SCIENCE IN PRIMARY SCHOOLS

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INTRODUCTION

The research described in this report was carried out to extend information concerning science in primary schools which was collected as part of the second *Annual Survey of Trends in Education* carried out by the National Foundation for Educational Research (NFER).

The survey was conducted in autumn 1995 and consisted of a number of 'barometer' questions together with a special focus. The 'barometer' questions look at current issues in education, and are therefore included in each survey in order to monitor changes in schools' perspectives over time. Each year the survey has a different special focus which is designed to obtain detailed information about one aspect of primary education. The special focus for the 1995 survey concerned science, and was intended to find out how schools are teaching science in the National Curriculum following the Dearing Review.

This report presents information collated from responses to the *Annual Survey* questionnaire, together with other information collected as part of follow-up work focusing on science in primary schools; it therefore includes:

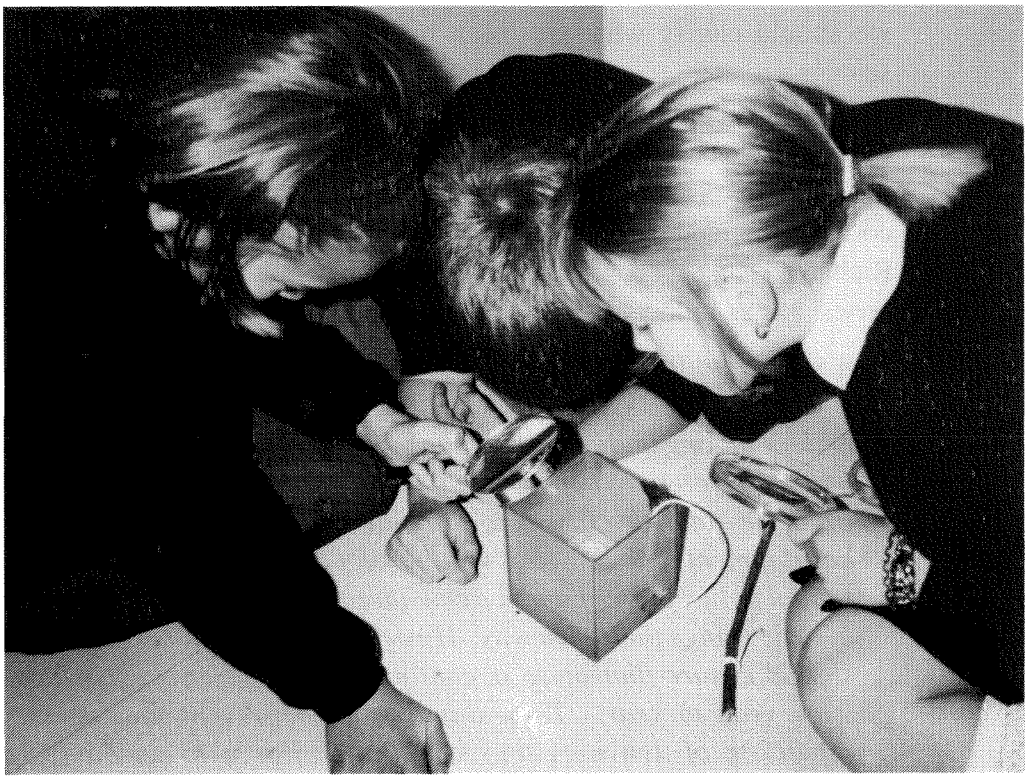
- a review of some of the current literature relating to the topic: some of the issues discussed arose from the literature studied, whereas other issues were suggested by an examination of responses to the science section within the questionnaire;
- details of responses provided by the primary school headteachers who completed and returned the questionnaire;
- an analysis of science policy documents which were provided by a small number of schools;
- more detailed information about the practices in place in a small number of schools: a few schools were identified as having some particularly interesting policies and/or practices with regard to science from their responses to the questionnaire. Where these schools were willing to assist with the research, in-depth information was collected by means of either visits to the schools concerned, or telephone interviews with key personnel.

A total of nine schools provided detailed information about their science teaching, five through visits to the schools (identified as Schools A-E within the report) and four through telephone interviews (Schools F, G, H and J). Descriptions of the practices and approaches used in these schools are included both to illustrate particular points in the text, such as practical science activities, and to describe some approach of interest, such as a system for locating particular resources. The illustrative examples can be distinguished from the main text as they are in a different typeface and are set within boxes.

This report is structured so that Part 1 presents the issues arising from current literature and/or questionnaire responses, and Part 2 presents information on responses to the questionnaire survey, together with the analysis of schools' policy documents. Illustrative examples of particular practices obtained from individual schools are included in both Part 1 and Part 2 as appropriate.

PART 1:

CURRENT ISSUES



1.1 DEVELOPING SCIENCE POLICIES AND SCHEMES OF WORK

Clearly, a whole-school policy for science which has been agreed by all teachers is an essential prerequisite if effective teaching and learning of science are to take place throughout the school. However, before going on to consider some of the issues concerning school policies for science, we should clarify what we mean by the term 'a school policy for science'.

Schools have been able to refer to the guidance offered by specialists in the field of primary science, published sources and materials and courses provided by LEAs, to name but a few. The guidance given by Richards *et al.* (1980, p.8) as part of the then widely used Science 5 - 13 series was as follows:

> *A school policy is not a syllabus, this must be made clear at the start. Rather a policy statement is an account of the school's understanding and interpretation of 'science' ... The policy should include reference to methods of teaching and how these change from the younger classes to the older ones and how records of development and activities will be kept and collated. Within the school policy there should be considerable flexibility for teachers ... to do things their own way. However, the guidelines laid down should ensure that there is continuity in children's experience from year to year. They should aim to prevent unnecessary repetition of activities thus enabling children to encounter a range of scientific ideas, and ensure that a record of progress is kept.*

Richards *et al.* (op. cit.) went on to suggest three main issues that should be addressed in a school policy for science:

- the time allocated for teaching science
- the collection, purchase, storage and retrieval of resources
- ways of working that concern the school as a whole.

More recently Cox and Taylor (1989) recommended that the school policy document for science should provide clear guidance to teachers in the following areas:

- a clear definition of the science subject matter to be studied
- a precise statement of learning objectives, which should promote children's conceptual understanding of science
- courses must provide for continuity and progression: this will require ongoing assessment so as to match teaching to pupils' stages of development.

Although clearly both of these sources pre-date the introduction of the National Curriculum and statutory requirements with regard to science as one of the core subjects, the guidance they provided would seem to be as relevant today as when it was originally written. Research carried out by Carrington and Tymms (1994) into primary headteachers' views suggested that there was widespread recognition of the importance of whole-school development of guidelines for teaching: over 70 per cent of respondents agreed that 'decisions about teaching methods and classroom organisation should be taken on a "whole-school" basis' (p.213).

However, in most, if not all schools, the overarching guidance provided in the school policy is supplemented by more detailed schemes of work which describe how the policy is to be implemented in terms of the experiences, resources, teaching styles, timescale and assessments relating to particular aspects of the science curriculum for specific age groups.

In terms of planning and teaching science within key stages 1 and 2, NCC (1993a, p.57) described the different levels of planning that are required as follows:

> *A scheme of work reflects the ethos of the school and is based within the contexts of its staffing, location and size. It expands on the school's policy for science education, which contains broad aims about the nature and scope of the science to be taught. Like the school's policy for science, a scheme of work is best developed by the whole staff (the detailed scheme of work sets out the structure of the learning experiences for the children). It ensures coverage of the PoS and ATs in appropriate ways and leaves room for flexibility. The scheme is a working document that supports planning. It should be constantly reviewed and changed in the light of experience and changing demands.*
>
> *The scheme of work for science is the broadest level of description of what is taught and the way it is taught. The next, more detailed, level concerns the component areas of study that are based on science ideas. Within these areas of study the classroom activities are planned which relate to knowledge and understanding, the skills and processes of AT1 and assessment opportunities. These represent the most detailed level of description of the teaching plan, and should leave teachers some flexibility in the structuring of activities, use of resources, including published schemes and other educational materials.*

SCAA (1995) identified three levels of planning:

- **long-term:** describing the overall curriculum aims for each year group within each key stage in the school

- **medium-term:** providing the details of work for each year group – this level of planning should involve year group/key stage teachers together with support from the science coordinator

- **short-term:** this focuses on how individual class teachers intend to implement the medium-term plans on a day-to-day basis.

SCAA went on to differentiate between two main types of work: **continuing work**,which would be ongoing throughout the year, and **blocked work**, which would focus on a particular aspect and therefore be taught within a finite period of time not longer than one term. In terms of covering the science curriculum, it would seem appropriate that the practical and investigative skills of Sc1 should be classified as continuing work; this would ensure that pupils were given opportunities to develop their skills in a variety of contexts, as they focused on different aspects of science content in their blocked work over a period of time.

NCC (1993a) suggested that the issues which should be addressed within the scheme of work included:

- **areas of study:** for each key stage and year group; the coverage of attainment targets across and within themes; opportunities for continuity and progression should be identified and built in;

- **activities within the areas of study:** each activity should detail objectives in terms of developing knowledge and understanding; they should also allow for the development of practical and investigative (Sc1) skills.

In more general terms, NCC considers that a scheme of work should ensure:

- *breadth, balance and relevance*
- *equality of access for all children*
- *continuity and progression*
- *differentiation*
- *links across the curriculum*
- *a range of teaching methods*
- *that appropriate assessment opportunities are identified* (p.58).

Further points which schools need to consider include:

- the time allocated for each section of work
- the links to the programme of study
- resource materials.

With regard to the issue of what impact the introduction of the National Curriculum has had on teachers' schemes of work for science, different commentators have expressed different views. In a report published as the National Curriculum was being introduced, Her Majesty's Inspectorate (GB. DES. HMI, 1989, p.10) described their findings from school inspections, and commented that although teachers were planning science activities for their own class,

> *... they seldom showed how the activities would progressively develop the children's scientific knowledge, understanding and skills ... The weakest aspect of planning was often at the level of the whole school, and this led to worthwhile science in individual classes being unrelated to the work which preceded or followed it.*

Similar views were expressed by Alexander *et al.* (1992) and OFSTED (1995), the latter observing: 'There is a lack of detailed curriculum planning for science at the whole school level in primary schools which hampers the monitoring of the experience of individual pupils' (p.4).

On the other hand, Smith (1994) considers that there has been a move away from teachers' independent planning of science teaching (frequently using a topic approach) for their own classes in the 1980s, where time was flexible and there was an amount of freedom to allow pupils to pursue areas of interest. Instead, the introduction of the National Curriculum has resulted in: '.... a growth of joint planning, sometimes in teams and sometimes done mainly by a subject coordinator who has an overall brief for the school. The scale of planning has stretched to span a Key Stage' (p.173).

Smith considers that, rather than enhancing primary science, this move has brought disadvantages:

> *... it has constrained teachers who had never operated within a statutory framework, directing their attention to long-term planning rather than detailed planning of lessons and classroom interactions... The preoccupation with the letter of subject Orders is reflected in the language of teachers' planning – 'covering', 'delivering', 'recording'* (p.173).

However, despite these reservations, Smith acknowledges that 'the collective planning and sharing of expertise by teachers is probably one of the major gains of the last few years' (p.173). This view is echoed by Gosden (1991, p.66), who considers that, with regard to the National Curriculum, '... one of the most noticeable developments has been the sharing of expertise amongst teachers and cooperative planning ... Planning has been more comprehensive and long term than in the past with benefits for all.'

An interesting approach to the planning of science work throughout the school was found in School D.

School D (a large suburban primary) had decided that the whole school would do the same general topic, focusing on the programme of study relating to the same attainment target at the same time. When I visited the school, everyone was involved in work related to Sc2: Life Processes and Living Things, although there were different emphases in different classes:

- types of plants
- growing plants
- classification of animals
- human skeleton
- human organs
- Sc1 investigation: do the children with the longest legs run the fastest?

The science coordinator explained that the task of determining individual pupils' levels of achievement was made easier by having the whole school (from reception to Year 6) involved in work related to the same attainment target at the same time because there was plenty of similar work to use for comparison.

Summary

Before the introduction of the National Curriculum, there was considerable variation in not only the content of schools' science policies and the level of detail of their planning, but also the range of experiences and activities offered to pupils. Although some commentators have suggested that the specificity of the National Curriculum Orders has restricted flexibility, many have observed the increased levels of collaborative planning and the improved cohesion in schools' science provision and concluded that this is undoubtedly one of the benefits of the introduction of the National Curriculum.

At school level, teachers need to prepare a school policy which addresses issues that affect the whole school, such as the time allocated for science, the resources available, teaching methods and assessment. This should be supplemented by schemes of work which describe long-, medium- and short-term plans for implementing the science curriculum within each year group and key stage.

1.2 ASSESSMENT

Many commentators (such as HMI, 1989; NCC, 1993a and ASE, 1993) have stressed the importance of identifying opportunities for assessing pupils' attainment when drawing up schemes of work. Some, such as Cox and Taylor (1989) and ASE (op. cit.) have pointed to the fact that assessment aids future planning, as well as serving a summative purpose, with the latter observing:

> *It can give teachers information about the levels of children's knowledge and understanding and help them to see which children need extra experiences and which members of the class are ready for more demanding work... It aids planning and thus helps to take children's learning forward. It also provides a summary of children's progress* (p.11).

With regard to **how** teachers assess their pupils, we may identify a number of strategies, including:

- observation of pupils carrying out practical activities and investigations
- questioning pupils about their work
- examining pupils' records of the work they have done
- the use of specific written tests.

The content-based attainment targets have made it feasible to use paper and pencil-type tests to determine whether or not pupils have assimilated particular aspects of knowledge; the format of standard assessment tasks at the end of key stages may also encourage teachers to familiarise their pupils with this type of assessment. In addition, the move from statements of attainment to level descriptions for each of the science attainment targets may have made the assessment of scientific knowledge and understanding more manageable for teachers.

On the other hand, the process skills clearly require a different type of assessment, in addition to a context within which to be set. Harlen (1991, p.327) stresses the fact that the context in which primary pupils exercise science process skills and attitudes will influence the level at which they operate:

> *In making an observation, proposing a hypothesis or planning an investigation there has to be some content – each has to be about something. What the 'something' is makes a considerable difference to the performance. For example, we make more relevant and detailed observations of something familiar than of something unfamiliar; we are more likely to plan a fair*

> *investigation of something if we know what can affect the result than if we do not; we may persevere and cooperate in a difficult problem if we know enough to believe that a worthwhile outcome can be achieved. Thus the level at which process skills are displayed depends on the subject matter.*

Having stated that in order for assessments of pupils' science skills to be valid, they should be carried out in the context of their ongoing activities, Harlen (op. cit.) goes on to suggest the types of question that the teacher may ask her/himself when observing the work of children at key stage 1, and questions relating to the particular activity which could form the basis of a discussion involving the teacher and the pupils after their activity/investigation. Harlen suggests that questions which focus on the skills involved and are independent of the context in which the activity is set (e.g. exploring the movement of toy cars, seeds growing, objects floating and sinking) can be used by the teacher in many different contexts. For pupils at key stage 2, Harlen describes the types of assessment of process skills that were carried out under the Assessment of Performance Unit (APU), where pupils were asked to respond to a number of questions set in different contexts. She comments that this approach has the advantage that 'the result is the average performance over a number of different subject matter items' (p.332).

Although there are obvious time considerations when a teacher decides to assess a child's process skills in several different contexts, Harlen (op. cit.) warns against assessing pupils' skills on the basis of their work in only a few contexts:

> *Because of the influence of subject matter on performance it is not possible for a few special activities to yield a very reliable assessment; thus these must be supplemented by observations made over the wider range available in normal learning activities* (p.337).

