

Nuffield Primary Science

SCIENCE **P**ROCESSES **A**ND **C**ONCEPT **E**XPLORATION

TEACHERS' HANDBOOK

THE EARTH IN SPACE

ELECTRICITY
AND MAGNETISM

FORCES
AND MOVEMENT

LIGHT

LIVING
PROCESSES

LIVING THINGS
IN THEIR
ENVIRONMENT

MATERIALS

ROCKS, SOIL
AND WEATHER

SOUND AND MUSIC

USING ENERGY

THE VARIETY
OF LIFE

Nuffield Primary Science
SCIENCE PROCESSES AND CONCEPT EXPLORATION

TEACHERS'
HANDBOOK

PUBLISHED FOR THE NUFFIELD CURRICULUM TRUST BY COLLINS EDUCATIONAL

Science Learning Centres



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NUFFIELD PRIMARY SCIENCE
Science Processes and Concept Exploration

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Safety adviser
Peter Borrowes

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Foreword

The publication of Nuffield Primary Science is an important moment in the work of the Nuffield–Chelsea Curriculum Trust. With this project complete we are, for the first time in all the years of our work, providing Nuffield science courses for pupils of every age from 5 to 19.

It also takes up again one of the first challenges to the early Nuffield curriculum developers. In 1967 the first Nuffield primary science project, directed by E.R. Wastnedge published a series of books for teachers suggesting topics and methods. In the intervening years there have been many curriculum initiatives in primary science. Each has made a contribution to thinking and to practice, and some have been outstanding in these respects. However, none has achieved widespread use in classrooms: not surprisingly, since only very few primary teachers were trained and confident to work with science, and there was no consensus about what teachers should try to achieve with young children.

The introduction of the National Curriculum has created a new opportunity and new needs.

The new opportunity is clear. The new aims are spelled out, albeit in broad terms, in the National Curriculum. At the same time, in-service training has been given a new priority, and important changes have been made in initial teacher training.

The needs are more difficult to define. Teachers need help through classroom materials, both teachers' resources and pupils' books. But what types of classroom activity are best for pupils taking their first steps in learning science? How can children begin to grasp the powerful concepts and processes of science? And if we could adequately answer these questions, what printed materials would we need in order best to help teachers respond to the new demands?

The purpose of the SPACE project, working at King's College London and Liverpool University, was to answer these questions. It began as a research study, generously funded by the Nuffield Foundation. Its aims were to explore ways of finding out children's own ideas about the natural world and then to test ways by which teachers might help children to develop more scientific ones.

The work, which has already lead to substantial research publications, was carried out in partnership with classroom teachers. The classroom trials in close collaboration with many teachers and children made the results a uniquely useful basis for designing classroom activities with written classroom materials to support them. Nuffield Primary Science is the product of this rare opportunity to write a complete set of teachers' and pupils' materials, based on this recent research and incorporating many of its results.

The Trust is conscious that this fine project could never have been brought to fruition without the advice, support and devoted work of many individuals and

groups. It is a pleasant task for me to express our gratitude. First, to the Directors of the space project, Professor Paul Black and Professor Wynne Harlen. It is to all the members of their teams in London and Liverpool, over six years, to their conceptions, their research and their drafts, that we owe the unique character of these books. Then to those others whose advice and guidance helped to shape the project: the Consultative Committee, with its wise and thoughtful Chairman, John Slade, and its expert members including inspectors, examiners, educators and scientists from the Universities, science advisers and, most important, science teachers.

I am happy to record our thanks, also, to the fertile imaginations of the many writers and teachers who invented ideas, collected material or wrote draft pages for the pupils' books.

Another important debt is to local authority advisory staff, and to the governors, staff, and pupils of the many schools who collaborated with us both in our research and our trials. It will be obvious to every reader that the teachers' guides could not have been created without their help, and especially without the children's drawn and written records of their hard work and their growing understanding of science.

Finally, and with great pleasure, I must thank all those in the Trust's office who have worked to let the materials see the light of day in such handsome form – our Publications Manager, Dieter Pevsner, with Catherine Blackie, Sarah Codrington, Ralph Hancock, Jean Macqueen, Patricia Verity, Anna Walsh and Deborah Williams. There would, of course, have been no books but for Roy Davey at Collins Educational and his colleagues, among whom we owe a special debt to Deborah Blackburn and Anna Clarkson, and to our initial publisher Lucy Hall. All of them have contributed with extraordinary generosity to the quality of what children and teachers will be using, by their considered advice and by their unflagging pursuit of the highest standards of design and manufacture.

K.W. Keohane

Chairman, The Nuffield–Chelsea Curriculum Trust



Introduction

What is the purpose of the Teachers' handbook?

This handbook is designed to help teachers to implement the SPACE approach to the teaching of primary science. It provides more detailed discussion than can be included in the Nuffield Primary Science teachers' guides about the underlying philosophy of the approach, and the way it links to implementation of the National Curriculum. It also gives practical guidance about the planning and procedures for classroom work, and so introduces the other Nuffield Primary Science publications and acts as a guide to their use.

How is it organized?

To make the material in this book easily accessible, it is organized in 26 short chapters, grouped into five sections.

The first section describes in outline the basis of the approach and the main publications.

The second section explains the underlying rationale of the SPACE approach in detail. It covers the National Curriculum, the science knowledge that teachers require, and the concepts, processes and progression in the learning of science.

The third section is about the practicalities of classroom work starting with an overview of the teachers' role. Various ways of starting, of eliciting and developing children's ideas, the use of language, of knowing when to stop and of ensuring equal opportunities for all pupils are covered in these chapters, which draw heavily on the experience of the classroom teachers who developed the Nuffield Primary Science materials in their schools.

The fourth section is also about practical issues, but is concerned with the planning of science teaching, particularly in relation to the whole curriculum.

Finally, the fifth section presents ideas and advice about assessment, record keeping and self-evaluation.

How should I use this book?

This book should be read both in preparation for using the SPACE approach and the Nuffield Primary Science teachers' guides and as a regular reference thereafter. The arrangement of the book is such that it can easily be dipped into as questions and uncertainties arise in the course of teaching.

It is an essential accompaniment to the teachers' guides and pupils' books which form the bulk of the published materials. The principles underlying the content and presentation of the guides are mentioned only briefly in each one because the full explanations are given here.

So we recommend that you read right through this handbook when you start to use the Nuffield Primary Science materials. After that there will probably be time during the busy teaching week only to dip into it, but by then you will know what there is and where it is to be found.

There is more to the SPACE approach than a set of printed materials. We hope this book will help you to use the Nuffield Primary Science materials with satisfying and effective results and to understand the broader approach which these materials are designed to support.

We also hope that you will enjoy reading it.

The SPACE approach

What is the SPACE approach to teaching and learning science?

A primary class where the space approach to science is being used may not at first seem different from any other class engaged in science activities; in either, children will be mentally and physically involved in exploring objects and events in the world around them. However, a closer look will reveal that both the children's activities and the teacher's role differ from those found in other approaches. The children are not following instructions given by others; they are not solving a problem set by someone else. They are deeply involved in work which is based on their own ideas, and they have taken part in deciding how to do it.

The teacher has, of course, prepared carefully to reach the point where children can try out their ideas. She or he will have started the topic by giving children opportunities to explore from their own experience situations which embody important scientific ideas. These will be situations from the children's experience, such as the changes which take place when solids are put in water or when food is cooked, or what is needed to cast a shadow or to make a noise; everyday experience abounds with applications of basic science concepts which young children can begin to understand at appropriate levels. While the children explore one such situation the teacher will ensure that they express their ideas about it, and by using one or more of a range of approaches – from whole-class discussion to talking with individual children, or asking them to write or draw – the teacher will explore the children's reasons for holding the ideas they express.

With this information about the children's initial thinking, the teacher will have decided how to help the children to develop or revise their ideas. This may involve getting the children to use their ideas to make a prediction, then testing it by seeing if it works in practice; or the children may gather further evidence to discuss and think about. In particular, the teacher will note how 'scientific' children have been in their gathering and use of evidence; and should, by careful questioning, encourage greater rigour in the use of scientific process skills.

So, by deliberately finding out about the children's ideas, taking them seriously and choosing appropriate strategies for helping the children to test their ideas, the teacher moves children towards ideas which have wider application, fit evidence better, which are, in short, more scientific. Working in this way, children do the changing, rather than simply accepting ideas which they are told are better; and they are advancing their skills and ways of relating ideas to evidence.

Managing this approach to learning sounds demanding, but it is no more so than any other approach to teaching science. For one thing, although children's individual ideas have to be taken into account, one of the best aids to developing ideas is for children to work in groups, where they hear other children's ideas and have to justify their own. Communication of all kinds, but particularly discussion, is cen-

tral to learning in science and, of course, contributes to language development. Another point to bear in mind is that taking steps to find out about children's ideas and skills means that continuous assessment is taking place, which in turn provides ample information for the Teachers' Assessment required for National Curriculum Assessment.

The Nuffield Primary Science materials, particularly the teachers' guides, provide detailed and specific support for teachers in planning and carrying out the varied role required to support this approach to science teaching – an approach in which children learn with understanding through the development of their own thinking.

The SPACE project

What were its aims?

Before the development of the Nuffield Primary Science materials there was the Science Processes and Concept Exploration (SPACE) project. From January 1987 this carried out research into primary children's ideas about some science concepts. When the National Curriculum was introduced the research was extended to each of its concept areas to investigate in depth:

- ◆ what ideas children held about aspects of the world around them;
- ◆ how they came to form these ideas;
- ◆ what were the possibilities of helping children to modify their ideas, to bring them closer to the more useful, scientific ones.

The research was carried out in classrooms with the help of teachers, so that materials relevant to everyday work could be produced.

What was found?

The findings provide a fascinating account of the ideas children use to explain the scientific aspects of things around them and the way in which these ideas differ according to children's age and experience. They also reveal that the range of ideas is limited and shows marked similarities from one school to another. Because many children independently came up with the same ideas to explain things, it was possible to give descriptions of ideas which might be expected in general from other groups.

Detailed technical reports describing the results of this research have been produced. Information about these reports is given in the Appendix.

How were the results used?

The project was able to give teachers descriptions of what they were likely to find if they explored the ideas of their children. The findings were also used to develop trial materials which helped teachers to plan activities to take children's ideas as a starting point in classroom work. These activities were designed to help children to develop or to change their ideas through exploration bringing them closer to the more powerful ideas of science. Systematic evidence about such changes was collected, so that it was possible to see how some, but not all, of the intended changes could be achieved. This evidence has provided the basis for the aims proposed and the methods suggested in the Nuffield Primary Science teachers' guides.

The Nuffield Primary Science teachers' guides

What are they?

The Nuffield Primary Science teachers' guides are a resource firmly based on the research findings of the SPACE Project. They are designed to help teachers put the SPACE approach to teaching and learning science into action in their classrooms. They do not constitute a programme to be followed step by step.

There are twenty-two teachers' guides in total: eleven address the concepts relating to the 'knowledge-and-understanding' attainment targets of the National Curriculum for Key Stage 2, and eleven (supplied in one ring binder with a single introductory booklet) for Key Stage 1. Each guide explicitly highlights Scientific Investigation (AT1) as an integral part of all learning in science. The KS1 and KS2 teachers' guides share a common set of titles. They are as follows:

The variety of life
Living processes
Living things in their environment
Materials
Rocks, soil and weather
Forces and movement
Using energy
Sound and music
Light
Electricity and magnetism
The Earth in Space

How does a teachers' guide relate to the National Curriculum?

It has been found convenient to organize the ideas, information and activities associated with a concept area of the National Curriculum into a theme. The themes – the Nuffield Primary Science themes – cover the concepts relating to Attainment Targets 2, 3, and 4 of the National Curriculum for each Key Stage.

The relationship between the Nuffield Primary Science themes at KS1 and KS2, and the strands of Attainment Targets 2, 3, and 4 of the National Curriculum is shown opposite.

This arrangement of the teachers' guides has been used so that teachers can readily identify aspects of science and then include them in their own preferred way of planning science work. Teachers will be able to find what they need to construct schemes of work which link science ideas from different ATs and also link science work with work in other aspects of the curriculum.

How is a teachers' guide organized?

