before they decide on a way of making the bridge for the fair test. Discuss with the children what is meant by ‘a fair test’.

- When the first fair test has been done, encourage the children to think about what happened by asking: Were their predictions right? Why do they think things happened as they did? Which materials do they think made the best bridges and why? Ask whether they think that they chose the best way to make the bridges? If so, why? If not, how might they change the way they made them?

Be prepared for the unexpected. Children may join strips of paper to make a ‘rope’-type bridge. Bridges may also be made out of boxed or folded card, rolled paper, corrugated paper, or corrugated paper held together with glued paper strips to hold the corrugations rigid.

In the short activity of making a paper bridge, children may learn nothing more than how to make a strong bridge from paper and glue. Asking them considered questions that probe their understanding can bring them to a realization of why bridges are structured in particular ways. Observations of real bridges, their construction, purpose, shape and material, will add value to the exercise.

Constructed problems can be of great help to a teacher when properly used and can:

- develop and reinforce an understanding of important concepts
- provide a means by which children can investigate the properties of materials
- provide a sequence of activities leading to the application of gained knowledge.

We saw how conceptual understanding was encouraged in the marble-rolling problem, for example, where the concepts of energy, control, time and speed were considered; in the bridge-building problem, the concepts were those of material strength, shape, size, stability and load. Numerous other set problems are available to support conceptual development, but it is often more useful if they are constructed by the teacher.
In the early stages, it is best to confine the problem to an investigation of the properties of one type of material, as shown in the bridge-building exercise. With experience, children will gain knowledge and be able to make comparisons of one material against another, and so learn how to combine materials to give the best results.

The following example illustrates how progression can be achieved through problem-solving. The children make predictions, observe outcomes, test hypotheses, try out prototypes and apply their knowledge in the design of an artefact. The process is a gradual one and should not be seen as a 'timed' activity. The activities could extend over a period of time as part of a topic on water transport.

Example 3

Water play is a feature of nursery and reception infant classes; however, recent research shows that little is carried on into middle infant classes, and it is virtually non-existent at top infant and junior levels. Example 3 builds on children's experiences of water play and requires children to express their ideas and predict possible outcomes. It also requires that they test their hypotheses.

As part of a project on problem-solving, 8-9-year-old children were asked to collect together an assortment of bottle corks and guess how these would float if they were placed into a container of water (i.e. upright, horizontally, at an angle, etc.). They then put the corks in water, and observed what happened. Afterwards they were asked: 'Did all the corks float in the way you expected them to?'

The teacher built on this knowledge by asking: 'Can you find a way of making your corks float in an upright position?' They were provided with a range of other materials, such as wire, weights, Plasticine, etc. When they succeeded in making their corks float in an upright position, they were encouraged to think of how this discovery could be used in real life, and asked to find out what other things float upright in the water.

After a day or two, the teacher returned to this activity to explore how wind could be used to make a sailing boat move. Again through questioning the teacher established from the group that sailing boats sail on water and use the 'force' of the wind to propel them along. They were then asked to make a sail for one of the corks using a cocktail stick and a piece of paper or cloth; after they had had an opportunity to try this out, they were asked whether the cork sailed well or whether the mast and sail toppled over into the water. The majority of models did not sail well; the children were then asked why they thought the mast and sail had toppled over.

Other questions posed in this part of the exercise were:
- Can you use your solution to the earlier problem to make the cork float upright?
- Can you now make the cork move along by blowing or fanning the sail?
- Did the cork travel along smoothly or did it bob up and down?
- Would a floating cork with a sail make a very good boat?

Much has been said about process being more important than product. Practical problem-solving requires both: process and product are indivisible. Earlier explorations provide the foundation of knowledge that leads to the design of the final product.

Records are vital if progressive understanding is to take place, and children should be making notes about and drawings of their observations and discoveries. The children in this project found out that a cork is extremely buoyant and has many uses; however, it is not a particularly suitable material for use in the design and manufacture of a sailing boat capable of transporting passengers and cargo safely. On returning to the investigation of other materials, they found that a material that was not a good floater in one form could be changed into one that
was; for example, a lump of Plasticine dropped into water would sink, but when modelled into a boat shape it would float.