Other issues relating to the effective implementation of assessments are listed by Donnelly *et al.* (1994, p.9):

> *... the number of times each statement needs to be 'achieved' before it is 'awarded'; whether different statements can be awarded on the basis of different investigations; whether a pupil can 'skip' levels; the acceptability of 'help' sheets; and so on.*

These comments were made before the publication of the 1995 Orders. Nevertheless, the issues remain relevant, although the move to level descriptions requires teachers to consider 'which description best fits the pupils' performance' (GB. DFE and The Welsh Office, 1995, p.49).

The subject of the questioning techniques used by teachers to make assessments of their pupils' scientific knowledge and skills was explored in some detail by Torrance and Pryor (1995), who studied interactions in infant classrooms and were able to propose two models of assessment (which could arguably be applied to key stage 2 as well):

- **convergent teacher assessment** – this represents a behaviourist view of education; teaching and learning are viewed in a linear progression; there is closed or pseudo-open questioning and tasks;
- **divergent teacher assessment** – this is characterised by less detailed planning; it represents a constructivist view of education (see Section 1.7); teaching takes place in the 'zone of proximal development';[1] questioning and tasks are open rather than closed; adherents hold a view of assessment as a joint venture by the teacher and pupil together rather than something the teacher does to pupils.

In the convergent model, the teacher is likely to plan a particular activity with the intention of using it to assess pupils; in contrast, using the divergent model, assessment may be more impromptu, capitalising on opportunities for assessment whenever particular behaviour is in evidence.

Torrance and Pryor's observations suggested that not only are both models found in the same school, but they are also used by the same teachers:

> *One teacher in the study, for example, uses two types of recording schedule when making assessment in the classroom: one consists of a (class) list of names with a space for a tick and a short comment, whilst the other is just a blank sheet of paper for each 'focus' group of eight children. The first is used for recording quickly whether or not, for example, the children can add up to ten accurately. The second is more open and flexible and is used more to record 'starting points' than final learning outcomes* (p.317).

With regard to the issue of teachers setting up specific activities for pupils with the intention of making assessments, it is worth noting the following comment made by OFSTED (1995, p.3): 'Science lessons are mostly well planned, with clear objectives, but over-prescription limits achievement in a significant proportion of lessons in all Key Stages ...' A further dilemma which teachers must face therefore concerns the issues of open-endedness of investigations and the manageability of assessment as compared with over-prescription and the possible consequence of limiting attainment.

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[1] Vygotsky (1978) defines this as 'the distance between the actual developmental level as determined by independent problem solving and the level of potential development as determined through problem solving under adult guidance or in collaboration with more capable peers' (p.86).

An important consideration for teachers to bear in mind is the time required to carry out assessment, as pointed out by SCAA (1995):

> *Assessment is an integral part of teaching and learning and the time allocations at the long-term level of planning will need to reflect this... Planning will also need to take account of the time required to carry out statutory tests and tasks at the end of each key stage* (p.7).

Of course, assessment generates a need for effective record-keeping: this should be in a format which is meaningful and easy to understand. As ASE (1993) observed, this is easy to manage *within* a school, but is more problematic *between* schools. Particular difficulty may be anticipated at the primary-secondary interface, where primary schools may send pupils to several different secondary schools, and conversely, secondary schools may receive pupils from several primary schools.

Cox and Taylor (1989, p.188) address the issue of **what** should be recorded, although it has to be remembered that their comments pre-date the National Curriculum attainment targets and the current level descriptions; the essence of their suggestions remains valid, however: the records for individual children should

> *highlight strengths and weaknesses, incomplete understandings and creative applications, as well as the development of skills in testing, care in observation, critical handling of information and attitudes to problems and their solution.*

Gosden (1991, p.65) expresses a view with which many teachers will no doubt agree:

> *Each school has been left to find its own method of recording which has been very time consuming. Scarce resources of time would have been saved if this had been thought out centrally and provided for teachers after proper exploration and consultation.*

This view is even more pertinent given the fact that teachers are currently implementing (and therefore assessing) the **third** version of the National Curriculum for science.

A further point to bear in mind is the fact that records showing individual pupils' levels of attainment are transferred from primary to secondary schools. It is clearly in the interests of all concerned if records at this interface are compatible, otherwise, according to Russell *et al.* (1993, p.26):

> *It seems likely that Key Stage 3 will continue to have administrative problems in using the qualitative and diagnostic records of the*

preceding six years of science education because of the lack of standardisation in record keeping and the number of feeder Key Stage 2 schools (with their attendant diversity of practices).

Finally, we must acknowledge that since the Dearing Review, teachers have had to move from their records of ongoing assessment based on the programmes of study to end of key stage levels based on the level descriptions within the attainment targets. Prior to the Dearing Review, assessments were related to statements of attainment, which, some would argue, made it easier to award end of key stage levels. It seems likely that there will be some differences in awarding (and interpreting) end of key stage levels until teachers on both sides of the primary-secondary interface are confident in the new structure.

Summary

Several authorities have recommended that opportunities for assessment should be identified and incorporated into schemes of work. At the same time, a number of commentators have suggested that assessment, teaching and learning are inextricably linked: in order for teaching and learning to be effective, there has to be assessment of children's scientific knowledge and skills before the teacher can determine the appropriate activities and experiences to enhance and develop children's attainments in science. Do these two views represent different approaches, or are they in fact saying the same thing? In practice, many teachers will carry out their assessments using a combination of:

- activities set up with the intention of allowing the teacher to make assessments
- impromptu assessments made when appropriate behaviour (in terms of knowledge or skills) is witnessed.

Schools need to ensure that they have suitable mechanisms for recording their assessments; although there should be no difficulty in arranging a uniform strategy throughout their own school, problems with the compatibility of record formats might occur at the primary-secondary interface. A centrally devised format that could be used by all schools would allow teachers to spend more time focusing on other pertinent issues, and would have the benefit of facilitating the effective transfer of information concerning attainment from one school to another when appropriate.

1.3 CONTINUITY AND PROGRESSION

For many people, one of the benefits of the introduction of the National Curriculum has been the fact that it has enabled teachers to share a common view in terms of the types of experiences that should be offered to pupils at different stages of development: the National Curriculum has become the shared mechanism by which continuity and progression have been improved, both within and between schools. This view has been expressed by commentators such as Gosden (1991), ASE (1993) and Jennings (1992), with the last observing:

> *There is universal agreement that much has been gained by establishing a curriculum in science that spans the years of compulsory schooling. Already primary science is far less opportunist and episodic because most schools have a structured plan. While teachers of younger pupils may not fully comprehend the science of Key Stage 4 they can now see where the work they do is leading. The unified curriculum structure will help to ease transfer between schools and encourage primary-secondary liaison... At the same time teachers of science will need to recognise that the intended curriculum will not automatically achieve continuity and progression* (p.33).

The point made by Jennings that simply having a National Curriculum will not in itself create continuity emphasises the fact that teachers must nevertheless make particular efforts if pupils are to experience a coherent science curriculum. We may argue that there are at least three ways in which teachers should focus on achieving continuity and progression in a practical sense:

1. **Repetition should be avoided:** NCC (1993a, p.7) comments: 'Planning for continuity means extending children's experiences without encouraging unhelpful repetition.' On the other hand, this needs to be balanced with the spiral curriculum, in which, according to ASE (1993, p.10), pupils 'meet concepts, skills and knowledge more than once and can refine and consolidate their learning'.

2. **The focus of planning should be child-centred,** taking account of pupils' individual development and understanding, rather than document-centred, concerned only with producing a structured progression on paper which may have no relevance to pupils' own development and achievements. ASE (op. cit.) suggests that where, in curriculum planning, reference is made to progression, it tends to be in terms of 'content and experiences rather than the progression of the children's understanding' (p.9). ASE goes on to argue that in order to achieve progression in children's understanding and

skills, detailed planning needs to take account of the children's existing levels of understanding, which can be determined by assessment.

3. **Effective record-keeping is essential:** the systems used for recording pupils' achievements should be compatible, both within and between schools. The transfer of records between schools is one of the potential weak points in maintaining effective continuity in pupils' learning experiences: if records are presented in a format which has been agreed by both the transferring and the receiving school, there is less opportunity for ambiguities or misunderstandings to arise.

NCC (1993a, p.9) emphasises the need for cross-phase liaison between schools so as to ensure there is continuity and progression in pupils' science work; areas which they suggest for particular attention are as follows:

- *they have common aims which they have discussed*
- *schemes of work relate to one another and show how continuity of experience is to be achieved*
- *there are appropriate expectations of the children*
- *record-keeping systems are compatible*
- *there is a common understanding regarding the reported achievements of children.*

Harlen *et al.* (1990) provide examples of ways in which continuity and progression can be promoted, especially at the primary-secondary school interface, including meetings between representatives from different schools within a cluster/pyramid; primary children visiting a local secondary school for some of their science work; and cross-phase projects started in the primary school and completed in the first year at secondary school. (*The full list of strategies is reproduced in Figure 1.*) Many of the strategies identified were observed by Lee *et al.* (1995) in schools and described in their report concerning continuity and progression from five to 16. With regard to cross-phase links, Lee *et al.* summarised the types of activities they witnessed as involving:

- subject working groups
- joint INSET activities
- jointly devised schemes of work
- pupil visits
- teacher visits.

FIGURE 1 – CROSS-PHASE LIAISON

Considering strategies for liaison

Many LEAs have begun initiatives to promote continuity and progression. Strategies vary. Here are some examples:

1. Representatives of a high school and its feeder schools, including the infant departments or infants' schools, meet every half-term. The venue is changed for every meeting so that teachers become familiar with the other schools. These groups are often called cluster or pyramid groups. Subjects for discussion are assessment, recording of children's work, developing investigative skills, visits to other schools and curriculum development work.

2. Joint inset takes place so that primary and secondary teachers can get to know each other and are able to discuss common goals and teaching methods.

3. Primary children visit the high school with their teachers on a regular basis. The teachers work together in a team teaching situation. When the children return to their own school they continue working on the same topic.

4. Science displays are organised where both primary and secondary children exhibit examples of work. Sometimes these are interactive, with children working on investigation and problem-solving exercises.

5. Working groups from pyramids or clusters produce curriculum guidelines based on the National Curriculum. The emphasis is on progression from Key Stage 1 right through to Key Stage 3.

6. Secondary teachers spend one half-day teaching in the primary school. They do not act as science 'experts' but take part so as to experience the ethos of the school and to become more aware of how young children learn.

7. Joint projects are planned for fourth-year junior and first-year secondary pupils who visit each other's schools and work together.

8. A more formal subject-based approach is adopted for the last term in the primary school.

9. Secondary schools lend equipment and also provide classrooms and laboratories where primary teachers can bring their classes.

10. Parents are invited to visit the secondary school with their primary-age children, where they work beside first-year secondary pupils.

From: HARLEN, W., MACRO, C., SCHILLING, M., MALVERN, D. and REED, K. (1990). *Progress in Primary Science. Workshop Materials for Teacher Education.* London: Routledge.

An example of the arrangements made for Year 6 children to visit their local secondary school for regular science lessons was provided by School F.

School F (a junior school) has been taking Year 6 pupils to its local comprehensive school for the last seven years: most of the children from the junior school transfer to this secondary school. There are two Year 6 classes; for one term (usually the spring term) each class visits the comprehensive school weekly, doing science and technology alternate weeks, so that by the end of the term both classes have had five or six sessions of both science and technology at the comprehensive school.

For science, the children have a one-hour lesson in a laboratory. The activities the children will do are decided jointly between the Year 6 teacher and the secondary school teacher: for example, during work on forces, the teachers agreed on one session on friction. The secondary teacher prepares five or six activities in a circus form of organisation: most children complete one or two tasks during the lesson, but some do three. All the equipment for the activities is already set out for the children so no time is wasted. For another visit, different activities would be available, again in line with their Year 6 science work.

The Year 6 teacher normally gives a general introduction to the work (about 30 minutes) before the visit. Once there, the secondary school teacher gives a more detailed introduction, with specific references to the activities; the children then spend time on the circus of tasks, working at their own pace. Towards the end of the lesson, the secondary teacher draws the lesson to a close, with pupils reporting on the activities they have completed. Tables and charts are on the board for the children to copy into their books and record their results (they take their primary school science books with them). The amount of follow-up work done at the primary school varies: sometimes the children do written reports, sometimes their report consists of the tables they completed during their practical work.

Their final session at the comprehensive involves a challenge: given a mixture of sand and rock salt in water, they have to separate the mixture into the sand and salt; this means they have to heat the mixture to dissolve the salt, filter the mixture to separate the sand, then leave the mixture to evaporate to retrieve the salt.

The primary school science coordinator identified the following benefits and drawbacks:

Benefits

- Primary teacher has access to the secondary teacher's science expertise.
- Good opportunity for the primary teachers to talk to secondary teachers.
- Helps children get used to the secondary school.
- Helps children get used to a different way of working.
- Helps children learn laboratory skills and be made aware of safety precautions.
- Children enjoy it, and like having the special treatment.
- Secondary teacher likes the fact that the children are keen and enthusiastic, in contrast with many older pupils at the comprehensive school who lose interest in science.

Drawbacks

- Walking there/back in all weather conditions (spring term). The secondary school is about a mile away – 20 minutes' brisk walk; this is tiring for the children. The secondary school has arranged the lessons so that the junior school is given either the first lesson of the morning, or the last lesson of the afternoon: this means the children only walk one way to/from primary school, the other journey being direct from their home (e.g. morning lesson: children go straight to the comprehensive and meet their primary teacher there, have lesson and return to primary school with her; afternoon lesson: children walk to the secondary school with their primary teacher, have lesson and are dismissed to go home from the secondary school).
- The change of routine for parents. A few parents have complained about the journey, but the primary school has pointed out that this is where most children will be going next year anyway, so it is an opportunity to make appropriate arrangements.

Lee *et al.* (op. cit.) also commented that all these types of activity required effective coordination 'to ensure that individual teachers and schools were not overburdened, and that efforts were concentrated on initiatives of most benefit to the pupils' (p.47).

However, in view of the latest revision to the National Curriculum for science, it is worth bearing in mind the fact that the programmes of study within the statutory Orders (1995) are now more prescriptive of the types of activities in which pupils should be involved at different stages.

In fact, Wiliam (1996) suggests that the specificity in itself acts against the interests of continuity and progression:

> *It has to be said that in the revised National Curriculum in most subjects (and certainly in mathematics, science and technology), the programmes of study for each of the key stages are so different that any kind of comparability across the key stages is unsupportable. At the very least, if there is any commitment to the original age-independent scale of levels, then the programmes of study will need to incorporate a more coherent notion of progression both within and between key stages* (p.137).

The issue this view raises for teachers concerns the types of activities they should offer to pupils who are working at levels of achievement outside the expected range for the key stage appropriate to their chronological age. Should they acknowledge certain pupils' specific needs and provide activities which are outside the relevant programme of study (either at a higher or a lower level) or should they only offer experiences as defined within the programme of study for the age concerned? This issue is addressed in the programme of study for science (GB. DFE and The Welsh Office, 1995), which states:

> *For the small number of pupils who may need the provision, material may be selected from earlier or later key stages where this is necessary to enable individual pupils to progress and demonstrate achievement* (p.1).