Structure and content of the Key Stage 1 teachers' materials

Introductory booklet

- 1 The SPACE approach to teaching and learning science
- 2 Useful strategies
- 3 Equal opportunities
- 4 Helping children to develop the process skills of AT1
- 5 Nuffield Primary Science and the National Curriculum
- 6 Planning for children's learning
- 7 What are 'key ideas'?
- 8 Resources
- 9 Pupils' books
- 10 Warnings
- 11 Index of science content

Background science book

Teachers' guide booklets

Chapter 1 Planning

Resources
Pupils' books
Warnings
Themes and the National Curriculum
Planning a topic: case study

Chapter 2 The themes of the booklet

The themes, in each of which there are:
Areas of investigation
Key ideas
A look at ...
Finding out children's ideas
Children's ideas
Helping children to develop their ideas

Chapter 3 Assessment

Examples of assessment in operation:
matching evidence of achievement with
statements of attainment of the National
Curriculum

Structure and content of the Key Stage 2 teacher's guides

Chapter 1 Introduction

The SPACE approach to teaching and learning science
Useful strategies
Equal opportunities
How the themes of the guide relate to the National Curriculum
Attainment Target 1

Chapter 2 Planning

Introduction: planning with children's ideas in mind
Cross-curricular topics
Topic plan examples
Use of information technology
Resources
Pupils' books
Warnings

Chapter 3 Exploring the themes of the guide

Theme organizer
For each theme:
Areas of investigation and key ideas
A look at ...
Finding out children's ideas: starter activities
Children's ideas
Helping children to develop their ideas

Chapter 4 Assessment

Examples of assessment in operation: matching evidence of achievement with statements of attainment of the National Curriculum

Chapter 5 Background science

Explanation of the scientific view of contents included in the guide.

Teachers' guide	Themes at KS1	Strands of the attainment targets of the National Curriculum	Themes at KS2
Living Processes	How do we know if it's alive? The human body and keeping healthy Plant and animal growth	2(ii) Variation and the mechanisms of inheritance and evolution 2(i) Life processes and the organization of living things 2(iv) Energy flows and cycles of matter within ecosystems	How do we know if it's alive? The human body Keeping healthy Plants
Living things in their environment	Waste and decay Habitats Effects of human activity on the environment	2(iv) Energy flows and cycles of matter within ecosystems 2(i) Life processes and the organization of living things 2(iii) Populations and human influences within ecosystems	Waste and decay Feeding relationships between organisms Habitats and environmental change Effects of human activity on the environment
Variety of life	Naming and grouping living things Individual variation Past life forms	2(ii) Variation and mechanisms of inheritance and evolution	Classifying and identifying living things Individual variation Fossils and past life forms
Materials	Properties and uses of materials Changing materials	3(i) The properties, classification and structure of materials 3(iii) Chemical changes	Properties and uses of materials Solids, liquids and gases Changing materials

Teachers' guide	Themes at KS1	Strands of the attainment targets of the National Curriculum	Themes at KS2
Rocks, soil and weather	Rocks and soils Weather	3(i) The properties, classification and structure of materials 3(iv) The Earth and its atmosphere	Rocks and soils Weather
Using energy	Energy sources Hot and cold Mechanisms	3(iii) Chemical changes 4(ii) Energy resources and energy transfer	Energy sources Hot and cold Mechanisms
Electricity and magnetism	Sources and uses of electricity Circuits Magnets	4(i) Electricity and magnetism	Sources and uses of electricity Circuits Altering the flow of electricity Magnets
Forces and movement	Pushes and pulls Floating and sinking	4(iii) Forces and their effects	Moving things Stopping and staying put Floating and sinking Structures and balance
Light	Light sources Reflections and shadows Colour	4(iv) Light and sound	Light sources and vision Reflections and shadows Colour
Sound and music	Sound	4(iv) Light and sound	Making and receiving sound Sound travelling
The Earth in Space	Time Earth, Sun and Moon Seasonal change	4(v) The Earth's place in the Universe	Time Day and night The stars and the Solar System Seasonal change

All guides are arranged in a similar pattern and include the following.

- ◆ Suggestions for planning work involving the science covered in the guide (expanded in Chapters 20, 21 and 22 of this Handbook);
- ◆ An 'A look at ...' section at the beginning of each theme which gives a description of the scientific concepts and understanding children could be expected to develop by the end of a Key Stage, through the study of that particular theme;
- ◆ 'Key ideas': these are important aspects of the scientific concepts covered by the theme. Some might be understood by the end of Key Stages 1 or 2, while others may not be comprehended until later. Even in the latter case, however, children may begin to develop their understanding of them. Key ideas are not specific points to teach – they will not engage with the child's own thinking. Rather they provide information to guide you in helping children to develop their ideas.
- ◆ Specific suggestions of ways to find out children's existing ideas. The activities and techniques included are based on those which were found to be successful during the research phase of the project (see Chapters 13 and 14 of this Handbook for further details of techniques);
- ◆ A description of the children's ideas that were identified during the research studies and how these ideas help to show development of the concepts involved in comparison with the accepted scientific view;
- ◆ A collection of strategies, ideas and activities which have been found helpful in encouraging and challenging children to review their ideas in the light of their new experiences (see Chapter 16);
- ◆ Guidance on assessing skills relating to AT1 and children's ideas as part of the teachers' interaction with them (see also Chapters 23 and 24);
- ◆ Background information on the scientific ideas relating to the subject matter of the guide (see Chapter 7);
- ◆ Information which will help teachers plan particular activities for children, as shown below.

**Explanation of symbols
in the margins
of the teachers' guides**



Warning



Good opportunities for work related to Attainment Target 1 (Science 1)



Notes which may be useful to the teacher



Vocabulary work



Opportunities for children to use information technology



Equipment needed



Reference to the pupils' books

How do I use the teachers' guides?

The use of any curriculum materials is a personal matter. It depends on the teacher's own experience and background, the children in the class and the school situation. This was emphasized during the trials, when teachers used the guides in a variety of ways. Thus the need for flexibility and adaptability has been taken into consideration in designing the Nuffield Primary Science teachers' guides.

Initially use of the guides might follow a pattern which involves:

- ◆ gaining familiarity with the SPACE approach and the scientific concepts being considered;
- ◆ identifying which aspects of the science contained in a guide are relevant to broader themes or topics, so that the work can be related to the curriculum as a whole;
- ◆ referring to the appropriate theme(s) within a guide and selecting suitable activities for finding out children's ideas (this is a key element of the SPACE approach);
- ◆ having determined children's existing ideas, using the guide to support planning of ways in which these ideas may be further developed through practical activities, vocabulary, and generalizations related to the concepts involved;
- ◆ making reference to appropriate sections of the teachers' guides as required, such as the 'Assessment' chapters.

The Nuffield Primary Science pupils' books

What is the role of the pupils' books?

The pupils' books are intended for use as a supplement to classroom work. They are not in general essential to the main activities outlined in the teachers' guides, and they are certainly not intended as a substitute for the practical work and discussion that are central to the SPACE approach for children's learning. However, they are available to enrich the pupils' work in science in the ways described below.

How are they presented?

There are 33 pupils' books, 22 linked in pairs with one pair to each teachers' guide at Key Stage 2, and one to each teachers' guide at Key Stage 1. Each is at the appropriate reading level for the age range intended. (For the linked pairs at Key Stage 2, one is aimed primarily at lower juniors – Years 3 and 4 – and one at upper juniors – Years 5 and 6.)

In each pupils' book there are eleven double page spreads. A spread can be a short story, or a poem, or a series of photographs. The content of the spreads are not usually linked to one another – the books can be dipped into whenever a particular spread seems to be useful. The topics have been chosen to match the interests of both girls and boys, and care has been taken to emphasize multi-cultural aspects and opportunities.

What can they be used for?

Some of the spreads help to support or start small-group activity amongst pupils. For example, some spreads have photographs chosen to serve as pictorial starting points, linked to a teachers' guide topic, and useful for arousing curiosity or provoking questions for discussion. An example could be optical illusion pictures in *Light*. Others can be the basis for other kinds of activity – paper and pencil games, picture completion or matching activities – which might serve to revise or consolidate classroom learning.

Other spreads are more specific in function, providing sources of information which might be needed for the work on a particular theme, for example *The Earth in Space*, or about animals for work on the *Variety of life*. Such information is provided in a variety of ways: pictures or photographs with discussion points, puzzles, or short pieces giving interesting facts and figures.

More generally, the spreads present material that is designed to be interesting to read, or to look at as a basis for discussion. Such pieces might be used as links with

work in other subject areas. For example, stories in which a science idea was a key to the plot can be used for reading development as well as for consolidating science work; a spread on the everyday applications of science, or about 'how it works', can be a starting point for work on identifying needs and opportunities in Design and Technology; a piece on a historical aspect of science can make a link with work in History.

Overall, the books should be a resource that can be used flexibly as an aid for learning; in particular, they should be of value in the organization of work that children can do on their own or in small groups, so that teachers can devote themselves to discussions with one or a few pupils at a time.

The Nuffield Primary Science in-service training package

What is the purpose of the in-service training package?

The aims of the in-service materials are to:

- ◆ inform teachers of the SPACE approach
- ◆ show teachers the potential within the SPACE approach for teaching and learning in primary science
- ◆ introduce teachers to the Nuffield Primary Science *Teachers' handbook* and teachers' guides.

What does the in-service training package include?

The package consists of four units, each covering a particular aspect of the SPACE approach. Each unit contains:

- ◆ a number of workshop activities for teachers
- ◆ suggestions for running the workshop activities
- ◆ background notes for the course leader and participants
- ◆ OHP masters of photocopiable notes and diagrams.

In all the units there are references to the *Teachers' handbook* and the teachers' guides – these materials are considered to be integral components of the in-service package.

Each unit covers a particular aspect of the SPACE approach. The contents of each unit are as follows.

Unit 1

The SPACE approach and children's ideas

This unit provides an introduction to teaching and learning science through the SPACE approach, and to children's ideas about the world around them. Children vary in their willingness to express their ideas, often because they fear being 'wrong'. Thus, we need to gain children's confidence and show that we value their ideas. This section explores strategies and techniques which can be used to find out children's ideas.

Unit 2

Helping children to develop their ideas: Part one

Ideas are provisional until tested, discussed and reflected upon. Ideas need to be challenged so that they may be justified or modified in the light of new evidence and experience. This section initially previews the ways in which children may be

helped to develop their ideas towards a more scientific understanding of the processes and concepts involved. The main emphasis here is on the use of practical investigations as an important strategy in developing and testing ideas.

Unit 3

Helping children to develop their ideas: Part two

In this unit other strategies to help children develop their ideas are considered. Whilst practical investigation has a very important role in helping children to develop their ideas it is not the only strategy available. Discussion of meaning of words, finding ways of representing events, and expanding the range of evidence available, all play an important part in developing ideas. This unit complements Unit 2.

Unit 4

Planning and assessment

Effective learning and teaching does not just happen: it needs to be planned so that each child can benefit from the opportunities available. Assessing where children are in their learning is necessary for this matching to take place. This section looks first at planning, and then at assessment of science as part of the SPACE approach. It discusses how to identify what constitutes progression and how to determine whether progress has been made.

How should the package be used?

The important aim of these materials is to convey the SPACE approach to teaching and learning and to cover its major features. The materials can be adapted to meet the needs of different situations. They can be used by practising teachers and by students in initial teacher training, and as part of school curriculum evenings for parents. Each course should attempt to:

- ◆ establish the nature of the SPACE approach
- ◆ consider the importance of finding out children's ideas, and encourage teachers to try the different techniques with their own classes
- ◆ look at ways in which children can be helped to develop their ideas.

The SPACE approach and the National Curriculum

What do children need to know and be able to do to meet the requirements of the National Curriculum?

The National Curriculum for Science is expressed in the Programmes of Study and four Attainment Targets. The Programmes of Study for Key Stages 1 and 2 indicate the proposed learning experiences for these stages. The Attainment Targets are:

- AT1 Scientific investigation
- AT2 Life and living processes
- AT3 Materials and their properties
- AT4 Physical processes

These titles may be somewhat off-putting to primary teachers, but they apply to the development of ideas all the way through to the age of 16.

There are two kinds of Attainment Targets here: AT1 addresses the processes and skills that are needed in scientific investigations, while AT2, 3 and 4 are concerned with knowledge and understanding of subject matter. It has been suggested that AT1 should be represented as an aim of all scientific activities to some degree, whatever their subject matter. The way in which these targets are covered across the Nuffield Primary Science teachers' guides is explained in Chapter 3 of this *Handbook*.

What do the National Curriculum requirements mean in practice?