In the project on floating and sailing, understanding of concepts was developed through trial and error; the children learned how to make something float the way they wanted it to, and discovered that non-floating materials could be used to stabilize a floating material. They also learned that this knowledge could be applied in a specific way. They recognized a range of uses for things that float on water, and the need to think carefully about materials, shape, size, mass, etc., when designing something for a specific purpose. Their education in structuring their enquiries made them able to construct criteria for success that proceeded via process to a well-considered, and successful, product.

THE WAY WE LEARN—CREATIVE AND REFLECTIVE THINKING

The examples of problem-solving in the classroom that we have been looking at show that teaching style, and a positive attitude on the part of teachers towards asking children questions, are crucial to drawing out ‘deliberate, effortful cognition’ (Brown et al., 1987). Open-ended questioning and a reciprocal/collaborative teaching strategy are held by Bruner (1978) to be a vital aspect of a teacher’s ‘expert scaffolding’. Expert scaffolding is a natural teaching style whereby a teacher provides a supporting context in which children acquire skills. As a child becomes more competent, the teacher raises the level of work to a slightly more challenging level.

Often a problem-solving approach is linked solely to creative and expressive modes of thinking/acting. Garrett (1989) says that:

Creativity has been discussed extensively and hesitantly in the literature ... One way in which many science courses seek to encourage creativity is to provide a problem-solving approach. This is firmly established at primary and early secondary level and powerful voices call loudly for this bottom-up change to continue through to advanced levels ... While recognizing problem-solving as an important process to be cultivated, a too narrow view of what problems are denies pupils the chance to exercise their creative potential. Most of what passes for 'problems' in science are a series of restricted and sterile puzzles requiring solutions or at best resolutions. Genuine problems—open situations, perplexities—demand a high level of creative effort to be understood and solved.

West (1981) has suggested that science within the curriculum will need to be radically reconstructed and has included in his restatement of the aims of education: ‘the scientific study of creativity—a study of problems and the production of solutions’. It may be that the records collected from schools that participated in the project on problem-solving will enhance the study required by West.

It can be seen that problem-solving is increasingly being recognized as an important part of the expert scaffolding of education, both as a means of facilitating learning and as an exercise in acquiring the skills of problem-solving itself. Certainly it is well regarded by teachers as a fundamentally valuable approach to practical activities. In addition to its links with creativity, there is evidence that problem-solving is linked with an increased aptitude for academic/reflective modes of thinking and learning.

The model of problem-solving outlined in this article mirrors perfectly other active approaches to learning. It is also congruent with the very elements of the way we all learn and come to a rational understanding, and with the accepted models of scientific and creative thinking.
CONCLUSION: RELEVANCE ACROSS CURRICULUM BOUNDARIES

All the set problems used as examples in this article can be inserted into a cross-curricular programme of work. It is, however, important on some occasions to establish skills, concepts and knowledge outside the topic, reinserting them at a later stage when it is necessary to bring out their relevance in a cross-curricular scheme of work.

To gain the full benefits of an investigative approach to learning, it should be consistent throughout a child’s schooling. It is a sad fact that all too few schools work to a common philosophy. Children can, unfortunately, be taught by formal teaching methods for one term and informal the next; this inconsistency surely is unacceptable. Learning strategies should, in themselves, be progressive and developmental. However, the project team found that in the main the quality of questioning diminished as children advanced through school; more searching, open-ended questions were asked at reception infant level than in the majority of junior classrooms.

In the experience of the project team, it has also been evident that an investigative approach to learning appears to be extremely successful when linked to cross-curricular schemes of work and cooperative learning approaches. The organization and management of work spaces is also very important, as is the creation of a stimulating working environment. However, the investigative approach is most effective when both teachers and children recognize their own importance, as sources of ideas that they are willing to share. It is an approach that fosters self-confidence, develops positive attitudes towards others, and encourages cooperation.

REFERENCES AND FURTHER READING


ASSESSMENT IN PRIMARY SCIENCE

Mary Horn
Advisory Teacher in Primary Science, Avon

In this article, Mary Horn examines what is meant by assessment and why we need to assess. She discusses methods of collecting and recording evidence of children's capabilities, and suggests ways in which assessing in science differs from assessing in other curriculum areas.

We examine a recent article by Dorothy Watt which considers the role of children's recording in the assessment process.