Summary

Most people consider that the introduction of the National Curriculum has provided a structure which has facilitated arrangements for promoting continuity and progression in pupils' science education. The main mechanisms for achieving continuity and progression at school level are efficient strategies for planning schemes of work, and assessing and recording pupils' achievements. Teachers' planning needs to take account of the benefits of the spiral curriculum, in terms of enhancing knowledge and depth of understanding, whilst at the same time avoiding fruitless repetition. Ongoing assessment of pupils' knowledge and skills is essential if the teaching programme is to enable children to progress from their own starting points.

Whilst whole-school strategies may support continuity and progression within the school, cross-phase issues need to be addressed if pupils are to experience continuity between schools: other commentators have identified strategies which may help to promote cross-phase continuity and progression.

1.4 PRACTICAL SCIENCE ACTIVITIES

The structure of the National Curriculum for science acknowledges the importance of both science process (Sc1) and science knowledge (Sc2-4); pupils may be involved in practical science activities with regard to both elements of the curriculum. However, the practical work in which pupils are involved may have a different focus or emphasis depending on whether, for example, the main objective is to explore the specific properties of different materials, or to refine the skills involved in designing and carrying out a fair test. NCC (1993a) suggests that practical activities in science can be classified into four main types:

1. **basic skills**, e.g. measuring temperatures, graphing results
2. **observations** using the senses, e.g. identifying similarities and differences; sorting and classifying
3. **illustrations**: practical activities which are used to teach particular concepts (e.g. some changes of state can be reversed, such as water freezing to ice then thawing again); all pupils follow specific instructions and are expected to achieve the same results
4. **investigations**: these set out to answer particular questions (which may be suggested by the children) such as 'Do sugar cubes take longer to dissolve than loose sugar?' or support/refute a prediction or hypothesis, such as 'I think all metals conduct electricity'.

This distinction between different types of practical work is helpful, and should help teachers in planning a range of experiences to develop pupils' skills in science processes. NCC (op. cit.) also suggests that the first three types of activity provide useful experiences which will enable children to develop their own investigations. It may be argued that children need to experience activities of the first three types before they can plan and carry out effective investigations.

In School B considerable emphasis is placed on practical science activities, recording observations and devising investigations.

When Mr D moved to School B (a small rural primary) to take on the roles of headteacher and science coordinator, he wanted to find something to act as the focus for science work, and decided to develop a pond within the school grounds. Children were actively involved in the design and construction of the pond, which has been a starting point for science work since its completion. The school has produced over five years' continuous work on the contents of the pond: it is sampled once a week throughout the year (including school holidays) by children in the top class (Years 5/6 with a few Year 4).

Samples are taken from four points: at each one children do five netsweeps, measure the water temperature and take water samples to check the pH and to study under the microscope. In addition one term per year is allocated to more detailed extension work, again by the top class; this involves children devising their own investigations concerning the pond.

The science work focused on the pond draws in other aspects of the curriculum too. For example:

- the weekly data collected are entered in a computer database which can then be interrogated to find patterns;
- data can be analysed to find the mean, median and mode number of flagellates in ten drops of water;
- all other ponds within a five-mile radius from the school were identified and sampled for comparative purposes.

Mr D commented that a major difference between the work concerning the pond and other science work (such as electric circuits) is that the teacher is unable to anticipate the outcome: in this respect, the teacher is investigating with the children.

The detailed work regarding the identification and characteristics of sub-species that the children have been involved in has led to liaison with staff at two universities in the area. Their work has also been recognised nationally through two major awards:

- the Queen's Bronze Award for environmental work, 1992 (a special award to mark the 40th anniversary of the Queen's accession to the throne)
- an award from the Royal Society, and the prestige of being selected as the Society's invited school for demonstrating their work at the annual exhibition.

The notion that pupils' practical activities in science should involve them in carrying out investigations is a development of earlier emphasis on practical work in general and requires a more open-ended approach to particular activities. NCC (1993a, p.22) offers the following definition:

> *Investigations allow children to test their own ideas, and those of others, by carrying out investigations in which they will make reliable and accurate measurements or observations (the evidence), and then consider what this evidence means in relation to their original idea, or the problem they are trying to solve.*

The programme of study for Sc1 in the post-Dearing curriculum built on this definition by identifying three aspects of experimental and investigative science as follows:

- planning experimental work
- obtaining evidence
- considering evidence.

Although teachers may be willing to organise practical science activities, some may feel constrained by particular difficulties, as in the case of School G.

The science coordinator in School G (an infant school) commented on the lack of investigative science within the school, and attributed it to the fact that teachers were contending with:

- large class sizes (e.g. 38 Y2)
- very poor levels of resourcing
- poor accommodation (e.g. 'mobile' classrooms without water)
- difficulties in organising practical science activities for some children within the class, whilst still supervising the rest of the class. This was felt to be a significant problem: the organisational/management aspects rather than an inherent reluctance regarding science investigations.

Commentators such as HMI (GB. DES. HMI, 1989) and Harlen (1991) have identified the importance of pertinent questions directed by the teacher to pupils as they are working: these can help pupils to reflect on their approach and possibly amend the design of their investigation if appropriate; pupils' responses can also be used for diagnostic and formative assessment purposes. However, judging the appropriate moment at which to intervene requires a certain amount of skill in terms of:

- a clear knowledge on the part of the teacher of the scientific context of the activity (both concepts and processes)
- a recognition of the stage the pupil has reached in terms of her/ his own science development (again, both concepts and processes).

In order to intervene effectively, and in doing so help pupils to develop their own capabilities in science, it is essential for teachers to have a thorough understanding of science themselves: this supports the argument for further INSET for primary teachers where necessary (see also Section 1.9).

One of the issues teachers have to address is that of providing enough support to pupils involved in practical activities to enable them to develop their skills further, yet at the same time not intervene too early so that pupils are not given the opportunity to refine their ideas themselves. This point is made by HMI (op. cit.) who state:

> *Helping children to plan and implement a 'fair test' requires considerable skill and well-timed intervention on the part of the teacher: one 10-year-old, when testing the solubility of a solid in water, found that not all the solid material had dissolved within the number of stirs she had prescribed for the test. The teacher had to judge at what point she should question the child or give information which would help her to redefine her plans. Too early an intervention would have reduced the opportunity for the child to improve the experimental design for herself. On the other hand leaving her to struggle when the variables involved in the work are complex or require explanation quickly leads to frustration and does little to foster good attitudes to science* (pp.16-17).

The issue of appropriate timing becomes more complex, however, when the teacher intends to make assessments. This point is made by Donnelly *et al.* (1994), who comment that teachers are in the difficult situation of finding that, having given pupils the opportunity to plan and carry out an investigation so as to assess their Sc1 skills, they may find that pupils show either misconceptions in relation to science knowledge and understanding (i.e. Sc2-4) or in relation to some aspect of their investigation (such as their ability to identify and control variables: Sc1). In instances such as this, the teacher is faced with a dilemma — should s/he not intervene and assess the pupils' work on what they actually do (and in doing so allow pupils to reinforce their own misconceptions), or should s/he abandon the attempt to make assessments and use the activity as a teaching opportunity? It could be argued that by opting for the first course of action, the teacher achieves the intended assessment but hinders future development, whereas by opting for the second course of action, the assessment opportunity is lost, but current areas of weakness are addressed so that the pupils will progress to higher levels of achievement in the future.

Finally, it is worth remembering that teachers have to organise practical activities in science just as they have to plan lessons in other subjects. There are a number of different organisational strategies open to them, ranging from the whole class working on the same task directed by the teacher, to individuals/small groups working on particular aspects of science work of interest to them. Richards *et al.* (1980) provide a useful summary of different organisational strategies together with the advantages and limitations of each. (*This is reproduced in Figure 2.*)

No one organisational strategy will be appropriate for every type of activity or class. Teachers will want to take into consideration a number of factors, including:

- **the type of activity:** the whole class working on the same task might be most appropriate for teaching *basic skills*, such as graphing results, whereas a circus of activities may be more appropriate for activities involving *observations* and *illustrations*, and small groups working on particular areas of interest may be more relevant for *investigations*;
- **the children's existing knowledge and capabilities:** different activities for different groups or individuals permit more challenging activities or extension work for able children and suitably supported tasks for slower learners such as those with special educational needs;
- **the resources available:** if there is only enough equipment for one or two groups to use at the same time, this precludes a whole-class activity;

- **the amount of teacher intervention required:** children carrying out observations may need minimal support, whereas children devising investigations may need more input, such as drawing attention to the need to carry out fair tests;
- **safety considerations:** if an activity involves some sort of hazard (such as burning candles or hot water) the teacher may prefer to limit this to one group only and/or consider seeking additional adult help (perhaps a parent volunteer or an ancillary helper) for supervising the work. In some instances the teacher may prefer to give a demonstration to the children.

FIGURE 2 – METHODS OF CLASSROOM ORGANISATION

Method of organising	Advantages	Limitations
Whole class. Teaching by 'chalk and talk' and demonstration.	Minimum organisational demands. Economical on time and equipment.	No first-hand experience. No allowance for individual ability of pupils. Difficult to involve whole class.
Class practical. Children work in small groups doing similar tasks.	Relatively easy to plan ahead. Children can work at own pace if extension work available. Equipment demands known in advance. First-hand experience for pupils.	Preparation of extension work. Follow-up lines of enquiry difficult. Quantity and duplication of apparatus. Involves much clearing away.
Thematic approach. Small groups working independently to contribute to the whole.	High in interest and motivation. First hand experience for pupils. Pupils work at own pace. Builds confidence in communication skills when reporting back.	Difficult to arrange balanced cover of science experiences. Difficult to ensure coherence and understanding from report back.
Circus of experiments. Small group rotating around prescribed activities.	Easy to plan ahead, less demanding on apparatus and all can use specialist items. High interest or motivation.	Activities cannot be sequential. Occasional pressure on completion time before change-over. Difficult to organise report back on whole circus. Method of briefing essential.
Small groups or individuals. Areas of study chosen by themselves.	Allows variety of interests. High on motivation. Children work at own pace and to own potential.	Demanding on teacher. Structured framework necessary. Stretches school's equipment and resources.

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From: RICHARDS, R., BAILEY, H., COLLIS, M. and KINCAID, D. (1980). *Learning through Science: Formulating a School Policy* (Science 5-13 Series). London: Macdonald Educational.

When practical activities are effectively organised, the related issues of pertinent questions and assessments become easier to manage.

Summary

Pupils' science work under the National Curriculum will inevitably involve practical activities: these can be organised in a number of different ways. Useful distinctions can be made between practical activities which involve basic skills, observations, illustrations and investigations. Teachers need sensitivity in judging appropriate points at which to intervene in pupils' practical activities if they are not to deny pupils the opportunity to refine and develop their skills, at least in part, through their own reflection. In addition, when pupils are engaged in practical activities, teachers must decide when utilising an opportunity for a relevant teaching point should take priority over carrying out a planned assessment.

1.5 THE BALANCE BETWEEN SC1 AND SC2-4: Process- and Content-based Science

Prior to the introduction of the National Curriculum there was a distinction between a process-based approach to teaching science in the primary school and a content-based approach, each of which had a different emphasis:

- a process-based approach placed emphasis on developing skills in applying the scientific method (e.g. identifying and controlling variables; developing and testing hypotheses)
- a content-based approach frequently used a published 'course' which might comprise pupils' materials and a teacher's guide; this approach usually prescribed activities rather than allowing them to originate from pupils' own ideas.

Cox and Taylor (1989) observed that, despite having been promoted as a desirable method of working over a considerable period of time, the process-based approach had, at that time, failed to become widespread, whereas the content-based approach was establishing more supporters:

> *Teachers are presented with two entirely different approaches to the teaching of primary science, often with no acknowledgement that they **are** in fact different. One has academic and professional respectability, is extremely demanding of teachers and has failed to become established in primary schools despite twenty years of promotion. The other, whilst not having the same status in the eyes of the teaching profession, satisfied many of the criticisms levelled at the 'process' method, seems to give greater security to the teacher. It would appear to be making a base for itself in schools which have established science as part of their curriculum. It may also have the great advantage of being easier to adopt and assess* (pp.179-80).

Cox and Taylor (op. cit.) went on to suggest that the two approaches

> *... are in fact different sides of the same coin. Science is both a body of accepted knowledge and a method of working, both formal and creative.... Any approach to the primary curriculum which ignores these different aspects of science will result in partial knowledge about it. It also overlooks the variety of knowledge, skills and ideas which children themselves bring to the classroom and closes off vital areas of experience necessary to their understanding of the physical world and their own part within it* (p.180).

Her Majesty's Inspectorate (GB. DES. HMI, 1989, p.22) predicted that one of the changes for primary schools as a result of implementing the National Curriculum would be that '... greater attention will have to be given to the development of scientific knowledge and understanding as well as the acquisition of scientific skills ...'

This comment may be taken as indicative of a policy shift from promoting process-based science to an emphasis on content-based science, as suggested by Kruger *et al.* (1990):

> *At Government policy level there has been an increasing tendency during the last decade to move away from a mainly process approach to primary science, which, it is claimed, has been manifestly unsuccessful in teaching children 'science' ... towards an increased emphasis on the teaching of conceptual understanding of science to primary school children* (p.134).

In fact, of course, both approaches were formally recognised in the National Curriculum for science: the statutory Orders (1989, 1991 and 1995) have all acknowledged that pupils' experiences of science should involve both process-based elements and content-based elements. In the current version of the Orders these are presented as:

- Sc1: Experimental and Investigative Science
- Sc2: Life Processes and Living Things
- Sc3: Materials and their Properties
- Sc4: Physical Processes.

Different terminology was used by the NCC (1993a, p.6) to differentiate between the two main elements of science, although the meaning is essentially the same. NCC distinguishes between **conceptual understanding** 'in which scientific knowledge is drawn together into a series of overarching ideas: the concepts' – these are described in ATs 2-4; and **procedural understanding** 'in which scientific skills and concepts are combined as part of an overall strategy. This enables children to carry out investigations to find answers to problems set in everyday and scientific contexts. AT1 describes this kind of understanding.'

Earlier versions of the National Curriculum (1989 and 1991) gave an indication of the proportion of science teaching time that should be spent on each of these two main elements, both indicating that at key stages 1 and 2 each of the two elements (process *and* content, which itself comprised three different attainment targets) should have approximately equal prominence, or 'weighting'. However, there has been no similar guidance with the current curriculum. Is it reasonable to expect that teachers will aim to maintain this relative balance, or will they spend more time on one element at the expense of the other, and if so, which one?

Previous guidance has suggested that Sc1 skills should be taught within the context of particular content areas, rather than in isolation. An example of this would be as follows: within the context of work on light and the formation of shadows (the programme of study relating to Sc4), pupils may investigate the effect that moving the light source in front of an object has on the size and position of the shadow formed. However, Smith (1994, p.169) argues that in practice '.... the increase in knowledge required by the other Attainment Targets and the rest of the subjects has limited the development of more investigative approaches in primary classrooms'. Smith also suggests that '... the sympathy of the primary profession for the emphasis on a scientific way of working has been tempered by the complexity, language and recurring alterations in Sc1'.

Some schools, however, remain committed to the principle of developing children's skills in experimental and investigative science, as is the case at School B.

At School B, the science policy states that there should be at least one major investigation per term for all children. This should be related to ongoing science work, e.g. electricity: devise and make an alarm that will...; forces: find the best seat-belt for an egg, the best packaging to send an egg through the post. Within the school, considerable emphasis is placed on children designing their own experiments and carrying them out. Reflection on their first attempt at the experiment is encouraged so that the children can identify for themselves areas of weakness, or ways to improve the tests. However, the science coordinator explained that talking these types of issues through with the children is very time-consuming if it is done properly, hence the school aims to do it well once a term.