Separating processes and knowledge and understanding in different Attainment Targets risks a separation of the two in teachers' planning and denies the importance of learning with understanding which is fundamental to the curriculum. Meaningful learning involves both concepts and process skills. Care has to be taken, therefore, in interpreting the relative 'weightings' given to the process and content (in DES Circular 17/91, paragraph 20), that is, 50 per cent scientific investigation, 50 per cent knowledge and understanding of science at Key Stage 1 and at Key Stage 2. These figures indicate the 'relative importance in the curriculum of the aspects to which the weightings relate', but should not be taken to indicate that the two aspects can be separated in children's experience.

In the Programmes of Study there are clear statements about the necessity for children to use process skills in coming to understand concepts, as, for example, in specifying that:

Pupils should investigate changes that occur when familiar substances are heated and cooled, and 'hot' and 'cold' in relation to their body temperature. (AT4(ii))

Also it is clear from the way the statements of attainment are expressed that they could not be achieved by rote learning (such as 'understand the meaning of 'hot' and 'cold' relative to the temperature of their own bodies'). Thus, intentionally, the curriculum indicates an investigative approach to science through and through. Whilst quantifying the weighting between process and content is largely meaningless, it has the value of assuring teachers that they are on the right lines if a good deal of their class time is concerned with the way children investigate.

What about attitudes?

During the development of the National Curriculum, the Science Working Group's Interim Report included scientific attitudes as well as process skills and concepts. These were not attitudes towards science but attitudes of science such as curiosity, perseverance, willingness to use and appraise evidence, willingness to tolerate uncertainty, critical reflection. But the Task Group on Assessment and Testing (TGAT) advised that 'the assessment of attitudes should not form a prescribed part of the national assessment system' (DES, 1988). This need not be interpreted as meaning that attitudes should be banished from the face of the curriculum; rather that they should remain as educational aims, performance for which might be reported in Records of Achievement but would not form part of the national assessment procedures. They remain an important part of learning science.

There is every reason, when schools create their own schemes of work, for attitudes to be included; otherwise there is a danger of neglecting the personal element in science and moving towards a mechanistic and impersonal view of the subject. Indeed it is difficult to entertain the idea of anyone, young or old, being scientifically educated unless he or she adopts, for example, certain stances towards seeking and using evidence, is willing to change ideas when evidence requires it, and has a respect for living things and the non-living environment.

To what extent will the Nuffield Primary Science materials provide what is required by the National Curriculum?

In the National Curriculum, neither the Programmes of Study nor the Statements of Attainment dictate the details of children's activities, much less the class and curriculum organization. For example, children might reach the point of being 'able to sort familiar living things into broad groups according to observable features' (AT2, level 2b) through a variety of different activities with quite different living things; they reach the same point through different routes. Their science activities may or may not have been closely integrated with other subjects. The National Curriculum Council's non-statutory guidance suggests that the activities should meet the following criteria:

- ◆ stimulate curiosity;
- ◆ relate to the interests and everyday experiences of pupils;
- ◆ appeal to both boys and girls;
- ◆ help pupils to understand the world about them through their own mental and physical interaction with it;
- ◆ involve the use of simple and safe equipment and materials;
- ◆ involve resources and strategies available to teachers;
- ◆ contribute to a broad and balanced science curriculum, bearing in mind experiences already selected.

It is for teachers to decide the particular subject matter and the details of activities, with these criteria in mind.

The Nuffield Primary Science materials add to the resources available to teachers in a somewhat different way. They give help, not only with selecting and setting up particular activities, but with an approach to teaching and learning which is based on careful research and on trials in schools. This approach guides children's development of science concepts and process skills through the activities.

The entire science National Curriculum at Key Stages 1 and 2 is covered by the Nuffield Primary Science materials. Details of what is covered where can be found in the National Curriculum charts at the beginning of each teachers' guide. In addition, the relevant portion of the Programme of Study is quoted at the beginning of each theme. (See also the chart on page 8–9.)

The science knowledge required by teachers

What do teachers need to know?

Many teachers feel that their own grasp of science ideas is inadequate. They may have had an unhappy time with science when they were at school, and that experience may have left them with a belief that science involves ideas that are so obscure that they cannot hope to understand them. As a result, they believe that they will be quite unable to explain those ideas to their pupils.

Each of the Key Stage 2 teachers' guides includes a background science chapter written to help teachers with the knowledge and understanding of science ideas that they will require for the topics involved. The purpose of this section is to explain how these requirements fit in with the SPACE approach. The background science is also published as a separate volume.

This section emphasizes two main points. First, the ideas that we want primary children to learn are well within the grasp of any primary school teacher. Secondly, the ways in which children should be encouraged to approach these ideas are fully consistent with good primary practice in other areas of the curriculum.

How similar are scientists' science and children's science?

There should be a great deal of similarity between the ways in which scientists work and the way in which children can learn science. In both cases, the ideas held before an investigation is started influence the way in which the task is understood and approached. However, in the case of the scientist, these existing ideas come from the powerful basis of knowledge and concepts built up over centuries and learned through extensive training and experience. In the case of the child the ideas come from everyday experience, from the language and ideas of those adults and peers who are close to the child and from the child's own ways of making sense of the world.

The view taken in this project about how children might learn science is set out in several of the following chapters, particularly Chapters 8 to 11. As emphasized in Chapter 6, the underlying feature of particular relevance here is that children's learning should involve a close interaction between the *content* of science and the *processes*. Children cannot explore and change their ideas unless they can use and develop their powers of observation, of seeing regularities, of making and testing hypotheses, and so on. Consider, however, as an example, an exercise in which children are asked to discuss the similarities and differences between several different sea-shells. The child who knows where sea-shells come from and their role in the life of shellfish is likely to notice quite different features from those picked out by a child to whom they are simply decorative ornaments. For example, many 'shells' that can be collected on a shore are half of the body case, others are the

whole case. However, if you don't know that shells are body cases and that they therefore have an inside and an outside, you will probably fail to notice many features of them which have biological significance.

Any such example will show that, because the process skills can only be exercised on some particular phenomenon or topic, the way children use them will depend on their existing ideas about the phenomenon or topic concerned. Indeed, one important object of any learning activity should be to develop and change those ideas through the use of the processes. The space approach has been built on the necessity for a close interaction between the *content* and *process* aspects, both in science itself and in the learning of science.

Are scientific ideas hard to grasp?

It has become clear in the last few years that one of the reasons why science has always seemed difficult to many people is that teaching has started by assuming that certain ideas about natural phenomena are obvious or very easily grasped, whereas to young children these ideas may not be obvious at all. It has also been realized that one reason for this is that young children have their own ideas about how things around them may be explained. If a science teacher gives them quite different explanations without an argument or evidence that they can understand, then they are confused and cannot see why their own ideas are inadequate and why they should modify them, or even give them up.

Thus a child might be told at home that you need exercise to build up your energy. If a teacher then says that exercise uses up energy, the child has a conflict to resolve. Children often resolve such conflicts by remembering to repeat what was learnt in school when asked in school, and using the home idea outside school.

Any approach to learning must take account of these factors if it is to succeed. The purpose here is to show that one consequence of this line of argument is that the scientific ideas involved will be at a level which will not be very demanding for teachers.

An example which illustrates this point is the understanding of light. Many people who studied physics at school will say that this is a very difficult subject. If they are asked what they recall about the physics of light, memories of lenses, ray diagrams, formulae in which the signs were governed by mysterious rules and only came out right if you worked backwards from the right answer, and things called virtual images which you could see but which were not really there, may all be evoked. If they are then told that they have to teach infant and junior children about light, they may well start to worry.

However, some of the main ideas about light that are set out in the first levels of the National Curriculum are:

- ◆ that some materials are opaque and some cast shadows;
- ◆ that the reflection of light enables objects to be seen;
- ◆ that light travels faster than sound.

The first two of these ideas are hardly ever taught at secondary level – they are 'obvious'. Yet to young children, they are not at all obvious; indeed in the past, the second idea has not been grasped or believed even by many pupils who have studied physics up to age sixteen. The third idea is closer to the conventional text-book work of secondary schools. However, all that is needed in the primary stages is to

provide an opportunity to observe the flash and the sound of a lightning flash and discuss why the two are not simultaneous.

These ideas are chosen because they are stepping stones to more advanced ideas; they form the basis on which later learning about light may progress, whether in the top juniors or in the secondary school. However, in themselves they are not complicated, and they do present interesting opportunities for work with everyday observations and simple equipment – torches, candles, mirrors, shadow puppets – in which children can develop both science process skills and skills of discussion and representation relevant to English and mathematics.

Similarly, it might seem formidable that children are expected to learn about and understand the processes of life. Adults may well recall their own past difficulties, for example with the idea that respiration involves far more than simply breathing air in and out, or in learning about the complex chain of reactions involved in photosynthesis. However, what children need to grasp are ideas more basic than these. For example, young children are not at all clear that plants grow continuously, finding the idea that something can be growing too slowly for one to see the size change directly, quite beyond them. They may also need to grasp, at first, that we have to have food in order to stay alive, not only to grow, and that we have to breathe in order to stay alive.

A third example illustrates a further important point. Many teachers may have found it possible to interest young children in observations and experiments involving colour. However, the scientific study of colour is very complex. It involves the physicist's ideas about the spectrum and about differences between light of different wavelengths, but it also involves the physiology of colour perception which shows that what we 'see' depends on a far more complicated set of factors than those considered by the physicist. It turns out that, because of this, many very simple observations with colour are very difficult to interpret, so that it would be almost impossible for children to build up a useful basis for concept development from everyday observations. Thus, although work on colour is a rich source for discussion, observation and investigation with young children, it cannot profitably be taken much further as a basis for developing the relevant science concepts. This explains why there are no elementary statements involving colour in the Attainment Target on light and only general references in the Programmes of Study.

This example illustrates a general point: that part of the task of the curriculum designer and of the teacher is to choose only those ideas and experiences that do provide opportunities to build up a useful basis for science concepts. The explanations of background science given in the teachers' guides serve to distinguish the basic and relevant ideas from those more complex ideas which can be ignored.

The Nuffield Primary Science materials and the SPACE approach will help children develop the scientific concepts required by the National Curriculum at Key Stages 1 and 2. These ideas were chosen because they are accessible to young children, mainly through observations and simple experiments, and because they form the essential basis for the later development of science learning. It follows that they should not present any significant problems for primary teachers. Indeed, teachers will find that most of them are ideas about the natural world which they have usually taken for granted but did not regard as a valuable part of their understanding of science.

What do I do when I can't answer children's questions?

There remains a possible difficulty in that a classroom using the SPACE approach must be one in which children are encouraged to express their ideas in an atmosphere of acceptance and encouragement. They should also try out their ideas, ask questions, and find out and bring ideas from a variety of sources, all in an atmosphere where ideas might be challenged by experience or by social interaction. It follows that, although a teacher may have a very good grasp of the main target ideas and of the reasoning behind the activities selected, he or she may not feel confident with questions or ideas that go well beyond that knowledge. For example, a child might ask: 'Why is the sky blue?'. The explanation of the blue of the sky requires university-level physics, and to work out a simple version to give to a child would tax the powers of most physics professors.

Two points should be borne in mind here. The first is that it is quite possible for the naïve inquirer to ask questions about the natural world that even the most able scientist cannot answer, particularly if that answer has to be expressed in simple terms. An example might be: 'Will the Universe go on for ever?' The second is that it does not really matter if a teacher has to say that she or he does not know the answer, particularly if this admission is followed by an attempt to treat the ideas seriously and discuss whether there is any evidence or test that could help take them further. What does matter is that any response be completely honest. Of course, it helps in this process if the teacher knows a great deal rather than a little about the science involved, but even the knowledgeable have to be very careful. An answer which displays superior knowledge could have the effect of closing off the child's thinking, and even of giving the child the idea that his or her ideas look silly when set alongside the profound insights of real science. Thus, a wise answer might use very little of one's background knowledge, and the priority, for the scientifically learned teacher or for the novice, might be the same: to encourage the child's own powers of thinking and observing and investigating further.

In the teachers' guides, the explanations of the scientific ideas provided for teachers are designed to set out the background of understanding needed in the role of guiding children's learning in the Nuffield Primary Science themes. It should not be necessary for teachers to go further to learn more extensive or more sophisticated science ideas.