INTRODUCTION

Assessment has always been an integral part of the teaching and learning process, whether at the level of an individual teacher's awareness of the general ability of a child, or as part of a more formal assessment procedure. The national curriculum has thrown the whole process into sharp relief, especially in science, where teachers often have little experience of teaching the subject and have done almost no assessment on it. In looking at the topic of assessment we need to consider a number of questions:

- What do we mean by assessment?
- Why do we need to assess?
- How do we collect the evidence?
- How do we record the assessment?
- Is assessment in science different from assessment in other areas of the curriculum?

The rest of this article will address these questions.

WHAT DO WE MEAN BY ASSESSMENT?

Assessment is the process of gathering information about an individual child. It provides information about the child's experience and achievement when compared with a certain level or standard, and helps to show what that child knows, understands and can do. It does not simply mean the testing of children; it is linked more closely with the need of the professional teachers to inform themselves about their pupils in order to help them make progress. The Task Group on Assessment and Testing (1988) states that:

The assessment process itself should not determine what is to be taught and learned. It should be the servant, and not the master, of the curriculum. Yet it should not simply be a bolt-on addition at the end. Rather it should be an integral part of the educational process, continually providing both 'feedback' and 'feed forward'. It therefore needs to be incorporated systematically into teaching strategies and practices at all levels. Since the result of assessment can serve a number of different purposes, these purposes have to be kept in mind when the arrangements for assessment are designed.

WHY DO WE NEED TO ASSESS?

It is important to answer this question, because the whole process of assessing, recording and reporting depends on your reasons for needing this information. If
it is not going to be valuable, then it is a waste of your professional time. If you are not convinced that assessment is of value, you will consider it to be a waste of time.

**Assessment should help the children to learn more effectively**

It should:
- inform teachers about the progress made by individual children
- enable their strengths and weaknesses to be identified
- indicate the next step in the learning process
- involve the children and show what they can do
- motivate children through success.

**Assessment should help teachers to evaluate their teaching**

It should:
- indicate strengths and weaknesses in the teaching programme and style of teaching
- indicate the next step in the teaching programme
- indicate which children need support and which need extension
- guarantee teacher–child contact.

**Assessment should provide information for others**

It should:
- provide information for parents
- provide information for colleagues in school
- provide information to assist in the transfer of the children to a different class or different school
- provide information for guidance and/or referral.

**HOW DO WE COLLECT THE EVIDENCE?**

As you work in the classroom with the children every day, you will get to know their strengths and their weaknesses. Teachers have always gathered information about their children that can be built up into a picture or profile of each one. Much of this information is conveyed in snippets: a significant phrase; an idiosyncratic sentence; a model or a picture that incorporates a particular detail; the way a child interacts with a friend.

Some ways in which you can gather the information are to note:
- what the children say—both to you and to each other
- what they do—how they tackle problems or investigations
- what they produce—whether it is written work, pictures, models or patterns on a computer screen.

The rest of this section draws on a recent article by Dorothy Watt (1990), which looks at examples of the types of recording that children do as part of science, and suggests ways in which these might be used by teachers to assess the children’s experiences and understanding.
The types of recording can be categorized as follows:

- **Recording as detailed observation**—Recording detailed observations in the form of drawings, or as a verbal or written report, can convey the children's understanding of what they have observed. The record should be seen as a starting-point for discussion between the child and the teacher. In this way, evidence can be collected of the child's ability to observe and to communicate.

- **Recording as thinking**—Asking the children to write or draw their ideas about scientific concepts before they have carried out any investigations on them gives them the opportunity to consider, at some length, what they understand by these concepts. Drawings or writings of this kind can show a child's ability to make predictions and hypothesize about an idea in science, a skill that is required at level 3 of AT1.

- **Recording as visualizing**—Children can learn to represent on paper processes such as sound travelling or evaporation. This is a valuable means of identifying the ideas that children have about scientific concepts.

- **Recording as planning**—It is important for the children to plan their activities logically. The teacher needs to keep a record of a child's progress in this skill.

- **Recording to recall**—Writing about science after an investigation has been completed can help children develop skills of sequencing and recall, and shows their interpretation of events.

- **Recording results**—Outcomes of scientific investigations can be recorded as tables or charts, a skill that is assessed in AT1 at levels 2 and 3. These forms can also constitute a working record, which the children can draw up as they are doing the investigation, and which will serve as an adequate summary of the work.