At secondary school level too, there appears to be some difficulty in teaching Sc1 within the context of work on Sc2-4. Their observations of science teaching at key stages 3 and 4 led Donnelly *et al.* (1994, p.8) to comment: 'Sc1 in schools at the present time appears to have been compartmentalized rather than assimilated into the rest of the curriculum. In some cases pupils' practical work is increasingly associated with Sc1 only.'

Apart from teachers' own decisions regarding the relative emphasis to place on Sc1 and Sc2-4 respectively, they are undoubtedly aware of the apparent status given to each in the SATs. Harlen (1992, p.2) expressed concern when Sc1 was removed from the key stage 1 SAT:

> *... teachers will feel obliged to spend more time on ensuring that children are at least exposed to the content for ATs 2, 3 and 4 so*

> *that they can answer the paper-and-pencil questions on them, with less concern for how this content is encountered by the children.*

Harlen considered that, by placing less emphasis on Sc1 assessment, there was an implicit suggestion that it was less important than Sc2-4, and went on to stress the importance of linking both process *and* content. (*Since Harlen expressed these views the situation has changed and there is now no mandatory assessment of Sc2-4 at key stage 1.*) Harlen's argument was that the value of developing Sc1 skills lies not in the skills in their own right, but in the fact that they help children to develop their own scientific thinking (a constructivist view, see Section 1.7); through Sc1 skills, children

> *... develop and use ideas which help them to understand the scientific aspects of the world around them. When faced with new experiences from which they can learn, children begin by trying to make sense of them using ideas formed from previous experience and through processes such as observation, question-raising, and hypothesizing. Then, through the processes of prediction, planning, experimenting and interpreting, conclusions are drawn as to whether the ideas fit the evidence. If these process skills are not carried out in a rigorous and scientific manner, then the emerging ideas will not necessarily fit the evidence. Ideas may be accepted which ought to have been rejected, and vice versa. Thus, the development of ideas depends crucially on the processes used. While the facts and generalisations are important, how we arrive at them and what makes us believe them are of equal importance* (p.2).

It seems likely that the issue of the balance between process- and content-based science will remain an important one. Certainly, when we consider the fact that pupils' primary school experiences are surely the essential foundations on which secondary schools continue to develop pupils' knowledge and skills, it is impossible to justify the marginalisation of science process skills at the expense of extending knowledge only, for as Harlen (1992, p.2) states, 'The continual interweaving of knowledge and process skills in the investigation of natural phenomena is an essential characteristic of science education at all levels.'

However, returning to the issue of whether or not the content-based element of the National Curriculum for science is equivalent to the science schemes or courses for primary schools which pre-date it, it would appear that there is in fact a difference. The difference is that whilst the majority of science 'schemes' or 'courses' for primary schemes describe specific activities and list resources, the statutory Orders for science define *what* should be taught, but leave the question of *how* it should be taught for schools/teachers themselves to decide. This, then, is one of the important issues facing schools today: pupils should develop both their skills and knowledge in science. Teachers must determine to what extent it is possible for them to teach science processes through the context of particular aspects of science knowledge and the overall balance of teaching time to be spent on the two aspects: science processes and science knowledge.

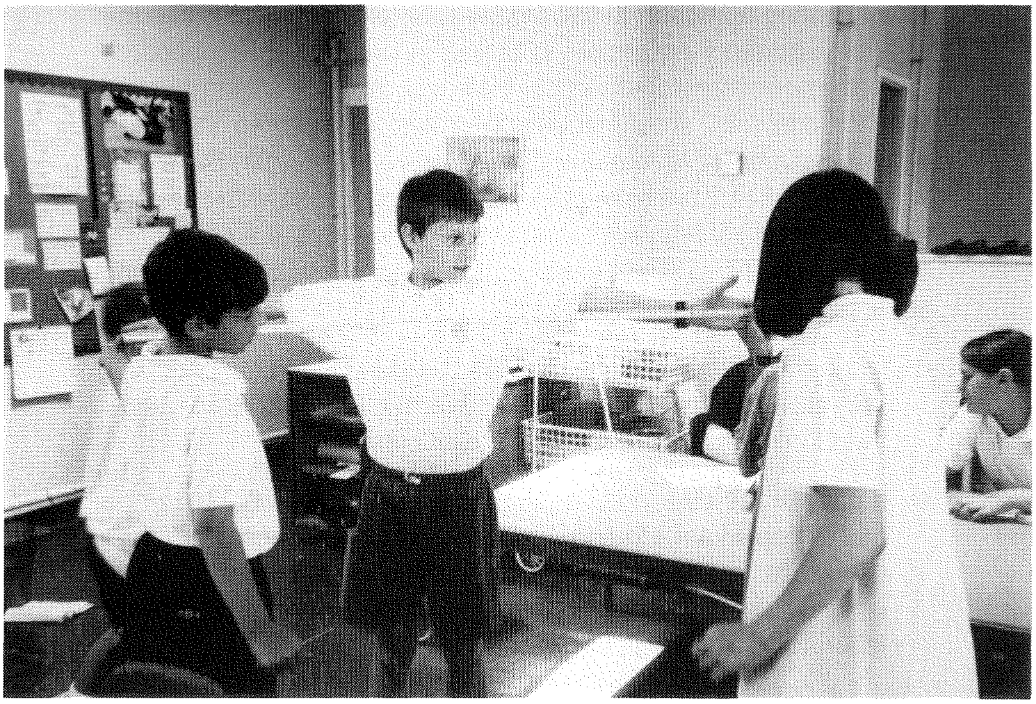
Summary

The teaching of science in primary schools involves two main elements:

- skills in scientific processes
- knowledge and understanding of content.

The National Curriculum for science includes both of these elements: Sc1 (process) and Sc2-4 (content).

The lack of clear guidelines regarding the relative importance of each of these elements, together with the fact that the status of scientific skills has been brought into question since Sc1 was removed as a part of SATs at key stages 1, 2 and 3, has led to some commentators expressing concern that teachers will spend more time focusing on Sc2-4 than on Sc1.



1.6 RESOURCING

Schools need a range of resources in order to teach science effectively. This has always been the case, irrespective of whether, in the past, schools have adopted either a process-based approach, or a content-based approach to teaching science. Even before the full implementation of the National Curriculum, HMI (GB. DES. HMI, 1989, p.8) noted that in about one-quarter of primary schools 'practical work was constrained ... by limited space and by a lack of other facilities such as a water supply in the classroom'. HMI went on to observe that:

> *Although the presence in a school of sufficient resources for science teaching did not guarantee that they would be effectively used, the best work was invariably associated with an adequate supply of suitable resources* (p.8).

Richards *et al.* (1980) considered that, in developing a school policy for science, teachers needed to address a number of issues concerning resources, such as:

- what resources are required?
- how should they be stored, maintained and organised?

School C (a middle school with a newly built science laboratory) has an interesting approach to the organisation of resources: within the science laboratory equipment is stored in drawers and cupboards under the perimeter workbenches. However, instead of being labelled with the contents, an alphanumeric system is used, so that each drawer or cupboard is uniquely labelled as A1, A2, A3, B1, B2, etc. A separate booklet lists the contents of each storage area, with one page for the contents of A1, another page for the contents of A2, etc. The science coordinator commented that this system had the following advantages:

- when the contents of any drawers/cupboards are changed, only the relevant page(s) in the catalogue need to be altered, rather than the labels on the drawers and/or cupboards
- a copy of the equipment catalogue is kept in the laboratory and further copies are given to each teacher for reference within their own class: this enables teachers/pupils to check what equipment is available and plan what they will use before going to the laboratory for the science lesson.

The introduction of the National Curriculum for science was attended by particular requirements in terms of resourcing: for example, how could schools teach children about electric circuits if they did not have the appropriate equipment? An examination of the science programmes of study indicates the range of equipment required: ASE (1993, p.15) considered that 'Many primary schools are inadequately resourced in terms of equipment to deliver National Curriculum science.'

ASE went on to refer to HMI's recommendation that primary classrooms should each have a basic set of science equipment, which should be supplemented by more specialised centralised equipment for use as and when appropriate. ASE also made the contentious suggestion that schools should be able to apply to a central agency for funding to purchase necessary equipment. While an official response to this suggestion might have been along the lines of 'each school has its own capitation from which to purchase the equipment required', it must be acknowledged that the National Curriculum may have increased the difference in resourcing levels found in different schools. Schools that were relatively well equipped with regard to science prior to the introduction of the National Curriculum will have had to spend less on essential equipment than those schools which were poorly equipped; the former will therefore have had opportunities to enhance their resourcing levels at the same time as the latter have been trying to establish minimum levels of resources.

Recent evidence from OFSTED inspections (1995) suggests that earlier inadequacies have been rectified, but primary schools remain under-resourced with respect to science:

> *The range of science equipment is satisfactory in the majority of primary schools to meet most of the requirements of the National Curriculum. The quantity of equipment available usually dictates the mode of classroom organisation, with only sufficient available for one or two small groups to carry out the same science activity at one time* (p.17).

For some primary schools, such as School J, links with a local secondary school have provided opportunities to borrow additional equipment for science.

School J is situated in a rural area and sends 90-95 per cent of its children to one particular secondary school. The school has strong links with the secondary school in a range of subjects. The science coordinator attends termly liaison meetings in her capacity as key stage 2 coordinator, and when, at one of the meetings a general offer was made to loan resources to the primary schools, she decided to take advantage of this offer.

The school has three key stage 2 classes which follow the same two-year cycle of science topics, hence all three classes work on the same topic at the same time, although at different levels. The three teachers look ahead to the work they want to cover and the resources they require for it so that they can request particular resources from the secondary school for the relevant weeks, for example during work on light, mirrors, lenses, prisms and microscopes were borrowed from the secondary school. The loaned equipment is rotated between the three classes.

A further benefit to the primary school is that when the science coordinator approaches the head of science regarding the loan of specific equipment, the latter will sometimes suggest other resources which would be relevant to the topic. Having access to secondary school equipment also benefits the more able children: on a few occasions where particular children could extend their work to level 6 (and therefore within the key stage 3 programme of study) more specialised resources have been available from the secondary school, such as the loan of prepared slides showing cell structure. The science coordinator commented that this sort of facility was a definite help in terms of differentiation of work for the class. She also remarked: 'More and more we find ourselves able to do whole-class lessons because we have enough equipment.'

Summary

Primary schools require specific equipment to teach the National Curriculum for science. Historically, many schools have been inadequately equipped with appropriate resources for science. Recent evidence suggests that most primary schools have the necessary range of equipment, but only in small quantities, which therefore restricts the types of classroom organisation open to the teacher.

1.7 THE CONSTRUCTIVIST MODEL OF LEARNING

The style of teaching adopted by teachers is influenced by a number of factors, such as:

- the number of pupils in their class
- the range of pupils' abilities
- the resources available
- the school policy
- the scheme of work for science
- the classroom accommodation and space available
- their view (philosophy) of learning.

Many of these factors, such as class size, are outside the control of individual teachers. One that is very personal to each teacher is her/his own view of children's learning, or the model of learning to which s/he subscribes. A model of learning which has been widely accepted in Great Britain and in other countries in recent years is the constructivist view.

Scott *et al.* (1987, p.7) summarise the constructivist model as the view that learning is a process in which knowledge is actively constructed by the learner. An important element of this model is not only the learning of *new ideas*, but a recognition that *existing ideas* may be modified in the light of experience, as Scott explains:

> *A constructivist view of learning perceives students as active learners who come to science lessons already holding ideas about natural phenomena, which they use to make sense of everyday experiences. Learning science, therefore, involves students in not only adopting new ideas, but also in modifying or abandoning their pre-existing ones. Such a process is one in which learners actively make sense of the world by constructing meanings.*

Harlen (1991) describes a similar view of learning within the constructivist model: the process whereby pupils test their current ideas against the evidence obtained from practical activities is the mechanism through which pupils modify their ideas or reject them and replace them with other ideas as a result of their experiences.

The main points in the constructivist model of learning are summarised by Scott *et al.* (1987) as follows:

- *what is already in the learner's mind matters*
- *individuals construct their own meaning*
- *the construction of meaning is a continuous and active process*
- *learning may involve conceptual change*
- *the construction of meaning does not always lead to belief*
- *learners have the final responsibility for their learning*
- *some constructed meanings are shared* (pp.7-8).

Cox and Taylor (1989, p.185) relate the constructivist view to the process of planning science work for pupils: 'The starting point for any primary science course must be the scientific *concepts* which the children already possess, altering and building on them, through the use of scientific methods of working.' Cox and Taylor go on to emphasise that this must be the preferred approach if learning is to be effective:

> *Teaching has to begin where the child is in terms of knowledge, understanding and skill and challenge these in constructive ways... In short, children need to learn to investigate using scientific methods and the concepts of the sciences. Scientific investigation based on anything else – the class topic, the child's interests or the teacher's preferences will result in learning that is fragmented, subject to chance and unreliable* (p.187).

Harlen *et al.* (1990, p.5.1) suggest that there are two main parts to learning: 'the gradual building of ideas and of the skills required to test ideas'; they go on to summarise the teacher's role in the development of children's ideas in four steps:

- *Finding out what the children's ideas are.*
- *Reflecting on where the children are in the progression towards developing more scientific ideas.*
- *Providing opportunities to test ideas or to have further experiences which challenge them, leading to possible change in ideas.*
- *Assessing the extent of any change in ideas and in process skills which may have resulted* (p.5.1).

However, many would argue that the introduction of the National Curriculum for science in 1989, and the subsequent revisions to the statutory Orders in 1991 and 1995, have made it increasingly difficult for teachers to implement a constructivist approach to teaching and learning. Jennings (1992) considered that the ten-level model introduced by TGAT did not sit happily with a constructivist view of science, and

Torrance and Pryor (1995) argue that this type of hierarchical model of achievement is in the behaviourist tradition. Although the post-Dearing situation is that the **statements of attainment** found in the earlier versions of the orders have now been replaced with rather more general **level descriptions**, the structure remains essentially hierarchical, and therefore still not necessarily compatible with a constructivist model of learning. Smith (1994, p.167) points to the increased prominence of prescribed content knowledge, and suggests that it has fostered a 'transmission' approach, in which teachers pass on information which their pupils receive: '.... the size and nature of the whole National Curriculum package has steered teachers toward a delivery mode, implying reception learning by their pupils.'

> The following extract from School D's science policy suggests a constructivist model of learning:
>
> 'Before starting to teach a particular attainment target, teachers need to assess the needs of their own pupils. This can be done either through discussion or by asking the children to draw or write. This knowledge will then inform plans for future work, and the grouping of children ... In this way teachers should be helping children to test their own ideas, and to refine and extend them towards a more scientific way of thinking. It is essential that children change their ideas only as a result of what they find themselves, not merely by accepting ideas which they are told are better.'

In terms of planning a scheme of work, rather than deciding at the outset what types of activities pupils should be involved in, a teacher implementing the constructivist model will regularly review pupils' learning, not only for assessment purposes, but also for the purpose of planning the appropriate activities to take pupils forward in their own thinking, as described by Scott *et al.* (1987):

> *The teacher can only decide on what exactly should be done in the next lesson when he/she has seen the pupils' experiments and results. As such, the teacher is in a blind situation. Activities cannot be planned in isolation and for weeks ahead – although a range of appropriate alternative strategies can be prepared* (p.16).

In practice, many teachers probably draw on a variety of techniques and strategies, some of which may be associated with a constructivist model of learning and some of which may be associated with other models, such as behaviourism, or a need to convey specific information in line with the National Curriculum programmes of study.