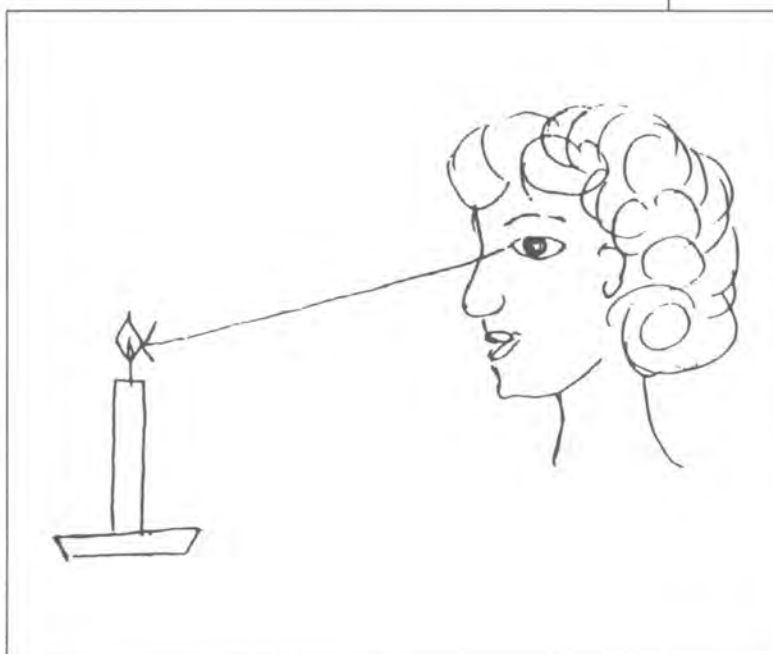
Ideas about science and learning science

What is happening when children learn science?

Science in the primary school, as elsewhere, is about developing understanding of the world around. It is concerned with a particular part of this world, the living and non-living materials in it, and with understanding which is developed through testing ideas against available evidence.

Learning science is the gradual building of these ideas and of the skills required to test ideas to see if they fit evidence from the world around. During this learning, the ideas children develop will necessarily be limited by their experience and by their still immature skills in testing them scientifically. It is the job of science education to extend their experience, to develop their scientific skills and to help them relinquish ideas which are of restricted application in favour of more scientific ones. 'Scientific' in this context means not only fitting the evidence available but also having the potential to enable a range of related phenomena to be understood.

The recognition that children already have ideas about the things around them which they bring with them to their science activities has significance for teaching, particularly when combined with the view of learning which acknowledges that learners take a part in constructing meaning for themselves. We see this happening when, for example, children think that seeing something involves their eyes in transmitting some sort of beam to the object seen; this drawing shows how a child aged ten added an arrow to a drawing to show how he believed the person could see the candle.



This idea does indeed make sense of much of children's experience (including phrases such as 'a piercing gaze' or 'casting your eyes around') and derives from thinking which has a certain logic. When children's existing ideas are acknowledged, learning is regarded as the change in these ideas resulting from testing them against evidence, in much the same way as scientists test their theories. The change may involve modification or rejection of initial ideas, or the adoption of alternatives which fit the evidence better. Whichever it may be, the change has to be car-

ried out by the child's own reasoning and the new ideas become his or her own.

The same view of learning is expressed in the Non-Statutory Guidance for the National Curriculum in Science:

In their early experience of the world, pupils develop ideas which enable them to make sense of things that happen around them. They bring these informal ideas into the classroom, and the aim of science education is to give pupils more explanatory power so that their ideas can become useful concepts.

For the child learning science, as for the scientist, the way understanding develops depends both on the existing ideas and on the processes by which those ideas are used and tested in new situations. (NCC, 1989, A7, paragraphs 6.2 and 6.3)

How much is learning science like 'real' science?

In the passage just quoted, children's learning is compared with the work of scientists. As pointed out in Chapter 7, there do appear to be many similarities in the way both scientists and children develop understanding. The scientist uses existing theories to attempt to make sense of new phenomena or to predict events. If evidence shows that the theory or predictions based on it do not fit reality, then some change may be made to the theory or an alternative tried. The same thing is happening when children bring their existing ideas to bear on a problem and test them out against the new information they gather. Looked at in this way, both the child and the scientist are 'learning science'.

Implied in this view of science is that ideas and theories are always subject to modification as new evidence comes to hand. It is not only in the well-known changes in theories, such as those associated with the names of Copernicus, Newton and Einstein, that developments in scientists' ideas are made evident; there are also important changes going on in matters which affect our daily lives more directly, such as understanding of the human body and of the effect of chemicals on it. What these developments depend on, at least in part, is the careful testing of ideas against new evidence. It is often the case that it is the way in which an experimental or theoretical test is carried out which determines whether or not a theory is considered to fit evidence. The history of science provides many examples of theories being accepted when they should have been rejected, or vice versa, not because the evidence was of the wrong kind but because error in procedure and methods gave a misleading view of the evidence.

Similarly, in the case of young children advancing their personal understanding, the methods they use in making sense of things around them and then in seeing if these ideas are useful for understanding other things play a central part. Their ideas gradually develop and change, just as usually happens in the development of scientific theories, by modification to fit experience. But in addition, for children as for scientists, the skills required for the processes of testing and modifying (process skills) also develop and change with experience. Thus the developments of process skills and of ideas go hand in hand.

Progression in learning ideas

Is change in ideas the same as progression?

Children's progress will not be limited to one facet of development. It will include progression in skills, in the formation of more abstract and more widely applicable ideas and in the social skills which support practical investigations in groups. If we are alert to the emerging signs of progress, we are more likely to be in a position to encourage children's development.

Given the existence of the National Curriculum, one answer might be to take the Statements of Attainment and see whether children have achieved the criteria for the next relevant level. This might be said to be a rather narrow and limiting approach: limiting to teachers in the sense that there are many interesting opportunities to engage children in science activities which are likely to arise but which are not mentioned within the very broad Statements of Attainment; limiting to children in the sense that there are many other subtle ways in which they may demonstrate progress; limiting most of all in the sense that such judgements would be 'all or nothing'. This may be the result of the language of attainment 'targets'. Targets are usually hit or missed. However, in thinking about children's progress, we must be absolutely clear that we are working in a time-scale not of the time it takes to tell a fact, but in the scale of time needed to understand an idea or acquire a skill. It may require days or weeks or years to build any depth of understanding.

When teachers are looking for signs of progression, it is absolutely crucial that their concerns should not stop at the products – whether or not the target is hit on the 'bull's eye'; we are looking closely and intently at the paths (there may be more than one route) towards the target. Teachers will be looking for opportunities to nudge, deflect or facilitate the course of development, to shape the outcomes. This chapter tries to show that there are some rather more subtle indicators of progression than page numbers in a science scheme.

What if children don't seem to be making progress?

Before looking at progress in its commonly used sense of moving forward, we might well consider cases where children appear not to move. Even the most carefully planned activities do not necessarily bring the outcomes intended. Paradoxically, however, some of the outcomes in which children appear to stand still, go backwards, or move sideways can be seen as part of progression.

There are sure to be times when children appear to be standing still, but these may be times when they are accumulating experiences, trading ideas, gathering breadth of understanding and reflecting. This is the progress of consolidation. Progress does not usually happen at a constant rate within a subject or concept area.

Perhaps more worrying to teachers who feel under pressure to cover all the ground and deliver children's science entitlement are the experiences of children 'going backwards'. What we have in mind here is not the 'They've forgotten everything!' syndrome encountered at the beginning of each term, especially following the summer holidays; that sort of forgetting usually relates to rules and conventions which tend to be fairly quickly remembered. The concern here is with a real decline in performance which is sometimes seen in children's developing science concepts and is associated with a deepening of their understanding.

For example, young children may develop a good intuitive understanding of temperature mixing, gained from many happy hours spent in the bath. However, during the middle years of childhood, this understanding often goes awry. This seems to be connected with the fact that children's understanding of temperature is progressing on another front – they are probably quantifying temperature, using thermometers – and the conflict between the two kinds of understanding causes a fall-off in performance. It is well known, for example, that many children at this age will predict that mixing two volumes of water at 30 °C will give a mixture at 60 °C, even though they know that two lots of warm water do not, when put together, make hotter water.

Sometimes we need to go backwards in order to go forwards. Progress inside an individual's head is not always visible in straightforward terms. Sometimes such reorganizations take place over a long period. They also happen fairly regularly as new learning occurs in a cycle of:

- ◆ initial control of a situation, but relying on limited procedures;
- ◆ an attempt to generate rules of a more general nature; this may result in a more erratic performance than in the first stage, even though understanding is greater;
- ◆ control of the new way of thinking in practice, with increased competence and improved performance.

Moving sideways is actually quite respectable in science. Some of children's science activities take them only indirectly closer to conventional scientific understanding. This happens when children convince themselves, as the result of thinking or doing, that the idea which they had previously held must be rejected. For example, during the SPACE research some infants asserted that mice must be drinking the missing water (evaporated) from a water tank. However, the cheese they left out to gather proof of unseen nocturnal revels remained uneaten and the children rejected their hypothesis. Had they made progress? In a sense they had, for they had succeeded in clearing an obstruction. They were not back where they had started – where they started had been put behind them. This, surely, was progress.

How do I recognize progression in ideas?

The reasoning of young children is often seen to be heavily dependent on direct sensory experiences or intuition. What we describe as knowing 'intuitively' is what we have directly experienced, without necessarily putting that experience into words. There are certain conclusions which children may draw from their direct perceptions which, though quite logical, do not accord with conventional scientific explanations: for example, that a toy car rolls along until it runs out of push (it can be seen gradually coming to a halt); or that the metal part of a desk is at a lower temperature than the wooden part (it certainly feels colder). What children sense (perceptually speaking) is what makes sense to them (intellectually speaking). A better understanding of science will gradually reveal that the explanations of the phenomena in both these examples are at odds with our perceptions – they are

'counter-intuitive'. The force of the push on the toy car is not used up or worn out; the car would carry on rolling forever were it not for opposing forces of gravity and friction. The metal and wooden parts of the desk are both likely to be at the same temperature as the air temperature in the room; the fact that heat energy is conducted away from the finger tips more readily by the metal than the wood produces the sensation of its being at a lower temperature. In these instances, children's concrete experiences will let them down. The direct experience has to be reinterpreted in abstract terms if the occurrence is to be understood in a scientific sense.

One strategy which we may adopt in an educational context is to avoid counter-intuitive concepts until children are capable of handling the abstract ideas involved. On the other hand, most children have experientially rich lives both within and outside the classroom and it is impossible and undesirable to filter and limit their experiences.

There is another way in which children demonstrate the concrete nature of their thinking. When confronted with the fall in the water level in a tank of water, almost every child whose opinion was invited was willing and able to put forward an explanation of some sort. For some, the water had ceased to exist. (These are the children Piaget would have referred to as being pre-operational or non-conservers.) There is little doubt that this group was 'perceptually dominated': 'If I can't see it, it doesn't exist.' Another group of children offered very 'sensible' explanations as to the whereabouts of the water. If the water was no longer in the tank, then somebody must have removed it. Prime suspect? The caretaker, of course! What is particularly interesting is the economy of the logic used; direct, like a short-circuit.

Another group of young children was aware that the plants which they had been tending were clearly increasing in height. They were equally certain that they had never seen a plant in the act of growing. Their logical conclusion was that the growth must have occurred when they weren't there to witness it. So the plants must have grown during the night.

Teachers with just a little experience of what to look for recognize fairly easily when children's reasoning is likely to be dominated by the evidence of their senses. Food is supposed to provide the body with energy, yet everyone knows that the bigger the lunch the more languid we feel. And what body ever felt that it had more potential energy after a steep climb to the top of a hill? It is also possible to see the signs of progression as children make the transition between a concrete interpretation of an event and a more abstract construction. For example, in the case of evaporation of water from a puddle or a tank, the abstract description is that particles of water too small to see leave the main body of water at a rate too slow to be perceptible to take up position as an invisible gas (water-vapour) dispersed in a transparent medium (air). One way that children might begin to get hold of this process is through becoming aware of the various forms which water takes in between being a pool of liquid and being invisible – mist, steam, spray, fog, droplets. These perceptible forms make the mechanism of evaporation of water plausible to them and, in time, they will feel comfortable with the idea of water, on occasions, taking up its invisible gaseous form. It is likely that many transitions to abstract models of how the world works are of this gradual and incomplete nature, rather than sudden revolutions in thinking.