- **Recording as interpretation**—This form of recording requires children to make sense of their results in the framework of their own understanding, and will provide evidence that the children are interpreting findings by associating one factor with another; this is a skill that is required at level 2 of AT1.

Dorothy Watt concludes that 'if children are encouraged to record in a meaningful way, then they might see the value of doing so and choose to do it of their own accord. Recording could become an independent learning tool for them'. She also suggests that children could use their recording as a basis for self-assessment, comparing predictions and hypotheses before they start an investigation, with the results obtained after it.

**ACTIVITY 1: CHILDREN’S RECORDING IN SCIENCE**

Over a period of 2 or 3 weeks, make an analysis of the function of the recording your children do as part of their science work. Compare the range of skills they use and develop with those outlined above.

It is essential to realize that assessing the process, or the stages through which a child works, is every bit as important as assessing the final product. It is not enough to observe a class as they go about their daily activities and pick up pieces of information; you need to talk to the children, or set them specific tasks that will supply you with information useful in assessing particular areas of their skills and knowledge. Sometimes it is necessary to work with individuals as well as with groups. Group discussion does not always inform you about what an individual knows. You also need to be aware that the use of jargon or technical language can mask a child’s lack of understanding.
A correct word repeated parrot-fashion, or given in response to a question, may deceive you into thinking that a child understands the concept that the word represents.

HOW DO WE RECORD THE ASSESSMENT?

As teachers, you make thousands of assessments each week, most of which it would be quite ridiculous to record, as well as being an intolerable burden. However, significant pieces of information of various types do need to be recorded, and suitable methods of doing this should be considered. You need to be able to jot down items on a day-to-day basis as well as supply a more formal assessment. Some suggestions are given below:

- Many teachers find a notebook useful for jotting down any day-to-day incidents or snippets of information. A page for each child should give you sufficient space.
- A more formal record sheet can be used to list certain information about the children that is intended to be a more permanent record of their abilities. Details can be filled in as a result of talking to them or setting them particular tasks.
- Photographs are useful to record transient products or events, such as models, which will eventually be broken up, or investigations that are under way.
- Written work, pictures, designs, graphs, etc., can build up to give a profile of a particular child.

All these different types of information, together with other evidence about the skills and understanding of the various children, form a huge database. You will need to be selective as you review, interpret and annotate this information so that it is presented in a manageable form. Most schools have designed some kind of summary sheet to help in this process.

Much of the information you have gathered will inform the planning of future work; some of it will help you to know whether the children have understood what you have taught them; and some of it will form part of the record that you will want to keep, and perhaps pass on to others.

ACTIVITY 2: RECORDING CHILDREN’S ACHIEVEMENT

Discuss with your colleagues in a tutorial the methods of recording achievement in your school.

IS ASSESSMENT IN SCIENCE DIFFERENT FROM ASSESSMENT IN OTHER AREAS OF THE CURRICULUM?

The science curriculum has certain aspects in common with other subjects as regards the teaching and learning processes. These common areas include:

- developing the child’s personal qualities, attitudes and ways of working
- encouraging the child to get to grips with the processes of learning, questioning, reasoning and responding to challenges
- developing the skills of communicating, discussing, exploring and interpreting information.
However, science is different from other subjects in that it includes two different but inseparable strands—the knowledge area of science and the processes of scientific enquiry.

**ACTIVITY 3: ASSESSING SCIENCE**

Devise a strategy for assessing an area of science you are currently teaching. Show how you would assess the appropriate levels of AT1 and the particular area of content you are covering.

Assessment in science must take account of these two areas—knowledge and processes. It is a relatively straightforward task to identify and assess one small facet (for example how well a child observes or how accurately measurements are taken), but an equally important consideration is whether the child knows what to observe or when he or she needs to take measurements to prove a hypothesis. How well a child performs a task should not be considered in isolation; you must always consider whether the task is the most appropriate one to perform at a particular time.

Ideas about ways of implementing assessment policies and schemes are bound to change over the next few years; we should be reassured, however, that there are no experts in making sense of the statements of attainment of science. What we will gain from assessment is an improved knowledge about children’s learning which in turn will be valuable for our own future planning.

**REFERENCES**