Summary

The constructivist model of learning is currently widely accepted. It acknowledges that learning is an active process in which individuals construct and modify their ideas, or, as a result of their experiences, reject their existing ideas and replace them with new ones. Teachers who implement a constructivist approach use their pupils' existing ideas as the starting points for new work. Some would argue that the quantity of scientific knowledge prescribed in the National Curriculum for science is more in sympathy with a 'transmission' model of learning, in which the teacher has information/knowledge which s/he imparts to pupils who then receive the same information/knowledge.

The model of learning held by the teacher influences their planning of schemes of work and activities for pupils: a teacher who favours the transmission model will be able to plan a sequence of activities in detail at the outset, whereas a teacher who favours a constructivist approach will have a more flexible plan, the ultimate direction of which will be continuously influenced by the ongoing development of the pupils' own ideas.

1.8 SPECIAL EDUCATIONAL NEEDS

Many teachers will at some time have pupils with special educational needs within their class (Warnock's one in 20 pupils), and their particular requirements need to be addressed in terms of their science education, as with other areas of the curriculum. OFSTED (1996) considers that, to be effective, provision for pupils with special educational needs (SEN) should be:

- part of a whole-school policy
- addressed in all subject policies.

Often, of course, additional classroom help is available to support the particular demands of pupils with special educational needs. Although this is likely to be available for only a limited period of time each week, the whole-school policy will no doubt provide guidelines concerning how the time should be spent. The specific needs of any individual will determine how classroom support can be best utilised for that child's development: some of the time available may be used to provide support when the child is involved in practical science work, for example not only to ensure that the child takes an active part in practical work, but also to ensure that someone is on hand to pose appropriate questions at relevant points. Fagg and Skelton (1993, p.21) suggest that:

> *... Teachers of children with learning difficulties, are particularly concerned with learning procedure rather than simply content,* [*so*] *AT1 provides the fundamental starting point for planning teaching and learning activities.*

Fagg and Skelton go on to take each of the four attainment targets of the 1991 science Orders and break down each statement of attainment into smaller components ('milestones') which enable teachers of pupils with SEN to monitor their range of skills and concepts. For example:

3/1a be able to describe the simple properties of familiar materials.

This is a level 1 statement of attainment, the lowest level defined in NC terms, but the authors proceed to break this down into six milestones, each with an example (i.e. as set out in NC Orders).

Milestones for the above include:

> *3/1a 1 react to visual and tactile stimulation without localising the source;*
>
> *3/1a 2 localise source of visual or tactile stimulation; etc.* (p.47).

Although the milestones proposed by Fagg and Skelton were based on the 1991 Orders, their concept of breaking down the statements at each level into a series of more specific 'milestones' remains valid even after the Dearing Review. Breaking down the programmes of study of the 1995 Orders into more specific milestones should help teachers to plan suitable activities to develop skills and concepts at appropriate levels for their SEN pupils.

In terms of recording progress, the use of the 'milestones' enables teachers to show new areas of science that pupils have assimilated over a period of time, whereas for SEN pupils, using only the National Curriculum levels may produce no evidence of progress at all because the steps between levels are so large in their terms. Furthermore, since SATs may be inappropriate for SEN pupils (legislation allows them to be disapplied for pupils for whom they are deemed inappropriate by teaching staff), teacher assessment therefore becomes their only means of assessment and milestones would be useful for this.

With regard to the practical issues concerning recording the achievements of SEN pupils, Fagg and Skelton (op. cit.) present an example of a recording system showing the National Curriculum statements of attainment broken down into milestones; for each milestone the authors suggest that entries can be made to show:

- *E experience (i.e. has participated)*
- *S study (i.e. has spent time working at the milestone in different situations, but achievement is not consistent)*
- *A achievement (i.e. consistent achievement in variety of situations)* (p.72).

Fagg and Skelton (op. cit.) also suggest useful strategies for recording pupils' work and the types of material that could usefully be included in a pupil's record of achievements file.

Finally, it is worth noting that OFSTED (1996) identified a number of key points that made lessons in mainstream schools more effective and valuable for pupils with special educational needs, including:

- careful planning of work, with activities matched to the capabilities of the pupils
- specific help to support pupils with special educational needs (i.e. provide them with help they need), including additional resources

- tracking of individual progress using appropriate procedures for assessment and recording
- effective communication between class teacher, SEN coordinator and (where appropriate) special support assistant about the work to be attempted; appreciation of the fact that SEN support involves providing help rather than doing work for the child.

With reference to the last point, it would seem appropriate to suggest that there needs to be effective communication about both long-term goals for SEN pupils and the short-term objectives for each lesson.

Summary

The particular demands of pupils with special educational needs should be considered within a whole-school policy; within this framework the most appropriate strategies for supporting individual pupils will be determined and implemented. Pupils with special educational needs can benefit from focusing on the skills and processes of science (which involve learning procedures) rather than limiting experiences to learning content.

A useful strategy to make planning and recording work more relevant for pupils with special educational needs is that of dividing the programmes of study into more specific milestones which acknowledge the smaller steps of progress made by these pupils.

1.9 PRIMARY TEACHERS' SCIENCE KNOWLEDGE AND INSET NEEDS

The fact that all primary school teachers are likely to be involved in teaching science to their pupils, since the National Curriculum established it as one of the three core subjects, has raised questions about the level of primary teachers' science knowledge and the training that is available to them, both as initial teacher education (ITE) and in-service training (INSET).

The situation regarding ITE at the time the National Curriculum was introduced was clearly unsatisfactory, according to the observations made by HMI (GB. DES. HMI, 1989, p.8): 'The substantial majority of class teachers had received only a short curriculum course in science during their initial training and some had had no initial training in science at all.'

A report by HMI (GB. DES. HMI, 1991, p.1) emphasised that initial teacher education needed to prepare prospective primary teachers to teach, to assess and to record their pupils' attainment, despite the fact that science was 'a subject with which many are unfamiliar and in which they lack confidence'. HMI (op. cit.) went on to comment:

> *The lack of systematic attention to enhancing students' own knowledge and understanding of science was a significant weakness in almost all courses. Whilst some incidental learning undoubtedly occurs, the weak science background of the majority of students demands that science be given a higher priority within the courses* (p.3).

Similar conclusions about the level of primary teachers' science knowledge were drawn by Cox and Taylor (1989) on the basis of the responses to a questionnaire survey which included questions about teachers' qualifications in science and their confidence in teaching the subject. Questionnaire responses showed:

- the widespread lack of science qualifications amongst primary teachers: the majority of teachers studied no science past O-level;
- the lack of confidence in terms of teaching science expressed by over half the respondents to the survey.

Cox and Taylor (op. cit.) concluded that an extensive programme of science education was necessary which would 'provide a firm grounding of scientific knowledge, most particularly in the physical sciences' (p.183) and they went on to comment: '... it is vital that teachers have the essential intellectual preparation before any effort is made to enforce legislation which imposes science as part of the primary school curriculum' (p.184).

Of course, we now know that despite the fact that various commentators had identified the unsatisfactory levels of primary teachers' science knowledge, no large-scale efforts were made to address the issue: teachers coped with introducing the National Curriculum in science as best they could. Jennings (1992, p.34) considered:

> *There remain many primary teachers whose scientific understanding is perilously stretched by the curriculum. Yet advisory and support services for science are less strong now than they were in 1989. Furthermore there are now primary teachers who, as one adviser put it, 'Think they know more science than they do, and this makes further training more difficult'.*

Gosden (1991) asserted that, in addition to the fact that many primary teachers' own science knowledge was inadequate, a further danger was that 'because so many lack sufficient experience some bad science may be imparted with great enthusiasm' (p.63).

Russell *et al.* (1993) investigated the implementation of science in the National Curriculum: they also found a widespread lack of science knowledge amongst primary teachers, and concluded that this resulted in:

- **reduced coverage:** teachers avoided teaching aspects of science in which they lacked confidence
- **restricted opportunities for learning:** teachers were unable to anticipate appropriate stages to facilitate learning; they were also unable to provide a range of learning experiences and, notably, to provide differentiation in experiences
- **less variety in teaching styles:** lack of knowledge led to some teachers adopting a didactic style of teaching; other teachers focused exclusively on practical work and avoided making any links between knowledge and process skills.

We may consider that science coordinators within primary schools have a crucial part to play in this respect: they, at least, should have higher-level qualifications in science, and through their role as curriculum adviser to teacher colleagues, they should be able to identify and rectify any areas of missing knowledge or misunderstandings. Moore (1992a, p.8) suggests: 'The coordinator's role may be especially significant in science, a core subject of the National Curriculum and one in which many primary school teachers have traditionally felt under-qualified.'

However, responses to a questionnaire survey Moore[2] sent to primary headteachers indicated that science coordinators' own subject knowledge and expertise were considered less important by heads than their role in supporting their colleagues in areas such as:

- explaining features of the National Curriculum
- giving short talks at staff meetings
- organising topic workshops for colleagues after school or on 'Baker' days
- identifying cross-curricular links to science.

(Each of these roles was cited by approximately 80 per cent or more of respondents.)

The headteachers' responses led Moore (op. cit.) to conclude:

> *Headteachers may have the view that co-ordinators do not need to be subject experts if they are not required to pass on this knowledge in an advisory role by giving teaching advice and classroom demonstrations* (p.14).

In other words, headteachers see the interpretational, organisational and managerial duties carried out by science coordinators as being more important than either their own subject knowledge, or their ability to share that knowledge with colleagues.

Moore (1992b)[3] also surveyed primary teachers (excluding those with curriculum responsibility for science), and asked them to indicate which strategies (out of the 14 ways suggested that a science coordinator could support them) they thought were most worthwhile. The four strategies selected by the highest numbers of teachers were (in descending order):

- topic workshops on 'Baker' days
- supplying resource packs on science topics
- team/joint teaching in non-specialist teacher's class
- help with identifying cross-curricular links.

Whereas the four methods of support listed above were each selected by at least two-thirds of respondents, only about half the teachers indicated that they thought it would be helpful for the science coordinator to explain science facts informally. This suggests that these teachers wanted help in the form of support for class-based work on science, rather than extending their own science knowledge.

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2 The sample for this survey consisted of schools from two adjacent LEAs (it is not clear whether all schools were surveyed or a sample) and the response rate was only 44 per cent; the findings and conclusions should therefore be treated with caution.

3 Responses were received from only 45 per cent of the schools that were randomly selected from one LEA; again, the findings should be treated with caution.

With regard to primary teachers' own science knowledge, both Kruger *et al.* (1990) and ASE (1993) emphasise the fact that all primary teachers should have at least the equivalent of a GCSE in science (National Curriculum level 7) to enable them to teach science up to and including level 5.

Kruger *et al.* refer to the findings of a survey conducted in 1988 concerning INSET offered to teachers under the Education Support Grant (ESG) just before the introduction of the National Curriculum. Main findings included:

- a process-based model of science teaching was promoted
- the issue of teachers' own lack of scientific knowledge was not addressed
- teachers were happy with short courses focusing on a specific topic (e.g. magnets).

Referring to the last point noted above, Kruger *et al.* (op. cit.) express the view that most teachers are unable to identify their own needs (i.e. INSET which will develop their own level of scientific knowledge and understanding, rather than suggest activities for pupils). The teachers' responses to Moore's (1992b) survey described above seem to support this view. Kruger *et al.* go on to argue that it is essential for science INSET to focus on teachers' understanding of science concepts, especially those relevant to the National Curriculum attainment targets and programmes of study, if science teaching is to be effective.

The approach adopted by School D involves the provision of relevant INSET and encourages teachers to provide mutual support.

In School D, the whole school focuses on the programme of study relating to a different attainment target (Sc2-4; Sc1 is ongoing) each term. The science coordinator runs INSET for colleagues on the aspects of science to be covered; she commented: 'People's confidence and competence in science has improved with the focus on one attainment target per term.' A benefit was the increased level of mutual support that teachers could offer each other: teachers were all sympathetic to questions about aspects of science raised by colleagues because they were working on a similar theme at the same time. The science coordinator went on to say that this whole-school approach also makes planning easier and helps to ensure progression because clearly two different year groups should not be doing exactly the same thing.

At this point it is appropriate to consider the general model of INSET in use. ASE (1993) raises the issue of who is targeted in LEA INSET: if subject coordinators are targeted, it means that teachers who have weaknesses in their own science knowledge are being denied opportunities to improve their knowledge. Although this may be true, one can argue that LEAs may offer several different types of INSET, including:

1. INSET designed to improve teachers' science knowledge
2. INSET designed to help teachers develop and implement schemes of work
3. INSET designed to develop the science coordinator's ability to carry out her/his responsibilities.

The extent to which each of these types of INSET is offered by LEAs will vary according to their own identified priorities. Teachers may, of course, attend INSET provided by other sources: the DFEE 20-day science courses have been established for some years and have no doubt been very beneficial to those who have attended them. Nevertheless, the fact remains that too few teachers have been able to attend INSET to develop their own science knowledge.

A further area of concern is that, frequently, a teacher who has attended an INSET course is expected to disseminate the information on her/his return to school so that colleagues may also receive some benefit, albeit second-hand. This model is known as the 'cascade' model, and has the theoretical attraction of passing on training to a relatively large number of teachers with minimal cost. However, as pointed out by ASE (1993), a weakness of the cascade model of training is the lack of time in primary schools for providing feedback.

Discussing the issue of primary teachers' lack of science knowledge within the context of the knowledge needed to teach the science National Curriculum, Cox and Taylor (1989) consider:

> *... the expertise necessary for developing science courses ... is not present. Primary schools are, therefore, in no position to produce a coherent science course... they need help from outside as a matter of urgency. Simply passing legislation will not make this help appear; it must be planned, financed and be committed to teaching science that is recognisably science* (p.195).

Cox and Taylor expressed reservations concerning the passing of responsibility for training teachers to LEAs since this would lead to different results in different LEAs, and, if LEAs utilised the 'cascade' model of training (as has frequently been the case previously), this would put further pressures on teachers, since this model:

> *....puts the onus on teachers to train themselves (while working full-time) and is an abdication of responsibility. Each primary school teacher must be thoroughly re-trained by primary science experts, so that the schools can provide courses which meet the legal requirements* [i.e. National Curriculum requirements] (pp.195-6).

Of course, we must acknowledge the considerable efforts made both by teachers in schools and LEA advisory teams in implementing the statutory Orders for science in recent years: the fact that OFSTED (1995, p.3) was able to comment that 'Standards of achievement were satisfactory or better in around four-fifths of lessons in all Key Stages ...' shows the level of commitment to implementing the National Curriculum. Yet, at the same time, OFSTED (op. cit.) also identified enhancing teachers' science knowledge as one of the key issues for primary schools (especially for teachers working in the upper years of key stage 2). It seems, therefore, that the issue of INSET remains pertinent.

Kruger *et al.* (1990) suggest that a new model for science INSET is needed, based on a constructivist view of learning: this would build on teachers' existing knowledge and understanding. They consider this is necessary since the 'classroom support' model is of little use in developing teachers' own understanding:

> *It can be argued that classroom-based learning with a colleague working alongside (often an advisory teacher), successful as it was in the case of the process approach to science, is not the way to develop further one's understanding of the fundamental concepts of science. It seems unlikely that learning through watching colleagues at work in the classroom followed by discussion will achieve any advancement of teachers' understanding of concepts unless one of them has sufficient prior mastery of the ideas discussed and is sensitive to a constructivist approach to the development of their colleague's understanding* (p.144).