Another way in which ideas progress from concrete to abstract is through the accumulation of experience. Familiarity with a wide range of instances of a class of objects – mammals, metals, conductors, flowering plants, or whatever – gradually enables us to abstract ('take from' them) their common property, their essential feature. We become able to distil mentally the essence of mammal, metal, and so on. A

child may notice rust on the precious shiny rims of her bicycle wheels; there may be rust on the school gate, on metal window frames, or on a bridge. Only very gradually will a child build the notion of common properties within these very different and apparently unconnected contexts. More subtly, what do we make of the coins which were once so shiny having taken on a dull, brown colour? And where do the rust-coloured cardigan and the autumn leaves which turn brown and disintegrate fit in this scheme?

Children show progress in the process of generalizing and discriminating more accurately. In time, the accumulated wisdom of science offers higher-order generalizations. In time, children will learn (but not in the primary school!) that all the examples of rusting have in common a reaction between the metal and oxygen in the air in the presence of water.

The role of process skills in learning science

What do we mean by the process skills of science?

In general terms, science process skills are what we use when we make sense of information about the world around us. Scientists use these skills in advancing knowledge of how and why things work; children use them in developing understanding of events and phenomena which they encounter in their rapidly expanding experience; anyone could use them in the continuing deepening of understanding throughout life.

It is helpful to identify separate process skills, although in practice they are rarely used individually but in association with one another. Analysing scientific activity in terms of separate skills, however, is necessary in defining their role and identifying the ways in which they change as increased skill is developed.

Making sense of things begins with some information, which is often gathered by observation or may be communicated in words or other symbols. An initial attempt is made to understand by recalling something from past experience; a curiously shaped object picked up on a beach is soon identified as originating from a living thing because of previous knowledge of shells or corals or sponges. Sometimes the attempt to use previous experience leads in the wrong direction, as often happens with children, who lack the wide range of experience available to adults. Children seeing two smooth wet wooden blocks stick together have assumed that the blocks have become magnetic when wet. The point here, though, is not whether the attempted explanation is correct or not, but that the process of using previous experience to understand something new has occurred in both cases. This process of suggesting a possible explanation is known as hypothesizing and includes a realization that the explanation is tentative and needs checking.

Scientific checking of a hypothesis involves using it to make a prediction, to say, for example, 'If this is the remains of a living thing, then it follows that ...' or 'If these blocks are magnetic, then iron things should stick to them or ...'. Testing the hypothesis means checking whether in practice these things which have been predicted really do happen or can be found. Testing requires planning some kind of investigation. The planning may be carried out before the 'doing' begins or in the course of the action. Whether this happens in advance or as part of the investigation, attention has to be given to ensuring that the test is 'fair' (that like is being compared with like) and that relevant observations or measurements are made. Then the results have to be interpreted objectively in relation to the original hypothesis so that inferences or conclusions can be drawn. The findings add to the pool of knowledge if they are communicated in some way. Scientists do this by writing papers and talking at conferences; children do it by describing to each other what they have done or by displaying their results and conclusions.

It is fair to ask: What makes these processes 'scientific'? Don't we all every day

make observations, hypotheses, predictions and inferences? We do, but not always with the rigour which is characteristic of science. 'I predict she will have a great future' is not meant as a prediction for testing a particular hypothesis; 'I observe that you have been late too many times' is a judgement and not information gained through the senses; 'what's your hypothesis?' often means 'what's your guess?' The process words are used where there is no intention to treat the subject systematically and rigorously. This treatment is that hallmark of scientific activity and makes all the difference between scientific and 'everyday' processes.

Which are the science process skills?

Here is a summary of the meaning of the process skills that we have identified in the context of scientific activity. (See also the NCC's Non-Statutory Guidance to the National Curriculum in Science, 1989 and 1991.)

Observing

Gathering information by using the senses; may result in identifying similarities and differences, noticing details and sequence, ordering events.

Measuring

Being able to say how much by comparing with a unit. This might be a non-standard unit such as a hand span but, with experience, it would increasingly be standard units (centimetres) and suitable measuring instruments (rulers).

Hypothesizing

Suggesting reasons for events or phenomena which can be tested scientifically; involves applying concepts and ideas from previous experience.

Predicting

Proposing what will happen, or what may be found, in the future, based on existing evidence or experience.

Planning and carrying out investigations

Identifying how to find something out through practical manipulation of materials, recognizing the variables to be controlled and changed, how measurements are to be made and how results are to be collected and recorded; carrying this out in practice. In an investigation where the effect of varying one thing at a time is being investigated, the thing that is varied is the **independent variable**. (In an investigation to compare the solubility of different materials in water, the independent variable is the type of material, such as salt, sugar and sand.)

The **dependent variable** is the effect or outcome of changing the independent variable, which is to be observed or measured to provide a result. (In the investigation above, solubility in water is the dependent variable; this might be judged by the amount of material dissolving in a volume of water.)

Control variables are those things which have to be kept the same throughout for the test to be valid. (In the investigation above, control variables could be the volume and temperature of the water in which each material is dissolved.)

Interpreting

Putting information together by identifying patterns or trends and relationships between one variable and another.

Inferring

Drawing tentative conclusions from results of an investigation or from information collected.

Communicating

Presenting information or an account of events in such a way as to be understood by the target audience; may involve appropriate use of diagrams, charts, tables, graphs and models.

What role do process skills have in children's learning?

Process skills are used by children in making sense of new experiences, as we have just suggested. When used with the rigour of scientific skills their use results in greater understanding. New experience is linked to existing ideas through the children's own observation, hypothesizing, investigation, and so on. Sometimes the initial idea is challenged by new experience and has to be modified or even abandoned in favour of an idea which fits the evidence. As a result the children's ideas become more widely applicable and so more useful in helping the gradual understanding of the world around. The word 'understanding' is important here, since we are concerned with the development of concepts which children regard as their own, ones they have worked out and which make sense to them. These are the ones they will use in trying to understand further experiences.

The way we use process skills depends on our knowledge of the phenomenon or object that we are investigating. In observing a patch of meadow, we might pick out some features or patterns that we thought important, but a botanist, drawing on greater knowledge of plants, would observe many patterns that we would not notice. Similarly, if you do not know that light affects plant growth, you would not control it in a test of other effects on plant growth, so that these tests, however well designed and carried out in other respects, would be worthless.

We can see the importance of these process skills in learning if we consider what happens if we attempt to teach concepts without using them. If we try to tell children that, for example, sound 'can travel through different materials' without enabling them to observe or test out this idea, then their only recourse is to rote learning. If the children believe, as many do, that sound passes from one place to another only through air and is stopped by solid materials, the new information is not only divorced from experience but in conflict with what they think happens. The children may memorize the 'correct' ideas but still believe their own version, and they will be mystified by the difference. Little understanding results. Much science teaching, from the object lesson onwards, has been taught in this way with disastrous consequences. Science becomes a set of rigmaroles to learn which don't make sense; the subject quickly becomes disliked.

If the children test out ideas, both their own and those they are given as alternatives, by making predictions and gathering evidence through observing, comparing and measuring to test these predictions, and are involved in deciding which idea fits the available evidence best, they have a chance of acquiring ideas which they see 'work' and which make sense to them. This is learning with understanding.

So the way in which the processes are carried out is crucial to whether the ideas are properly tested. Children do not immediately carry out the process skills as described in the above definitions. These abilities have to be developed in order that their understanding can develop. As ideas become more sophisticated and abstract, so the ways of testing also need to become more precise, better focused and more consciously applied. Here we see the importance of helping children to develop their process skills and the reason for the emphasis on this in the space approach to teaching science.

Progression in learning process skills

How do I recognize progression in process skills?

Observation and interpretations

In the course of the SPACE project work, teachers and researchers spent many hundreds of hours listening to many hundreds of children. Children's ideas and opinions were usually invited with the subject of the discussion in view: if discussion centred on plant or caterpillar or stick insect growth, the subject of the children's attention would be present as a focus. This was to ensure that children had every possible support for the ideas they were attempting to express; they could point and gesticulate, move things around, to make their points clear. What was noticeable, even with this contextual support, was that apparently obvious features were often ignored.

Children's initial comments tended to be fairly low-level, and there weren't many of them. This is not to say that children didn't have lots to say. If they had raised a plant from seed they were proud to talk about it; children who had hatched chicks, or left a selection of materials outside to 'weather', showed tremendous involvement in the activities and wanted to talk about them. However, when the transcripts of these conversations were sieved for essential details, it appeared that the number of solid comments, even those at the level of straightforward description, seemed to be more limited than expected. It was also clear that the number of comments on average increased with increasing age, and that following more focused observation during further active investigation, the detail and number of observations which children made also increased. These are some of the signs of progress to look out for in children's observations.

From descriptions to explanations

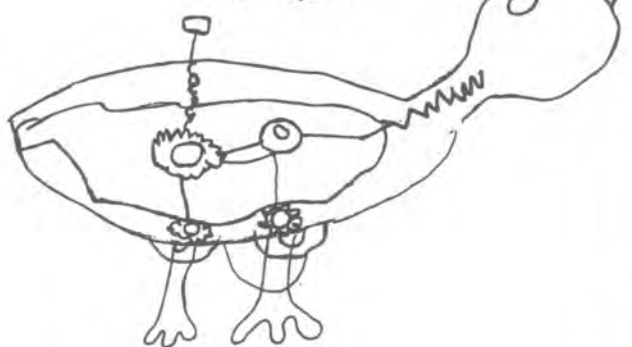
Another kind of progression which is apparent in children's comments is the shift from the superficial to the more interpretative – what we might describe in non-technical language as children becoming more 'thoughtful' in their comments. This progression is apparent as children become more familiar with a situation and is also seen more frequently as children get older. It might be described as a progress which goes beyond surface features and begins to attempt to describe less visible or underlying causes and mechanisms. This is sometimes referred to as causal reasoning and can be illustrated by reference to children's descriptions of the internal workings of clockwork toys.

For many young children a sufficient account of the working of clockwork mechanisms was that 'you turn the key and the wheels go round'. Young children may be found to be happy with this as a sufficient explanation. Only as children become drawn into the fascination of the mechanism, or more immediately if they are older, do they make attempts to fill in the gap between action and outcome. Initial attempts may be only fragmentary. Perhaps one component of the mechanism is

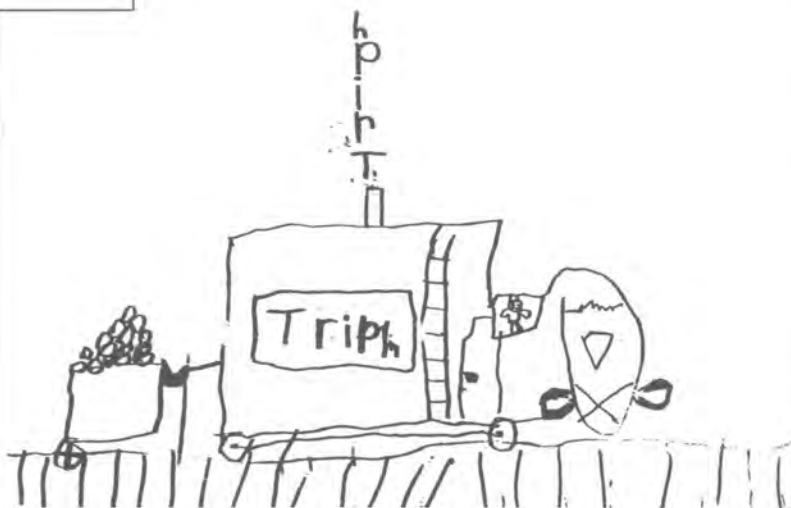
described – a spring, a wheel, a cog – but without any clear links or sequences.

Clockwork toy

The inside of
a duck.



On occasions the chain of causal reasoning may be described in reverse direction – infants may well assert that it gets dark because they go to bed. Or they may refer to supernatural agents. For them, there is plenty in the world that happens perhaps by magic, perhaps because fantasies about magic wands and tooth fairies are generated and sustained by adults.



The train moves with the key. The key makes the wheels spin.

Expressing testable ideas

One kind of progress towards the generation of testable ideas, of which teachers taking part in the SPACE research were very keenly aware, was in the reaction of children asked to make open-ended suggestions. Teachers found that they were regarded at first with suspicion, particularly by the high-achieving children who were the most reluctant to voice imaginative speculations. These children were used to success and expected this state of affairs to continue. They asked themselves: 'What is the right answer to the question?' and were confused to find there wasn't an expected right answer. Those children with lesser classroom reputations to protect and embellish were more likely to accept the spirit of the regime. They were not trapped in a history of being right. In time, of course, all the children came to understand more clearly that they were really intended to give their own ideas.

This kind of progress underpins the possibility of children testing their own ideas and should not be taken for granted. It is necessary to help children to understand that they are invited and expected to express their ideas, however idiosyncratic. If only one class in a school is operating in this way, the teacher will not be able to assume the existence of these attitudes and skills.

When children begin to feel confident about expressing their ideas, the gentle challenge that they should justify their assertions can begin. They should be encouraged, whenever possible, to test their assertions in a rigorous manner. Then the conclusions which they have drawn from their investigations should be reflected upon and discussed with other children. While the teacher's role is to 'stand off' during the stage of the formulation and expression of hypotheses (see Chapters 14 and 15), as children move into testing them, their ideas have to hold up against a public set of rules. Anyone is free to hold the most outlandish or idiosyncratic belief – for example, that the Moon is made of cheese. But if we wish to convince others that our belief is worth sharing, we have to learn the procedures for generating and presenting our evidence.

What are the signs of progression in process skills?

There are several pointers to progression in scientific thinking and the use of scientific procedures. These procedures have to be learned and are not acquired all at once. Examples of the changes which this learning entails are:

- ◆ Children have to learn how to express their ideas in a form which can be investigated. They must be aware which sorts of ideas can be investigated and which cannot.
- ◆ Children have to learn to observe more carefully and thoroughly, so that they come to recognize regularities in the world around them and start to question how these happen.
- ◆ Once they have framed their question, children have to learn to see their thinking through. Typically, young children become fascinated by side issues and distracted from their initial intent.
- ◆ Children seem to have a natural inclination to view things (especially the actions of adults) as fair or unfair. They have to learn how to run a fair test of their idea. Many children's early activities are open attempts to confirm their assertion rather than to investigate a hypothesis.
- ◆ Increasingly, children should be willing to use some form of quantification in their investigations. They may start with comparisons rather than measures.
- ◆ Children should progress in their ability to translate a problem from a vague formulation ('which is best?' for example) to a form in which comparison or testing is made in terms of measurable quantities.
- ◆ Children also need to learn about, and to use effectively, an expanding range of measuring devices.
- ◆ There must be increasing organization in the collection and recording of information or data. From simple written key-word summaries they should gradually move to appropriate conventions such as tables, histograms, graphs, pie-charts, etc.
- ◆ Once collected, information has to be displayed and interpreted. The kind of progression to expect might be from 'this is the largest' to expressing a general pattern in a vague way, 'this goes with that', to expressing patterns more precisely, 'as this goes up, so does that', through to describing more complex patterns.
- ◆ Gradually, children need to become more objective, which for young children means being less egocentric, trying to see the evidence from someone else's point of view. The ability to reflect critically on their own plans and procedures may be found to lag slightly behind their capacity to express doubts about those of others.

The teacher's role

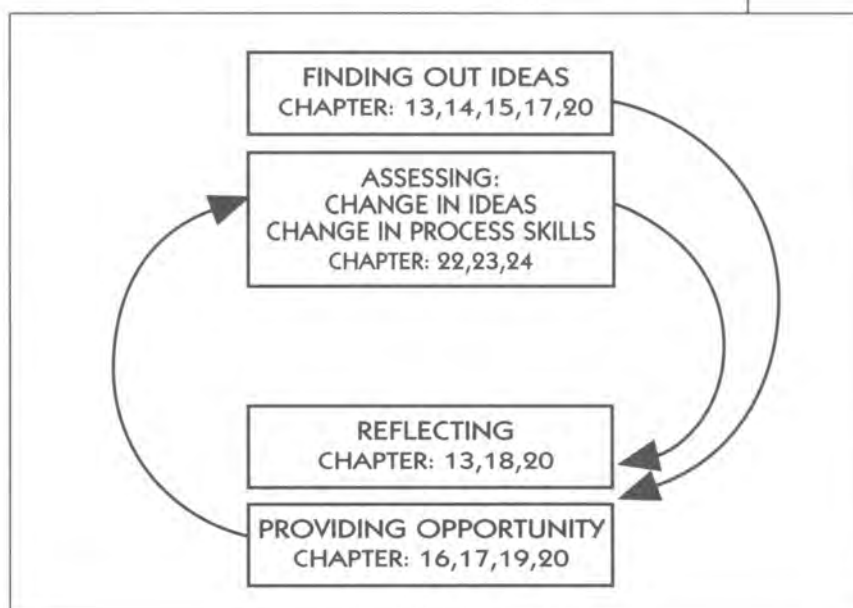
What role do I have in the SPACE approach?

In the SPACE approach, children's ideas form the key to their learning, and their activity is a basis for developing those ideas. However, these features do not mean that the teacher's role is a passive one. On the contrary, the teacher has an active and central role in the child's learning. The five main aspects of that role are as follows:

- 1 finding out what children's ideas are;
- 2 reflecting on how children may have arrived at their existing ideas and on where they are in a progression towards developing more scientific ideas;
- 3 helping children to develop process skills so that they test out and apply their ideas scientifically;
- 4 providing opportunities which test or challenge ideas, leading to possible changes;
- 5 assessing the extent of any change in ideas and in process skills which may have resulted.

These are not isolated aspects of teaching. The third and fourth aspects are interwoven parts of the same process of teaching and learning, for if children do not develop rigorous ways of testing their ideas they may not see any need to change them in the light of their evidence. The first and fifth aspects are likewise closely linked. The first may be a distinct step at the beginning of a new topic, but as the topic activities proceed, the last step of assessing change becomes the first step for subsequent activities. Finally, the second aspect pervades most of the work as a teacher develops understanding of a child and decides how to guide that child accordingly.

The diagram represents these aspects on a simple version of the cyclic model of teaching used in the SPACE approach. The different aspects will be important at different stages of children's learning. Other chapters of this book give more detailed guidance; the purpose of this chapter is to give an overview. For this reason, references to the appropriate chapter are written on the diagram.



What is my role in finding out children's ideas ?

As emphasized in Chapter 1 and explained in detail in Chapters 13, 14 and 15, the key to the teacher's role at this stage is to be responsive – accepting and exploring the child's ideas – above all to be non-directive. The idea of standing back in order to avoid suppressing certain ideas and imposing others may be unfamiliar to some teachers. The temptation to intervene and correct wrong or confused ideas may be very strong if one is used to instructing pupils.

While it is non-directive, the role is not passive. Careful listening has to go along with careful questioning designed to encourage children to explain their ideas and to give the teacher as full a picture as possible of their thinking. Reflection on the answers is essential if follow-up questions, and associated activities, are to be framed to open up the children's communication. Chapters 14 and 15 give detailed guidance, and include advice on a variety of methods, not just open questions, but also use of children's drawing, writing, class discussions and group discussions.

What role do I have when encouraging children to develop their ideas?

Here, the second, third and fourth of the aspects in the list at the start of this chapter are all involved. The teacher's role has to change from one of inquiring in a non-directive way to one of provoking, challenging, questioning. The aim is to lead children to develop or change their ideas. However, they will have no personal reason to reconsider unless they encounter a new experience or situation which makes it necessary or interesting.

It follows that the first task of the teacher is to set up activities for children which will lead them to think again. Such activities have to be chosen after reflecting on the evidence of the ideas that children already have, the second of the aspects listed above. Chapter 16 gives detailed guidance about ways of choosing such activities and of guiding children as they take part in them, while each of the teachers' guides contains tried and tested ideas for its particular topic.

The teacher's role here will still be more subtle than one of telling the children what they should think or believe. Essentially, it is to make sure that children are careful and thorough in collecting and thinking about new evidence. It also involves making sure that they give reasons to support their ideas and can think out, and carry out, ways of testing them. The degree of guidance will depend on children's responses, but children should be encouraged as far as possible to feel that they are working with their own ideas.

This approach is far from letting children discover for themselves. So-called discovery learning requires children to derive, on their own initiative, general ideas from a set of observations or experiences. This is not only impractical because it expects far too much from the unaided efforts of children, it is also unrealistic because it is not the way in which scientific knowledge is usually generated.

Thus the teacher's role is again an active one, requiring skill in judging when and how to intervene. The teacher has to know both the child's starting point and the destination – the more scientifically useful idea. The teacher has to guide pupils so that they make their own path towards scientific ideas and do so by developing their science skills.

What are the other aspects of the teacher's role?

Assessment must be an integral part of the teaching and learning process. The first aspect above, finding out what children's ideas are, is one stage in the programme of formative assessment. As one activity is completed and another one planned, formative assessment will again be an essential feature. Chapters 23 and 24 give further advice on this role, whilst Chapter 25 discusses the related task of record-keeping.

Finally, the teacher will have to organize and plan so that the various stages – of finding out children's views, of setting up classroom activities to explore and challenge children's thinking, and of assessing their progress – all take place within a coherent scheme of work and in relation to children's other learning activities. These aspects are discussed in Chapters 20, 21 and 22.

Starting from children's ideas

Why do we need to use children's ideas?

It may be tempting to ask: 'Why bother to find out what children think when I can just tell them what I want them to know?' Such formal instruction results in narrowly focused skills which children are unable to apply beyond the situation in which they were learned. Telling children may result in their knowing what they were told but not necessarily understanding it or being able to use it. There are very sound reasons for finding alternatives to formal methods of teaching.

Learning with understanding is demonstrated by the ability to apply skills and knowledge appropriately and imaginatively. It occurs when people take part in thinking things out for themselves. In the case of children, the teacher who helps them learn with understanding requires much expertise (as discussed in Chapter 12) in guiding children while, at the same time, letting them 'think through' their ideas.

Reasons for finding out children's ideas and using them, discussed in depth in Chapter 8, can be summarized briefly as follows:

- ◆ Using children's ideas reflects the way in which children learn naturally. They develop ideas about the world around them and, when faced with new experiences, test out how well those ideas explain the experience.
- ◆ Scientists themselves behave in a similar way. They use the ideas they have and test them out to develop further understanding.
- ◆ More pragmatically, consider what happens when children's ideas are not taken into account. Children do not give up their own ideas; they appear to hold on to them with a conviction that is not easily shifted. This is not surprising when it is realized that their own ideas make sense to children because they have worked them out for themselves.

Many teachers involved in the SPACE project have been surprised by what children have said, drawn or written. The ideas the children expressed were sometimes contrary to what had been taught before the use of SPACE methods. Those teaching older children in particular commented on how easy it was to make a wrong assumption about what a child knew. This is not a message of despair, saying that ideas will never change. However, it is clear that if children's ideas are not brought into the open they are less likely to change.

Moreover, there is a danger that a child will come to see science as detached from his or her own personal views. Children may use a scientific idea to solve a specific problem without really believing in the idea they are applying. It is our belief that it is only by starting from children's ideas that a deeper, real and personal scientific understanding can be developed.

How do children get ideas of their own?

A central tenet of the SPACE approach is that children have ideas about the world around them, about how and why things happen. These ideas are not confined to those which children have been taught but may originate in the personal, physical experiences of the child. Thus, for example, some intuitive notions about friction may be gained by sliding (or not sliding) on different surfaces. Notions constructed from such direct experiences are often particularly resistant to change. People and the media may be the source of other ideas. For example, adverts involving cave-men and dinosaurs encourage children to think that both lived at the same time.

While the sum total of each child's ideas will be different in detail, since no two children will have had exactly the same experiences, this does not mean that the range of ideas on a particular topic will be infinite. Experience has shown that within a particular area children are likely to have had similar experiences and built up similar ideas to explain them.

What if children don't seem to have ideas?

With this rich background for the origin of ideas, it is, at first sight, surprising that children will say, 'I don't know' when asked to say what they think. It is also a serious worry because it is no basis for developing the children's ideas. It may take time for children not previously accustomed to expressing their ideas to develop the confidence to do this and this is one of the most common reasons for a blank response. Other reasons may be as follows:

- ◆ It may be an almost automatic response by a child who expects that all questions require a 'right' answer. This will be considered in more detail later.
- ◆ 'I don't know' may also be a way of coping with a question which the child finds too threatening. A younger child with a short attention span may be temporarily more interested in something else. It would be appropriate to wait and ask the question again.
- ◆ The question may have come out of the blue. The importance of giving concrete experiences before questioning should be stressed. This will have given the child time to consider the matter in hand. It might also be appropriate to rephrase the question or to set it in a context which gives more time for response, by giving the opportunity to draw, for example.
- ◆ Similarly the reply 'I don't know' may be an indication that a child genuinely has not thought about the situation before. Although children will have worked out ideas on some topics, they are not likely to have preconceived ideas on everything. There the teacher might respond by encouraging a child to think it out, if that is appropriate. The teacher would have to allow the child time to do this and possibly to offer the opportunity of representing thoughts by writing or drawing. If, as already suggested, questions follow experiences, more children are likely to have given some thought to a situation.
- ◆ Ultimately, however, there should always be the option of a genuine 'don't know' – one that means 'I don't know but want to find out' (if it is knowable!). This is a correct scientific attitude of inquiry.