With this in mind, Kruger *et al.* propose that a new model of INSET is needed which confronts teachers' misconceptions and weaknesses in scientific knowledge in a non-threatening way and allows them to acquire new concepts, use them in their own teaching, and in doing so check that they have understood the concepts themselves. Materials such as those produced by NCC (1992, 1993b, 1993c) and subsequently by SCAA (1994a, 1994b) may be regarded as offering a new model of INSET: supporting open learning which can be arranged individually or collectively, within or between schools to meet the needs they have identified. Whether this type of strategy will prove effective in improving primary teachers' science knowledge remains to be seen, however.

Summary

The fact that many primary teachers have limited science knowledge was established even before the introduction of the National Curriculum. Since science is one of the three core subjects of the National Curriculum, it is essential that primary teachers themselves have the necessary knowledge and understanding to teach the subject effectively to their pupils. Recent evidence suggests that primary teachers' science knowledge remains an area of weakness and a subject for INSET. Alternatives to the traditional cascade and classroom support models should be considered, perhaps utilising a model which acknowledges a constructivist view of learning.

1.10 SMALL SCHOOLS

In England and Wales there are approximately 4,600 primary schools that may be regarded as small schools (i.e. their number on roll is less than 100). These schools may face particular problems, such as:

- limited access to coordinators with expertise in specific subjects: with fewer members of staff there are fewer individuals to offer subject specialism in each of the National Curriculum subjects
- limited funding for resources, by virtue of the fact that they have small numbers of pupils, and therefore financial allowances calculated on a *per capita* basis allocate small schools proportionately less funding than larger schools, despite the fact that they have to teach the full curriculum.

Some of the difficulties facing small schools were evident in School E.

School E, a small rural primary school in a particularly isolated position, faced a number of challenges, including:

Mixed year groups: currently in the mornings classes span R/Y1; Y2/3; Y4/5/6 and in the afternoons R/Y1/2 and Y3/4/5/6, although for one afternoon all the KS2 children go swimming and for two further afternoons there are two teachers working with the children, doing design technology and history/geography. The fact that classes are all mixed ability means that there is a large range of ability from the weakest, youngest children in a class to the brightest, eldest.

Part-time subject specialists: only two teachers (including the headteacher) are full time, with a further three teachers working part time in the school. All teachers have to offer guidance/leadership in at least two areas of the curriculum, and in some cases three. The science coordinator works a 0.6 timetable in the school and also coordinates IT and design technology.

Lack of adequate accommodation: the hall is currently used for lessons, for lunch and (rather limited) PE. As a result the school has to run on a very tight timetable because of the need to make facilities available to another class at a particular time.

Adequate resourcing: on occasions the school shares equipment with other primary schools relatively close by, but the secondary school is too far away for borrowing equipment from there to be practical.

Isolation: the distance to the local secondary school is too far to make cross-phase liaison feasible. Teachers rarely attend INSET at the regional training centre due to the time and costs (about a two-hour round journey; the cost of travel has to be reimbursed by the school, in addition to supply cover for all daytime courses).

One of the school's successes has been the development of environmental resources on the playing field adjacent to the school: a pond has been built, trees planted and a rock pile formed. These resources are well used by the whole school, including the playgroup.

HMI (GB. DES. HMI, 1989, p.10) identified the issue of schools' coping with the problem of having few staff but needing subject expertise in all areas of the curriculum, and observed that 'Many of the smaller schools have drawn together in clusters to assist one another and as a result there is some sharing of teachers who have expertise in science.'

Hargreaves *et al.* (1996) investigated the implementation of the National Curriculum in a sample of small schools (60-100 children on roll) by means of a questionnaire survey, focusing particularly on teachers' levels of confidence and competence in teaching National Curriculum subjects. Teachers were asked to rate their competence in teaching National Curriculum subjects on a four-point scale, as follows:

level 1: 'I need more experience, training or support'

level 2: 'I am able to teach my own class'

level 3: 'I am able to be a curriculum leader'

level 4: 'I am able to run workshops for other schools'.

With regard to science, only 11 per cent of teachers indicated that they needed more experience, training or support to teach the subject, suggesting that the majority of teachers felt able to teach science.

In terms of teachers' confidence in teaching National Curriculum subjects, they were asked to respond using a five-point Likert-type scale, ranging from 'very confident' to 'not very confident'. In total about half the respondents chose the two positive options ('very confident' or 'confident'), as compared with about the 20 per cent who chose the negative options; the remaining respondents indicated their confidence was 'neutral'.

As had been observed by HMI (op. cit.) earlier, the strategy of drawing mutual support from clusters was found to be of use. Hargreaves *et al.* (op. cit.) found that whereas within schools that were part of the least developed clusters, when teachers sought help it was most likely to be from colleagues (including the head) within the school, in schools which were part of the most developed clusters, teachers were equally likely to seek help from:

- colleagues
- advisory teachers
- teachers in neighbouring (i.e. cluster) schools.

In other words, involvement in a well-developed cluster seemed to make teachers more likely to approach 'experts' outside their own school, and therefore draw on a wider sphere of expertise.

Hargreaves *et al.* (op. cit.) concluded that teachers in small schools are no less able to cope with the implementation of the National Curriculum than colleagues in larger schools:

> *What can be stated with some confidence, however, is that compared to teachers in larger schools, and contrary to the pessimistic views about the ability of small schools to deliver adequately the National Curriculum, the teachers in small schools were generally as confident, if not more so, than their colleagues in larger schools* (p.98).

However, despite these apparently encouraging findings, it should be borne in mind that Hargreaves *et al.'s* analysis is based on the responses of relatively few schools (53 schools out of a total of 90, representing a response rate of 59 per cent). In addition, it is possible that, due to the fact that only three LEAs were surveyed, particular policies and/or practices promoted in those LEAs may have led to particular types of responses (i.e. the responses analysed may be representative of the situation in the LEAs surveyed, but these LEAs may as a group be atypical of the national situation).

Summary

Teachers in small schools face particular problems in implementing the National Curriculum in terms of the range of subject specialisms they can draw upon within the school: there are fewer teachers within the school, and therefore specialists in fewer subjects. The limited evidence available suggests that teachers in small schools are no less confident in their ability to deliver the range of National Curriculum subjects (including science) than their colleagues in larger schools. A useful strategy that teachers in small schools may employ in order to gain access to a wider sphere of expertise is that of drawing on the expertise of other teachers within their cluster of schools.

PART 2:

THE SURVEY

2.1 BACKGROUND

2.1.1 The sample

A total of 619 questionnaires was sent out to primary schools. Of these, 208 were sent to schools which had been surveyed the previous year where the headteachers had indicated that they were willing to be surveyed one year later. The remaining 411 questionnaires were sent to schools randomly selected from across England and Wales: the sample included LEA-controlled schools, schools with grant-maintained status and independent schools. The sample was stratified to include schools of different sizes, to represent different geographic locations and metropolitan and non-metropolitan areas. The sample included the following types of school:

- infants only
- juniors only
- infants and juniors
- first schools (covering ages 5-8; 5-9; and 5-10 respectively)
- middle schools (those deemed primary schools)
- first and middle combined schools
- independent (covering ages 5-11).

2.1.2 Response rates

Of the schools surveyed the previous year, 151 responded to this survey, giving a response rate of 73 per cent. Two-hundred-and-seventy-three of the schools randomly selected for the first time for this survey returned questionnaires, giving a response rate of 67 per cent. Overall, the response rate for the survey when the groups were combined was 69 per cent.

2.1.3 Background information on schools

Schools were asked to indicate whether their catchment area was best described as: country town and/or rural; suburban; or urban/inner city. Forty-five per cent of respondents indicated their school was situated in a rural position, 25 per cent stated their school was in a suburban location, and the remaining 30 per cent were located in urban areas.

Although the age range of pupils varied according to the type of school, information held on the NFER's register of schools indicates that 366 schools had pupils for at least part of key stage 1, and 349 schools had key stage 2 pupils; some of these (304) schools had children in both key stages. The total number of pupils on roll varied considerably, from 16 children to 844 children, although 50 per cent of schools had 200 or fewer pupils.

The mean teaching time available in the school week was 25.3 hours, after excluding all breaks for lunch, playtime, etc. together with the time allowed for assemblies and registration.

2.2 QUESTIONNAIRE RESPONSES

2.2.1 Planning and implementing the National Curriculum

The majority of schools had spent time working on a post-Dearing school policy for science: 58 per cent indicated that they had prepared a curriculum plan and a further 36 per cent stated that such a document was being developed, as shown in Table 2.1.

Table 2.1: Percentages of primary schools that indicated different stages of development of a curriculum plan for science

	%
Yes, curriculum plan for science prepared	58
In preparation	36
No curriculum plan prepared	5
No response	1

Based on responses from 426 schools.

However, of those who stated that a curriculum plan for science had been prepared, only about half had taken the further step of translating the policy into schemes of work for KS1/2, although the majority of the rest of the headteachers indicated that such a scheme of work was in preparation.

The science coordinator in School H (primary) was able to draw on advice from an LEA science adviser in drawing up science guidelines and schemes of work for use throughout the school.

At School H, the time spent with the adviser arose from the fact that another member of staff had been booked on a course (and therefore it had been paid for) but was subsequently unable to attend, so the adviser suggested running a training session at the school instead. He spent a half day leading a whole-staff session about the types of science activities that could be included in schemes of work. As a result of this, Mrs M (the science coordinator) spent some time drafting science guidelines for staff. At the same time, the science adviser was scheduled to have an input into a particular topic which was ongoing in another class: after an initial visit, he visited the same class on two or three further occasions over the half term. Mrs M took advantage of the science adviser's visits to speak to him regarding the guidelines she was preparing for the staff and to get a second opinion on her proposals.

One particular benefit Mrs M received from liaising with the adviser was that he was able to show her planning aids which the advisory team had devised: these were designed to help teachers break down the science guidelines from a *termly* focus to *half-termly* and *weekly* planning of activities in line with the scheme of work. Mrs M initially concentrated on drafting proposals for key stage 1: once these were prepared they were passed on to the key stage 1 leader, who in turn passed them on to all the key stage 1 teachers for fine tuning of the details of the schemes of work. The guidelines for key stage 2 were prepared in a similar way, with the draft passed on to individual teachers for fine tuning. Mrs M considered that the benefits of this approach were:

- having had opportunities to discuss the guidelines with the adviser, she was alerted to a useful system for breaking down the planning into progressively more detail;
- the non-science specialists within the school felt comfortable with the level of input they had had into the detailed schemes of work.

2.2.2 The science coordinator

Questions concerning the school science coordinator focused on two main areas: non-contact time and the range of activities undertaken.

2.2.2.1 Non-contact time

Three questions addressed the issue of non-contact time allocated to the science coordinator. The first question was concerned with whether or not non-contact time was available. As shown in Table 2.2, only 25 per cent of respondents indicated that science coordinators were allowed regular non-contact time.

Table 2.2: Provision of non-contact time for the school science coordinator

	%
Regular non-contact time	25
Non-contact time for specific task(s) only	36
No non-contact time	33
No science coordinator in school	5
No response	3

Based on responses from 426 schools; percentages do not sum to 100 as some respondents ticked more than one option.

Where regular non-contact time was allocated to the science coordinator, headteachers were asked to indicate the amount of time allowed per week. Table 2.3 shows the non-contact time allocated to those science coordinators who received regular non-contact time each week (i.e. the 25 per cent identified in Table 2.2). The time allowed varied considerably, ranging from a minimum of ten minutes to a maximum of 16-and-a-half hours per week. Thirty-nine per cent of the respondents to this question reported that science coordinators were allocated one hour or less per week as non-contact time, although some (14 per cent) were allowed more than three hours per week.

Table 2.3: Percentages of science coordinators allocated different periods of non-contact time

Non-contact time	% of science coordinators
Up to 30 mins	9
31 - 60 mins	30
61 - 120 mins	24
121 - 180 mins	13
More than 3 hours	14
No response	9

Based on responses from the 107 schools that indicated in Table 2.2 that regular non-contact time was allocated.

Where the science coordinator was allocated non-contact time for carrying out specific tasks, again there was some variation in the times allowed, although most science coordinators had been allowed only one or two days for this purpose during the first half of the term in which the survey was conducted (autumn 1995).

2.2.2.2 Activities undertaken by the science coordinator

In order to determine the type of activities undertaken by primary school science coordinators, headteachers were given a list describing nine different activities: they were asked to indicate which duties were undertaken by their science coordinator. Responses are shown in Table 2.4.

So as to determine which of the various activities were perceived to be most valuable, respondents were then asked to indicate the **three activities** they considered to be the most important. Although this part of the question was answered by fewer respondents (360), there seemed to be a general consensus concerning two tasks which were widely acknowledged to be important:

- coordinating the planning of the post-Dearing science curriculum

- coordinating the translation of the overall curriculum plans into what children do in the classroom.

These were each cited by more than 70 per cent of the headteachers who completed the second part of the question. Two further activities were also frequently cited, although by fewer respondents:

- monitoring the implementation of the curriculum
- supporting colleagues in the classroom.

Both of these activities were selected as being important by about 50 per cent of the respondents. Other activities in the list were identified as most important by 25 per cent or fewer headteachers.

Table 2.4: Percentages of science coordinators undertaking specific tasks

Activity	%
Coordinating the planning of the post-Dearing science curriculum	81
Attending INSET courses	68
Coordinating the translation of overall curriculum plans into what children do in the classroom	65
Attending external meetings	64
Monitoring the implementation of the curriculum	56
Supporting colleagues in the classroom	42
Providing INSET for colleagues in the school	42
Teaching classes other than her/his own	12
Providing INSET for colleagues in other schools	8
No response	10

Based on responses from 426 schools; percentages do not sum to 100 since respondents could tick more than one option.

One of the science coordinators interviewed was disappointed that it had not been possible to release him from his class so as to enable him to work alongside colleagues, and commented that he 'thought it was part and parcel of being a science coordinator'.

2.2.3 Patterns of science teaching at key stage 1 and key stage 2

The issue of how teaching is approached within the primary school years rose to prominence following the publication of the report on curriculum organisation and classroom practice by Alexander *et al.* (1992). This report argued that teaching subjects by means of multi-disciplinary topics was not always the most effective way, and more consideration should be given to separate subject teaching. Headteachers were therefore asked to indicate the approximate proportion of time for which particular patterns were used for teaching science at key stages 1 and 2. Three different approaches were listed on the questionnaire:

- a separate subject
- part of a science-based topic
- part of a multi-disciplinary topic.

Headteachers were also given the opportunity to describe any other approach used in their school. For each approach, headteachers were asked to indicate whether it was used *(nearly) always; about half the time; or (almost) never.* Responses have been collated so as to indicate the main approaches used and are shown in Table 2.5.

Table 2.5: Percentages of key stage 1 and key stage 2 schools using different approaches for teaching science

Approach	KS1 %	KS2 %
Predominantly separate subject	6	25
Predominantly science-based topic	22	18
Predominantly multi-disciplinary topic	21	7
Combination of separate subject and science-based topic	10	20
Combination of science-based and multi-disciplinary topic	27	12
Combination of separate subject and multi-disciplinary topic	3	4
Combination of all 3 approaches	10	13
Other approach	1	1

Based on responses from 362 schools with KS1 children and 360 schools with KS2 children.

Evidence collected from schools suggested that even where a topic-based approach predominated, teachers recognised that it was preferable to teach some aspects of science as a separate subject, rather than to force them artificially into the topic framework. One science coordinator stressed this fact, referring to 'a common-sense approach to teaching science'; she went on to say: 'There is no set rule - it varies from year group to year group, class to class and topic to topic.'

The headteachers' responses suggest that at key stage 1, there remains an emphasis on teaching science using a topic-based approach (whether a topic with a science emphasis, a multi-disciplinary topic, or a combination of both), with 70 per cent of headteachers indicating that this approach was used about half the time or more. For key stage 2, however, a rather different picture emerged, with much more emphasis on teaching science as a separate subject for at least some of the time available, and with science-based topics more widely used than multi-disciplinary topics. Only one per cent of schools at each key stage indicated that they used a different approach for teaching science from those specified.

The following descriptions relating to Schools E, D and A illustrate some of the differing approaches to teaching science used in schools.

In School E (a small rural primary school) science is predominantly taught as a separate subject. A part-time teacher (0.6 contract) is responsible for coordinating science, IT and design technology throughout the school. The school aims to make full use of individual teachers' particular subject strengths by swapping classes (e.g. the science coordinator teaches the science to the reception/Y1 class while their class teacher takes art with the Y2/3 class), so that, to date, the science coordinator has taught most of the science in all classes.

The headteacher commented: 'Only by using specialists do children have the opportunity to experience the quality of input from specialist teachers.'

In School D (a large suburban primary) all subjects, including science, are taught separately. At KS2, children are set for all three core subjects: English, mathematics and science. Setting for science is done on the basis of pupils' results on standardised (NFER) mathematics tests which are administered twice a year, in September and June. The school acknowledges that mathematics results may not be the best indicator for science, but has so far been unsuccessful in identifying a more appropriate alternative, although KS1 science SAT results might be used for Year 3.

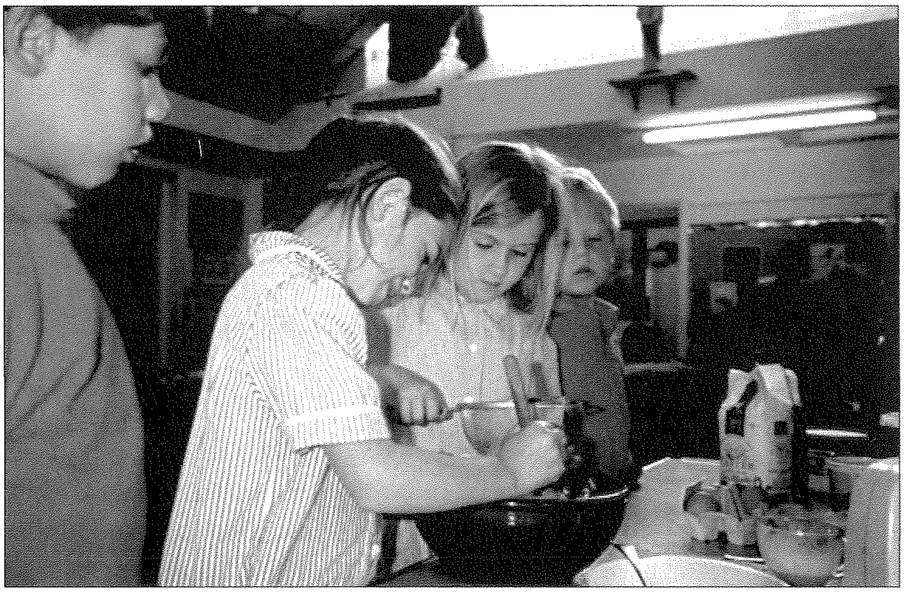
Essentially, children are placed in one of two ability groups (sets) for science. There is flexibility in the sets so that children can be moved from one set to another if teachers feel it is appropriate. The science sets still have pupils of different abilities, but the range is reduced by the setting process, so that teachers are working with a class of similar ability.

School A (a small four-class primary school) had a science carousel for the two infant classes one afternoon each week. This involved planning a number of science activities suitable for the age/ability of the children (from reception to Year 2). On the afternoon I visited the school, the carousel was organised so that one teacher took the six reception children plus two more of the younger children for particular activities, whilst the other (head)teacher worked with the larger group of 24 children from Years 1 and 2. All the activities were related to ongoing topic work: on this particular occasion work involved **materials** as part of the topic on **our school**. After a short introduction to the session in which the headteacher talked to the children (and asked questions) about the work they had covered on materials over the last few weeks, the children split into two groups and the activities for the afternoon were outlined. The younger children had two separate activities:

- a walk with the teacher around the outside of the school, looking for different materials and taking rubbings of different surfaces
- back in the class, a feely bag was passed round and the children felt the different materials inside the bag: each child had to try to name one of the materials.

Four different activities were prepared for the Year 1/2 children:

- making fairy cakes with a melted chocolate topping (an ancillary helper was supervising this)



- watching a video about different objects made from wood
- observational drawings of natural and man-made objects (e.g. a shell, a metal bowl)
- sorting and classifying objects into natural and man-made groups, with an intersection showing items that were part natural and part man-made (e.g. a screwdriver with a wooden handle); once the children had sorted the items they were given a worksheet asking them to draw or write four other objects which would go in the natural and man-made groups.

The older children were organised into four groups, each starting with one of the above activities. After about 20 minutes the teacher moved the groups round to a new activity, then after another 20 minutes on to a third and final activity. As the children worked, the teacher moved from one group to another, talking to them and posing questions.

2.2.4 Time available for teaching science

With regard to the time available each week for teaching science, Dearing (1994) provided guidelines on the number of hours per year primary schools should spend on particular subjects, suggesting 54 hours per year on science for key stage 1 and 72 hours per year for key stage 2. These guidelines approximate to one and a half hours per week for science at key stage 1 and two hours for key stage 2. Of course, the Dearing Review released a theoretical 20 per cent of primary schools' teaching time to be used on aspects of the curriculum at their own discretion: some schools may have decided to use some of this time for teaching science, either as a subject in its own right, or through a topic or thematic approach to learning. Some variation in the time allocated for teaching science was therefore to be expected.

The questionnaire asked headteachers to indicate how many minutes pupils at key stages 1 and 2 were timetabled for science. Headteachers' responses have been grouped into three main categories, as shown in Table 2.6: periods of time in line with the Dearing guidelines (±15 minutes), and periods of time which were either *less than* or *greater than* these recommendations.

Table 2.6: Percentages of headteachers who indicated different periods of time were spent on science per week at key stages 1 and 2

Time allocated to science	KS1 (Dearing guidelines approximate to 90 mins per week)	KS2 (Dearing guidelines approximate to 120 mins per week)
Less than Dearing recommendations (by more than 15 mins)	29	30
In line with Dearing recommendations (± 15 mins)	31	36
More than Dearing recommendations (by more than 15 mins)	40	34

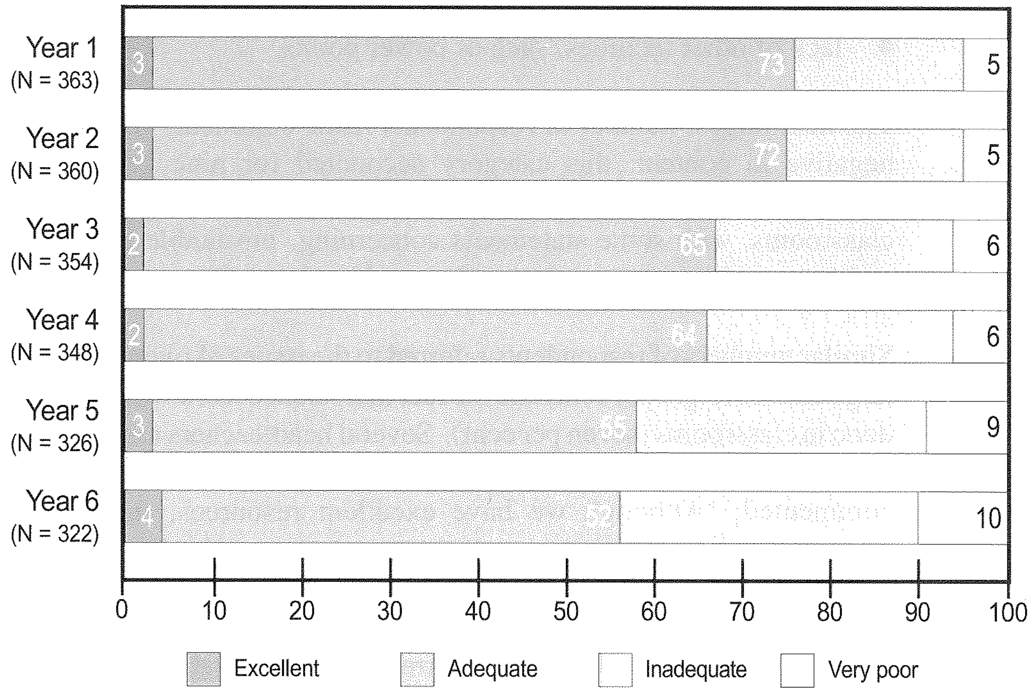
Based on responses from 332 schools with KS1 pupils and 339 schools with KS2 pupils.

Headteachers' responses suggested that at both key stages, the majority of schools (71 per cent at key stage 1 and 70 per cent at key stage 2) allocated periods of time for science each week which were in line with, or greater than, the recommendations provided in the Dearing Report.

2.2.5 Science teaching accommodation

Headteachers were asked to indicate the adequacy of the school accommodation for teaching science to particular year groups using a four-point scale, ranging from **excellent** to **very poor**. In addition they were invited to comment on their accommodation, for example to give examples of either very good or very poor facilities. Responses concerning the adequacy of accommodation are shown in Figure 3.

Figure 3 Percentages of headteachers indicating different levels of adequacy of accommodation for teaching science in specific year groups



The number of respondents for each year group varied due to the different age ranges in different schools, but was always at least 98 per cent of those eligible to respond (i.e. with the year group in the school).

The majority of respondents for each year group indicated that the accommodation in the school was *adequate* for teaching science (ranging from 73 per cent for Year 1 to 52 per cent for Year 6). However, it is disturbing to note that the percentage of headteachers who considered the accommodation *inadequate* increased steadily from Year 1 (19 per cent) to Year 6 (34 per cent), with a further ten per cent of respondents reporting that their Year 6 accommodation was *very poor*.

Approximately 40 per cent of headteachers made comments relating to the quality of their school's accommodation for teaching science. Up to five comments per questionnaire were coded so as to reflect the content of the response. While some responses were of a general nature, the category which was most frequently mentioned by headteachers concerned a lack of specific (named) facilities. A total of 24 per cent of respondents to this question referred to a lack of particular resources, with the following being most frequently cited (listed in order of frequency, i.e. most frequently cited first):

- lack of space
- lack of an appropriate area for experimental/investigative science
- lack of water facilities
- lack of storage/resource area
- lack of other facilities, such as power points.

The next largest number of respondents made comments which were negative in content: this category accounted for nine per cent of responses. Typical comments referred to the inadequacies of temporary classrooms, with some statements concerning 'unsuitable buildings' and 'no suitable accommodation for teaching level 6'.

Similar numbers of respondents referred to the issues of overcrowding/ large classes (eight per cent) and the fact that science work was routinely done in classrooms (seven per cent). Several headteachers remarked on the problems caused by 'small rooms and large classes' and one commented: 'Although we have excellent resources, the regular classroom environment is not conducive to experimentation/investigative activities.'

However, not all respondents reported an unfavourable or difficult situation: a total of seven per cent of respondents made specific references to the availability of particular facilities, such as space, wet areas, environmental/nature areas and specialist science areas. At the level of more general comments, one headteacher observed that accommodation for teaching science was 'not a major issue', and others offered positive comments such as 'classroom spaces are flexibly used to accommodate science' and 'central science resources are well used by all'.

Some schools, such as School C, had specific areas allocated for science work.

School C (a middle school covering Years 4-7) had decided that new facilities for teaching science were urgently needed and raised £10,000 towards the cost of a new purpose-built block which was supplemented by the LEA. Two members of staff with particular expertise in science liaised closely with the LEA architect concerning the design and specification of the new block, which was completed in March 1995. The science block consists of a large, well-equipped laboratory with a storage room for large equipment to the rear: the fact that it looks very much like a secondary school science laboratory was intentional. It is furnished with large, free-standing workbenches which can be moved if required (according to the activities taking place) and stools for the children. Around the perimeter of the room are further workbenches with gas taps, electric points and sinks; plenty of windows allow good light for using microscopes. Children are taught to follow certain routines for safety, such as on entering the laboratory they put on aprons and check they have a pair of safety goggles in the pocket.

Nevertheless, on the whole, the responses suggested that for a significant number of primary schools, the physical accommodation within which teachers work imposed particular difficulties with regard to the teaching of science, such as insufficient space for practical activities and no facilities for work involving water.

2.2.6 Successes and challenges

The final question in the section of the questionnaire regarding science in the primary school asked headteachers to list the successes and challenges/difficulties their schools had faced to date in implementing the post-Dearing National Curriculum in science. Up to five separate codes were allocated to ***SUCCESSES*** and ***CHALLENGES*** respectively on each questionnaire so as to represent the particular points made by respondents.

2.2.6.1 Successes

Table 2.7 shows those areas identified by headteachers as successes in terms of implementing the science curriculum.

Table 2.7: Percentages of headteachers identifying particular successes in implementing the post-Dearing National Curriculum in science

	%
Schemes of work	24
Staff issues	20
Planning strategies	19
Teaching practices	13
National Curriculum coverage	10
Resources	7
Achievement/standards	5
Status of science	3
Pupil-related	2
Other	15
No response	25

Based on responses from 426 headteachers. Percentages do not sum to 100 since headteachers could make up to five comments.

Clearly, the area which was regarded by the largest number of headteachers as a major success was concerned with ***SCHEMES OF WORK*** (cited by 24 per cent of respondents). This category included comments relating to the various stages involved in a scheme of work for science, including:

- **defining** (e.g. 'Getting a scheme of work partly approved by an Inspector. Nobody seems to know what one is – or there are many and various definitions!')
- **producing/developing** (e.g. 'Using the opportunities of change to write schemes of work for science.')
- **modifying/revising** (e.g. 'Previous allocations of ATs/PoS to year groups have initially been aligned with new requirements – now only needs fine tuning.')
- **implementing** (e.g. 'Being implemented by all staff.')

The ***STAFF ISSUES*** category represented responses made by 20 per cent of the headteachers, and embraced a number of types of comment, as follows:

- **positive attitude** (e.g. 'Staff determination to succeed despite changes and difficulties.')
- **confidence** (e.g. 'Teachers feel confident when tackling science.')

- **INSET** (e.g. 'Staff INSET in science.')
- **whole staff/collaborative approach** (e.g. 'Collegiate staff planning and support.')
- **role of the science coordinator** (e.g. 'Science coordinator to assist colleagues in planning and monitoring plans.')
- **other** (e.g. 'Appointing a new science coordinator.')

A further 19 per cent of respondents made general comments on their *PLANNING* and/or described their arrangements for promoting *CONTINUITY AND PROGRESSION*. Headteachers typically referred to 'coordination and unity in planning'; 'planning across both key stages' and 'whole school long- and medium-term plans'. Other comments mentioned 'whole-school approach to ensure continuity and progression'; 'continuity in planning for each half term' and 'all school teaching to a continuous scheme reflecting continuity and progression'.

The ***TEACHING PRACTICES*** category (representing about one in eight respondents) included comments on such issues as:

- **assessment** (e.g. 'Making assessment more manageable.')
- **differentiation** (e.g. 'Growth of workshop approaches to the teaching of science, with differentiated activities.')
- **topic-based science** (e.g. 'Science now in blocked areas of work under a mainly science based topic.')
- **investigative science (Sc1)** (e.g. 'Increase in experiment/ investigative science.')