An absence of response at some stage in work on a topic may also be an indication that a place to stop has been reached. This is considered further in Chapter 18.

How are children's ideas recognized?

In some cases it is possible for children to have ideas but not communicate them in a way recognized by their teacher.

With some children it may be that they are unable easily to express what they think. Here the teacher may be able to tease out thoughts and help in their formulation. Modes of expression other than spoken may prove fruitful.

Younger children, in particular, may be unable to express their ideas. Their ideas tend to be bound up and integrated with action. When infants in one project school were given toy cars and a ramp, they rushed to see if they could get the car down the ramp without its falling off. They did not seem interested in saying why the cars went down. While the children were clearly playing there are likely to be ideas behind what they were doing.

It may also be possible to infer the children's ideas from their actions. This is obviously difficult, but we should remember that even very young children show evidence of thinking before they speak. Babies may show, for example, that they realize a ball is still there when it has rolled out of sight. They have an idea of the ball's permanence before they put that idea in words.

Alternatively, in such a situation a teacher may turn the questioning towards what seemed to govern the children's activity. They may be asked what made the cars go down the ramp instead of why they went down. If the teacher is still set on finding out if a child has an idea why the car goes down, the 'why' question may be made less threatening by different phrasing: 'Why do you think ... ?' or 'What do you think makes the car go down?'. Some ways of phrasing questions will be found more productive than others in generating dialogue (see also Chapter 14). Not only does the 'right' question need to be asked but it needs to be asked at the 'right' time. It may be better to give children the opportunity to play before asking for their ideas.

A further difficulty may be in recognizing what is meant by 'an idea'. Some teachers who said that children did not appear to have ideas were perhaps looking for rather complex and theoretical concepts. Consider these statements made in answer to a question about why a toy car moves down a slope:

It moves because of its engine.

It moves because of its wheels.

It moves because it is pulled downwards.

The third statement is the most scientific because the child has recognized that rolling down a slope is an example of the more general idea of moving downwards under the influence of a pulling force. The big ideas of science – in this case, gravity – have this quality of greater general application and are able to provide explanations behind events. However, all three statements are 'ideas' in the sense of being opinions about why something has happened. Similarly, simple factual statements by children may express what they believe 'Sound goes further when you shout', 'The Sun is alive', whether that idea stands up to the tests of experience, further reflection and other people's ideas or not.

While teachers sometimes had a concern that some children appeared to have few ideas, they also felt that the complete opposite occasionally applied. Rather than having no ideas, a few children, particularly younger ones, seemed to have too many; that is, they often volunteered a stream of opinions without showing a par-

ticular commitment to any of them. Having ideas became an exercise in fantasy or imagination.

While fantasy goes beyond scientific endeavour, imagination definitely has a key role in it. Children should not be discouraged from thinking up ideas. But what they must gradually become aware of is the need to test those ideas critically. This is a necessity in science. Where ideas are so fantastic that there is no way they can be tested, they need not be dismissed, but at the same time they have to be recognized as being outside 'science'.

Finding out children's ideas by discussion

What can I do to encourage children to express ideas?

The teacher who wishes to start from children's ideas needs to know what the children are really thinking, not what they think they may be expected to say to the teacher. Finding out ideas is a prerequisite for encouraging a child to change them; each judgement of a child's current understanding is an assessment of his or her thinking. But we can't have direct access to children's thoughts; they must be given the invitation and the support to express what they are thinking.

Both the nature and the context of the 'invitation' are important in giving the child confidence to reveal his or her thoughts. As far as possible, real objects should be present or real events taking place to provide a focus for thinking: for example, in work on evaporation, a tank of water could be placed in the classroom; or when energy-storing devices are being considered, some clockwork toys could be displayed.

Opportunity should be given for children to spend time observing and exploring real objects. They arouse interest and focus attention so that children are really 'tuned in' to the events involved. They have time to think and to ask themselves questions about what they have noticed. The teacher's questions will thus appear more natural than if they arise without such a real context.

Those questions need to be phrased so as to allow a variety of responses. As emphasized in Chapters 12 and 13, the teacher's reaction to those responses is accepting and non-directive. In this 'finding out' role the teacher is a listener, encouraging children to put forward ideas and probing for further clarification where necessary.

We outline in this and the following chapter several techniques which SPACE project teachers have used to draw out children's ideas. They are:

- ◆ open questioning
- ◆ whole-class discussion
- ◆ children-only group discussion
- ◆ annotated drawings and diagrams (including comic strip drawings)
- ◆ writing (including class log books).

While these techniques lend themselves to finding out children's ideas, above all it is the teacher's attitude that is crucial. He or she must encourage the expression of these ideas and treat them with respect as the child's starting point. If the teacher immediately offers a more scientifically acceptable alternative to supplant those ideas, children will quickly realize that their views are not being taken seriously. It is the child who must come to realize whether his or her ideas are adequate in standing up to reflection on new experiences, testing by investigation and the opinion of others.

What is meant by open questioning?

One of the lessons learned by teachers involved in SPACE research work was that they needed to word questions in such a way that their children felt free to express their own ideas. Such questions are open, in that they have no preconceived, single, correct answer. Some examples from trials of the SPACE approach are:

- 'What do you think makes it stop?'
- 'Can you tell me a bit more about that?'
- 'What could you do to make it quieter?'
- 'What do you think is happening inside the eggs?'

In practice, the degree of open-endedness in a question is determined by the preceding dialogue. It is often useful to formulate questions from the actual wording used by children. For example, a child who talks about a spiky ball pushing wheels along might be asked, 'In what way does the spiky ball push the wheels along?' Accepting the language used by children helps them recognize that their ideas are respected and valued. This in turn gives them the confidence to say more and to explain their ideas further.

The way in which a teacher reacts to a child's reply to an open question is an important part of the technique. Both what is said and what is done must be carefully controlled. Children are adept at picking up non-verbal responses, particularly those shown by facial expression. It will require some skill to avoid showing that a response is not in line with your own understanding. 'That's an interesting idea; how could you test it out?', delivered with an encouraging look, is the most productive kind of reaction.

It is also necessary to give children time to formulate their answers to these open questions. The normal response of a teacher to two seconds or so of silence following a question is likely to be to ask another question or to take some other similar supportive action. However, it would be much more helpful to extend this 'wait-time' deliberately to eight to ten seconds. Once children have accepted that you will wait for an answer, more thoughtful and articulate answers become possible. There will be far fewer 'don't know' replies. But if the teacher doesn't wait, children learn that the answer will eventually come from the teacher and so they will cease to do the necessary thinking.

How can I make the best use of whole-class discussion?

Whole-class discussion is a commonly used teaching technique, particularly when starting a topic or rounding one off. In such discussions teachers frequently do most of the talking. Typically, children address all their comments to the teacher. If the aim is to find out children's ideas, then the teacher has to be far more of a listener.

The starting point will need to be an open question about a shared experience. Children will need encouragement to make contributions in response to each other's as well as to the teacher's remarks. Those remarks will be designed to guide the discussion, in as unobtrusive a way as possible, such that each child

- ◆ knows that the question under discussion is genuinely open,
- ◆ feels secure in expressing his or her ideas because they will be taken seriously,
- ◆ has ample opportunity and time to express ideas,
- ◆ acknowledges the value of ideas put forward by others,
- ◆ is prepared to offer and to receive comments in a constructive way.

Children's involvement in the activity of formulating their ideas, attempting to communicate them and listening to alternative explanations by their peers is a valuable learning process. It will give them a greater awareness of the role of debate and inquiry within science itself.

How can children-only group discussions be useful?

In any class there are children who, in spite of our best endeavours, find it extremely difficult to contribute to discussions held in large groups. Using groups of only four to six can certainly help these children. Furthermore, discussions within groups of this size give all children an opportunity to share in the thinking of their peers in much greater detail. They can also concentrate more on the issues that they think are important.

Here is a short extract taken from one such discussion.

- | | |
|---------|--|
| Denise: | <i>When you hit it, the sound sort of vibrates around the drum and at the bottom it comes out.</i> |
| Chris: | <i>The sound travels around the air until it gets to you.</i> |
| Denise: | <i>When you beat it, the sound vibrates, and if you hit it heavy it makes a loud vibrating sound. The vibration travels to your ear to the brain.</i> |
| Ashley: | <i>The sound runs down to the bottom and goes back up and through to the top to the ear. The sound runs from the ear to the brain and tells you that a drum is making a noise.</i> |
| Chris: | <i>The vibrations send out sounds which our ear picks up.</i> |
| Sonia: | <i>I think when we beat the drum, the sound echoes to the bottom and then comes out and makes a sound. It goes to the bottom, it bounces off the bottom, echoes back up and makes a booming sound.</i> |
| John: | <i>No, the thin material is tight to give the echoey sound. The material is so thin that when you hit the drum the noise goes into the wooden bit at the bottom and echoes.</i> |

It is doubtful whether a teacher-managed discussion could have been so effective in bringing out these idiosyncratic understandings.

Obviously it is not possible to listen in on several small-group discussions simultaneously. It may, however, be possible to record them on tape and to listen to them at another time.

Just listening in on one or two such discussions will give an indication of some ideas held. Alternatively children may report on their discussions. Again, they should be aware that the intention is not necessarily for them to reach a group conclusion but rather to present their ideas, whether similar or different.

It is undoubtedly true that both this kind of discussion and whole-class discussion will cause shifts in the thinking of some children. They will be influenced by each other. It should be remembered that no technique for finding out a child's ideas necessarily leaves them unchanged. Both articulation and modification of existing ideas can occur. In either case a basis for further work has been found, and this is the reason for finding out where the child is.

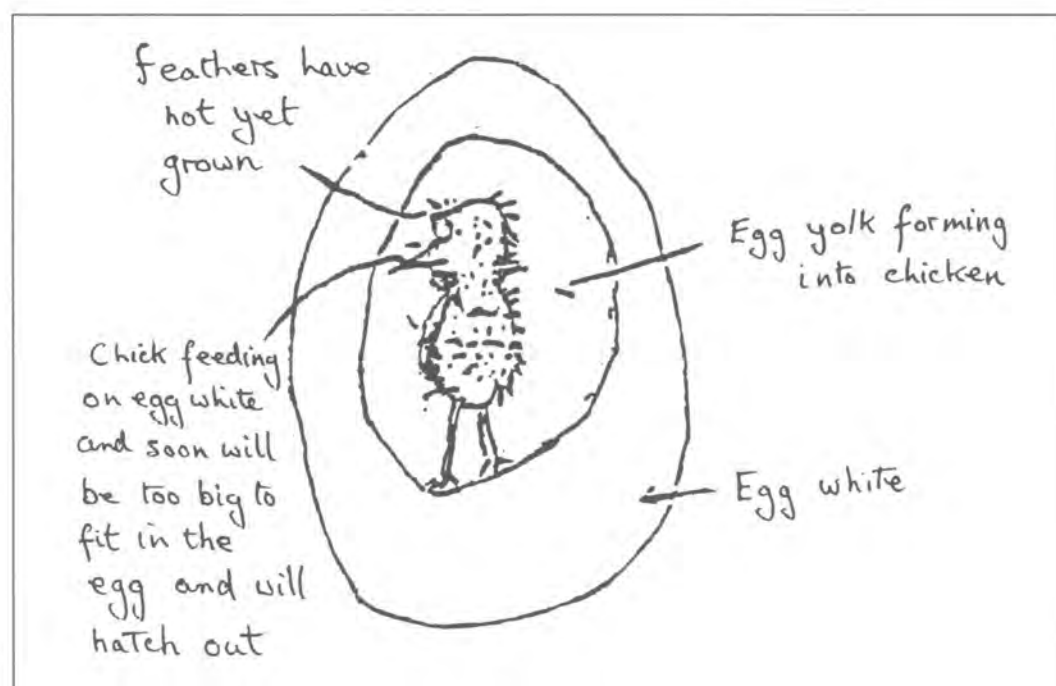
Children may take time to become used to working together in groups. First attempts are often not successful, particularly with children accustomed over several years to classrooms where discussion has not been encouraged. Building up confidence and effectiveness in group discussion has importance extending beyond science. For example, it is central to Attainment Target 1 in English as well as relevant in other curriculum areas.