Ten per cent of headteachers made references to ***NATIONAL CURRICULUM COVERAGE***, with comments such as, 'Ensuring that all aspects of the National Curriculum are covered'; 'Policy reflecting National Curriculum requirements' and 'Team work to make sure programmes of study are covered – to include some revisiting of topics'.

Headteachers' comments under other categories were each mentioned by fewer than ten per cent of respondents.

Some of the successes mentioned by headteachers suggested there was considerable enthusiasm within the school regarding science, as in the case of School G.

Some while ago School G (an infant school) took part in an exhibition of science work from primary schools organised by the LEA. Schools were able to decide the focus of the work themselves and had the incentive of prize money for the best work submitted by three schools at key stages 1 and 2 respectively. The exhibition/competition was open to anyone who was interested in submitting work, and schools were encouraged to consider investigative science. Participating schools were asked to provide a display of the work done (such as filling two display boards and a table). In School G the science coordinator decided to take part, and chose as the theme *Couch Potatoes at Seven*: a reference to the fact that, at the time, there had been a lot of media interest in the poor levels of fitness amongst children. (This topic was in addition to the ongoing science work in line with the scheme of work.)

Over the course of half a term, the class of Year 2 children carried out a number of activities, such as:

- measuring each other's height
- weighing themselves
- recording pulse rates before and after exercise
- writing to particular organisations for information leaflets etc.

Some of the work took place within the children's classroom, but some activities (such as stepping up and down on to benches) were carried out in the school hall using PE equipment.

In addition to displaying some of the children's own work for the exhibition, the teacher concerned prepared a board of photographs showing the children at work. The exhibition was held at a local venue where it was open to schools and members of the public to visit. The LEA science adviser judged the entries: School G was awarded second prize in the key stage 1 class and received £200.

2.2.6.2 Challenges/difficulties

Table 2.8 shows those areas identified by headteachers as challenges/ difficulties in terms of implementing the science curriculum.

Table 2.8: Percentages of headteachers identifying particular challenges/difficulties in implementing the post-Dearing National Curriculum in science

	%
Lack of (named) resources	37
Staff related	18
Teaching practices	13
Planning	12
Interpretation of orders	10
'Change again'	8
Pupil-centred	7
Mixed age classes	6
Conflicting demands/prioritisation	5
Other	11
No response	21

Based on responses from 426 headteachers. Percentages do not sum to 100 since headteachers could make up to five comments.

One category accounted for over a third of responses (37 per cent) concerning difficulties schools had encountered in implementing the Post-Dearing science curriculum: ***LACK OF RESOURCES.*** This main category was subdivided into a number of further categories representing particular facilities that schools were short of, with the following listed by headteachers:

- **lack of equipment/resources** (e.g. (the difficulty of) 'getting sufficient resources for five classes'.)
- **lack of a suitable resources/storage area** (e.g. 'Lack of storage space for equipment.')
- **lack of suitable teaching areas** (e.g. (the lack of) 'feasible science areas'.)
- **lack of space** (e.g. (the difficulty of) 'providing adequate space'.)
- **lack of time** (e.g. 'Attempts to manage teaching and learning in blocks of time allocated'; 'Finding time for Coordinator to support colleagues.')

- **lack of funding** (e.g. (the problem of) 'resourcing further developments from poor budget'.)
- **lack of adult resources** (e.g. 'Shortage of adult resources.')

Eighteen per cent of headteachers' comments were ***STAFF RELATED***, and three main categories emerged:

- **lack of confidence with regard to teaching science** (e.g. 'Continuing lack of confidence among some staff.')
- **need for INSET/enhancing staff knowledge/confidence** (e.g. 'Arranging sufficient training for all members of staff.')
- **other** (e.g. 'Absence because of illness of science coordinator.')

A further 13 per cent of responses focused on ***TEACHING PRACTICES***, with headteachers mentioning:

- **monitoring** (e.g. 'Monitoring appropriate assessment/record-keeping for AT1.')
- **assessment/moderation** (e.g. 'Assessment to inform planning is not coherent across all the year groups.')
- **records/recording** (e.g. 'Meaningful recording and reporting.')
- **experimental/investigative science** (Sc1) (e.g. 'Gathering variety of activities/ideas to complete the required investigation'; 'AT1 not so successful.')

Whereas a considerable percentage of headteachers reported aspects of their ***PLANNING*** as a success, 12 per cent indicated that this area had been a challenge. Comments referred to **schemes of work** (e.g. 'Need to link each area to schemes of work') and **continuity and progression** (e.g. 'Identifying elements to be addressed in each year group to ensure progression.')

Headteachers' comments under other categories were each mentioned by ten per cent or fewer respondents to this question. A number of respondents referred to the impact of another change in the science curriculum: further amendments to policies and having to reorganise topics into a new framework. Some headteachers emphasised the fact that science was only one of the National Curriculum subjects, and time had to be found to address issues concerning other subjects too.

2.2.7 Summary

Overall, the headteachers' responses to the questionnaire suggested that in the majority of schools teachers were exerting considerable efforts to ensure that they were planning, developing and implementing schemes of work in line with National Curriculum requirements for science. At key stage 1, science was taught predominantly using a topic-based approach (either a science-based or a multi-disciplinary topic), whereas at key stage 2 there was more emphasis on teaching science as a separate subject. Over a third of respondents indicated that a lack of specific resources made it more difficult to implement the science curriculum. In addition the quality and suitability of school accommodation posed further difficulties, particularly in the upper years of key stage 2: for Years 5 and 6 a substantial number of headteachers reported that their accommodation for teaching science to these year groups was *inadequate* or *very poor* (42 per cent and 45 per cent respectively).

2.3 SCHOOLS' SCIENCE POLICIES/ SCHEMES OF WORK

One of the aims of this study was to obtain and analyse school science policies/schemes of work which had been prepared since the Dearing Review. Accordingly, within the questionnaire a sentence was inserted stating that we should be grateful to receive copies of any completed plans or schemes of work. Unfortunately, very few schools responded to this request, and only ten documents were sent in. During visits to schools, two further documents were collected, resulting in a total of 12 science policies/schemes of work for analysis. Due to the small numbers involved, the observations and conclusions drawn concerning these documents should be treated with extreme caution.

The science policies/schemes of work submitted by schools were examined to determine the content. Three main aspects were covered in most policies:

1. **Aims for science education within the school**: in some cases these were expressed in general terms, such as referring to opportunities for children to enjoy science, to be involved in investigative science and to increase their own knowledge and understanding. In other instances, more specific aims and objectives were identified, for example by listing particular skills and attitudes the school wanted to develop in each child, and the means by which the school intended to develop scientific knowledge.

2. **A list of topics to be covered per year group per term**: some schools' documents suggested that in certain terms there was to be a greater emphasis on history/geography topics, possibly drawing in relevant science work as appropriate, whereas in other cases it was clear that particular aspects of science work would be done each term.

3. **An indication of the content to be covered by each year group**: in some cases this was organised by listing the science content according to *science attainment targets*, and in others by listing the science content related to particular *topics or themes*. Where the former approach was used, suggested activities were provided for each of the three content-based science attainment targets (Sc2-4). An indication of the progression that should be evident as children advanced through the school was usually given in the form of either:

   i) relating content to age groups (e.g. infants, lower junior, upper junior or specific National Curriculum years); or

   ii) relating content to National Curriculum levels of attainment.

Three of the documents also indicated the progression in skills with reference to Sc1: Experimental and Investigative Science. Where the thematic approach had been adopted in schools' policies, schemes of work listed the science content and typical activities related to the particular themes or topics prescribed for specific year groups (e.g. Year 4 work on 'Forces' during the spring term: the document listed the learning objectives related to this topic, the relevant sections of the new statutory Orders and the assessment objectives).

The documents provided by four schools showed that the school had a rolling programme of topics which were covered over the course of more than one year (usually a two-year period). It is likely that some schools, at least, had adopted this strategy as a means of coping with mixed-age classes. In some instances the outlines of work to be covered in particular year groups were very specific, in one case detailing the content of work to be covered by Years 3/4 and Years 5/6 respectively for each week of the year over a two-year rolling programme. Other details included in the guidance provided by different schools included:

- questions to ask children
- related scientific vocabulary
- suggestions for practical activities and investigations
- resources (published and/or for practical activities)
- learning intentions
- assessment opportunities/resources
- references to the appropriate part of the programmes of study.

Apart from the main elements described above, the documents examined contained a number of other types of information, mostly at the general or policy level, but in a few cases, at the more detailed scheme of work level. Each of the following was mentioned in only one or two document(s):

- **teacher expertise**: suggestions for sources for teachers to improve their own background knowledge of science;
- **equal opportunities statement**: emphasising the need to make opportunities available to all children irrespective of ability, gender, or ethnic background;
- **planning**: details of where long-, medium- and short-term plans were stored;
- **differentiation**: guidance on ways of catering for the range of ability within the class;
- **lesson organisation**: suggestions for managing the class;

- **safety**: general safety procedures to be followed within the school; one document provided detailed lists of chemicals that were either safe to use; safe to use with reasonable care; or unsuitable for classroom use;
- **recording methods**: suggestions for varied methods for children to record their work, including flow diagrams, cartoons and tape recordings;
- **monitoring science work**: the arrangements for the science coordinator to monitor science work throughout the school;
- **equipment lists**: details of equipment available;
- **cross-phase links**: a statement of what links were in place;
- **reporting to parents**: a summary of the arrangements for reporting both orally and in writing on children's progress;
- **author**: who prepared the document.

Of course, the level of detail within the documents examined probably reflects the purpose for which they were intended. General whole-school policy documents would typically describe the school's overall philosophy of science education and their approach throughout the school: these could be expected to be used more for reference. The level of detail in some documents (with outlines of specific activities, resources, questions for the children, etc.) suggests that they were schemes of work: documents to help in the day-to-day planning of lessons.

Clearly there can be no uniform way of presenting information in schools' science policies and schemes of work: each is uniquely relevant to one school, in terms of the various factors that have to be taken into consideration, such as:

- ♦ children's needs and capabilities
- ♦ staff expertise
- ♦ resources available
- ♦ school organisation (e.g. vertical grouping)
- ♦ time available
- ♦ approach to teaching (e.g. topic-based or specific subjects)
- ♦ National Curriculum programmes of study
- ♦ assessment requirements.

Documents which are comprehensive, unambiguous and meaningful to all staff are most useful. However, the real measure of the appropriateness of policy documents and schemes of work is not defined in terms of their contents, but by the extent to which they are implemented throughout the school to provide a coherent whole-school approach to science.

2.4 THE WAY FORWARD

It is clear that there are still difficulties concerning the teaching of science in primary schools in England and Wales.

Some would argue that the National Curriculum in science, and the establishment of science as one of the three core subjects, was intended to signal the importance of the subject as part of the primary school curriculum and to clarify what should be taught. Many commentators have identified the improvements in planning for science at the whole-school level and the increased attention to continuity and progression, both within and between schools, as benefits of the introduction of the National Curriculum for science.

Others, however, consider that the National Curriculum has highlighted particular areas of concern, such as levels of resourcing for science within schools, and primary teachers' own (lack of) science knowledge.

Changes in the statutory Orders for science twice since their introduction in 1989, together with the implementation of National Curriculum assessment requirements, and, at the same time, a lack of any suggested format for passing records between schools, have created additional burdens for teachers during a period of extensive changes within the educational sector.

In addition to describing some of the current concerns regarding science in primary schools, this report has identified instances where effective practices have been introduced and where both children and teachers have benefited from the initiatives implemented. The fact that teachers are continuing to make considerable efforts to improve the range and quality of science teaching and the experiences offered to children is evidence of the commitment of primary teachers and the enthusiasm of science coordinators.

Much has been achieved in a relatively short time. In some primary schools, prior to the introduction of the National Curriculum, very little science used to be taught (in many instances it existed mainly in the guise of nature studies), whereas today science has the status of being one of the three core subjects. After a period of phasing in the statutory Orders to all year groups over successive years, the National Curriculum and its associated assessment arrangements are fully in place in state primary schools, and some independent schools also choose to follow the National Curriculum.

In the period of relative calm following the Dearing Review, teachers are implementing the latest revision of the science curriculum, which, we are told, will remain in effect for at least five years. At the same time, we must seize the opportunity to build on existing strengths and to address weaknesses so that we can be confident that all primary children are receiving the quality and range of science education to which they are entitled.

OFSTED (1995) identified five key issues regarding the teaching of science in primary schools:

1. enhance science knowledge for teachers, especially in the upper years of key stage 2
2. ensure strategies are in place for assessment and ensure standardisation of the judgements of different teachers
3. systematic whole-school curriculum planning for science
4. key stage 2 teachers need to build on key stage 1 experiences and achievements
5. sufficient non-contact time for science coordinators to fulfil their responsibilities (including monitoring science teaching throughout the school).

In addition, evidence collected during this study suggests that, in some schools, teachers need more support regarding Sc1: Experimental and Investigative Science.

Some of these issues clearly have to be considered and resolved at school level, such as ensuring sufficient non-contact time is available for science coordinators to fulfil their responsibilities. Others would benefit from input from LEA science advisory teams, such as guidance regarding whole-school planning for science and suggesting appropriate strategies for carrying out assessment and moderation. One may argue that there is also scope for further initiatives at a national level, such as:

- Increased levels of initial and in-service training to ensure that all primary school teachers who teach science have the necessary scientific knowledge themselves. They should also have the confidence to vary their teaching styles, to be sensitive to their pupils' needs and to encourage children to develop their own investigations.
- Development of a record-keeping system which would ensure that records of children's achievement were compatible when pupils transferred from one school to another. This could have 'preferred' status to encourage schools to use it, but also allow clusters of schools that have effective existing systems which span the primary-secondary phases to retain these systems.

Individual primary schools will identify their own needs and priorities with regard to continuing to develop effective science education throughout the school; in some cases, these will be formally documented within the school development plan. Although some development may be achieved without support from external agencies, additional support will on occasions be beneficial and even necessary. By drawing on support that is available at the local level through clusters of schools, at regional level from LEA science advisory teams and from national organisations and initiatives, primary schools can continue to develop policies and practices in science which will fulfil their needs and meet their pupils' entitlement.

Finally, it is not clear how science teaching in primary schools in England and Wales compares with the curriculum implemented in other countries. Information about pupils' performance in science and the styles of teaching used in other countries will be available when a major international survey (the Third International Mathematics and Science Study – TIMSS) presents its findings regarding primary-age pupils in summer 1997.

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SCIENCE IN PRIMARY SCHOOLS

Drawing on information collected as part of the NFER's *Annual Survey of Trends in Education*, this report describes current issues regarding the implementation of the National Curriculum for science in primary schools.

In Part 1, the views of contemporary experts in the field of primary science are presented and discussed. The range of topics includes:

- school policies and schemes of work for science
- assessment
- practical science activities
- primary teachers' science knowledge and INSET needs
- problems facing small schools.

Part 2 focuses on headteachers' responses to questions within the *Annual Survey* concerning the teaching of science since the Dearing Review of the National Curriculum. Specific aspects covered include:

- planning and implementing the National Curriculum
- the role of the science coordinator
- patterns of science teaching at key stages 1 and 2
- time available for teaching science
- science teaching accommodation
- successes and challenges in implementing the post-Dearing curriculum for science.

Throughout the report, illustrative examples show the diversity of approaches and specific successes achieved by primary schools.

An analysis of science policies and schemes of work submitted by schools provides further evidence of the differing approaches adopted by schools to the teaching of science.

This report is essential reading for all those concerned with the teaching of science in primary schools: teachers, governors, LEA advisory teams, teacher trainers and policy makers.

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