Finding out children's ideas by written work

Can children's ideas be found from their annotated drawings?

The answer to this question is a definite 'yes' as long as the children are asked to express in their drawings what their ideas are and not just to represent what can be seen. Often their drawing ability is not up to expressing their ideas, and this is where annotation comes in. Annotated drawings and diagrams were succinctly described by one very young SPACE project contributor as 'pictures with words on'. They can provide particularly useful insights into children's thinking.

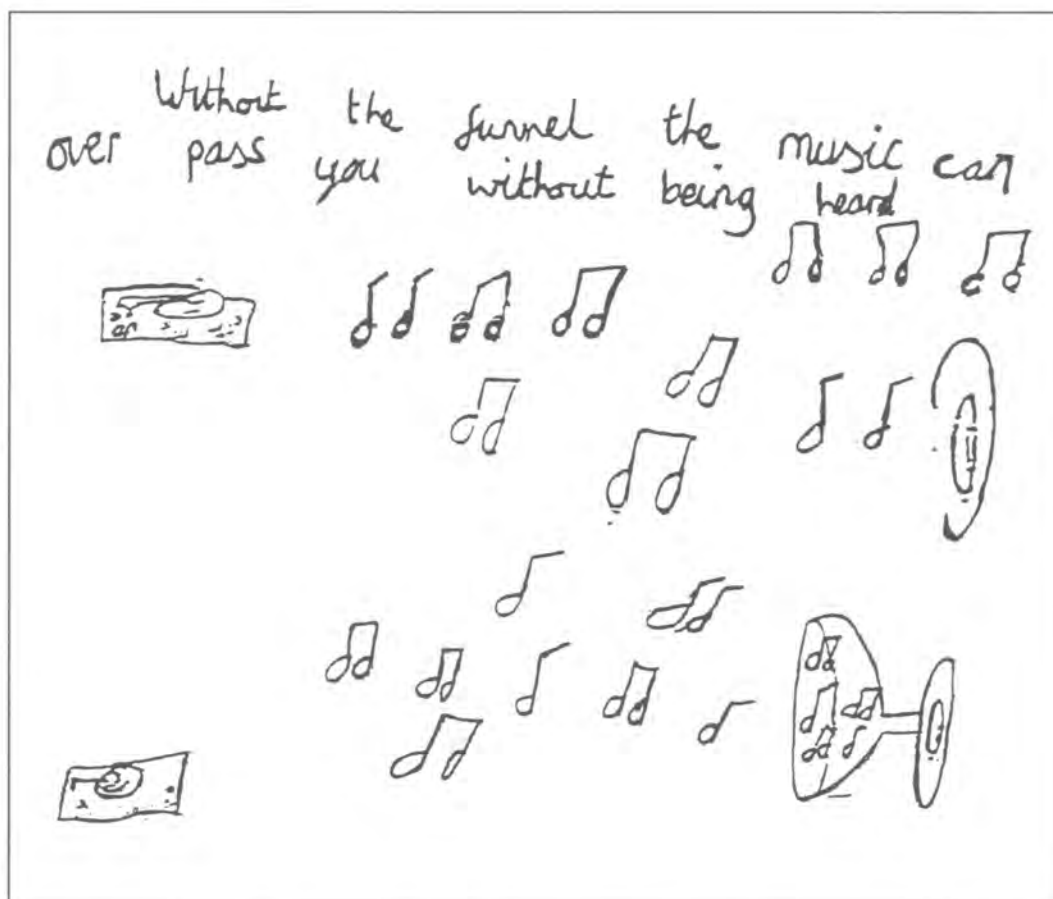
This drawing shows one child's view of what was inside a chicken's egg placed in an incubator in the classroom.



The technique makes relatively modest demands on teacher-time in class. It does not require a one-to-one interaction, nor do children have to be present when their drawings are assessed for the ideas they contain. A further advantage is that it provides a means of access into the thinking of those who for one reason or another find expression through writing difficult. Some of these children may need help with the annotation.

It is often rewarding to talk to some children individually about their pictures. This may be the case if what has been drawn or written is not clear to you. It can also be done to give a child the opportunity to expand on some point he or she appears to have made in the drawing.

In this drawing a child was explaining why she could hear music better when using a funnel placed close to her ear.

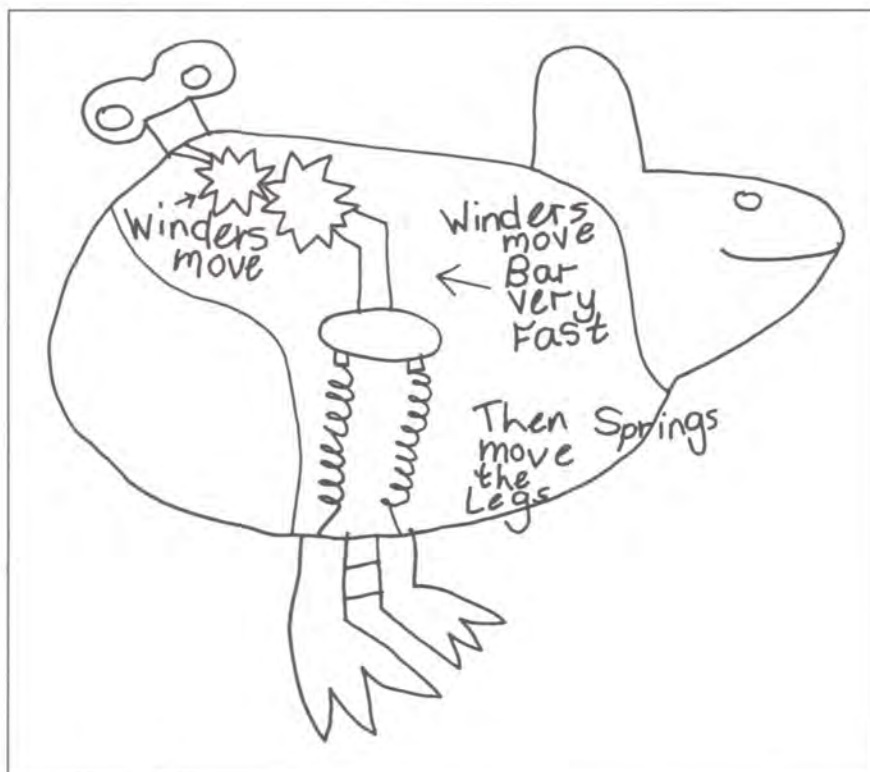


Clearly the external ear has not been recognized as a smaller funnel. It also appears that the sound is going in one direction only. Is this what she actually believes or did she limit herself to drawing in this direction because she wanted to represent only how she heard the sound? Only further questioning can answer this. Other questions spring to mind. Do the 'notes' indicate that she regards the sound as made up of discontinuous packages or are they merely an indication that the particular sound was music? Would she use the same notation to represent a different kind of sound? The drawing may thus serve as a focus for the kind of open questioning described in Chapter 13. Once again, the intention is to draw out the child's ideas rather than to suggest alternatives. 'Tell me about your picture' is one possible opening remark when searching for further insight into a child's ideas.

Children may not be used to mixing drawing and writing. At first they may be puzzled about what is being asked of them and so some initial encouragement and guidance will be necessary. They need to be assured, for example, that their diagrams will not be judged for their artistic merit. Similarly, the request for annotation is not one that seeks complete and necessarily accurate sentences. It is the expression of ideas that is important and the annotated drawing should capture that.

The annotation itself clarifies aspects of a drawing which are difficult to represent. For example, the writing on the drawing of an egg on page 46 indicated that the unhatched chick could feed; it would not be easy to show this by drawing alone.

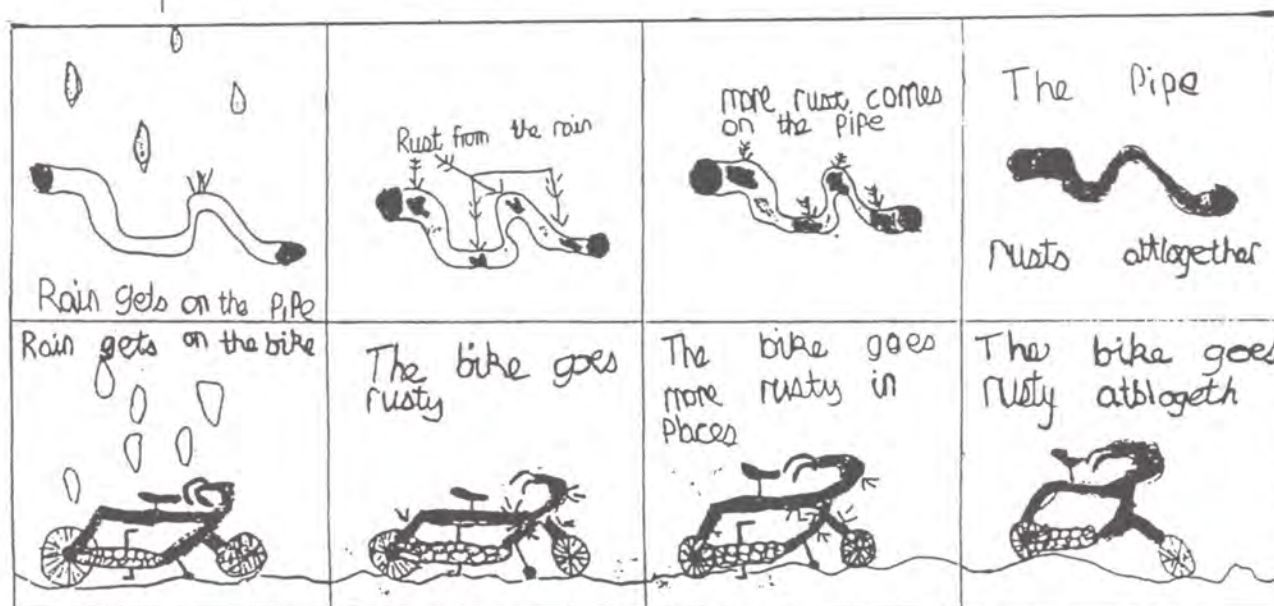
Annotation can also direct a child away from considerations of observed or imagined features to underlying mechanisms or causes. Consider how the writing on



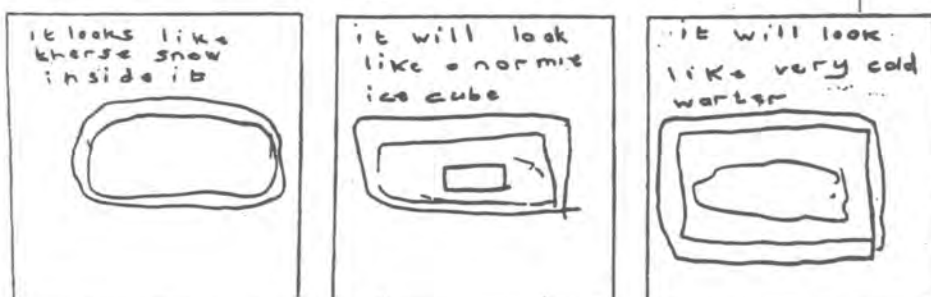
this drawing of a wind-up frog indicates how a child believes it works.

Annotated drawings can also be used to show changes taking place over a period of time. It is then often revealing to ask for a series of diagrams arranged as a comic-strip. Suppose the child who produced the diagram of an egg on page 46 had been asked for a sequence of drawings, perhaps from the laying of the egg to its hatching, then additional insights might have been gained into her ideas about the developmental process taking place.

In some cases a change occurs at such a slow rate that change itself is not perceptible. This example shows, in the form of a comic-strip, one child's view of what happens during rusting.



The comic-strip technique can also be used to explore children's predictions about non-instantaneous changes. This is a drawing made in response to seeing a large ice block and being asked to show what it would be like later that day and on the next day. It not only gives a view about what will happen but also about how quickly it will happen.



Can children's writing help to reveal their ideas?

If children have the ability to express themselves reasonably fluently through writing, then their responses to the teacher's open questions can be explored in this way. Ideally these questions will follow experience of real objects or events.

Here is the writing of one child who had seen a torch shine on a piece of paper.

it pushos the air out the way and then
when it gets on the card because the card
is hard the light cant get through so it
get stuck so you can see some light

This child has an idea about light travelling. More experience and thinking about what happens to light on the card is needed. However, the present viewpoint at least indicates that light is prevented from continuing and would be useful in accounting for shadow formation. Clearly finding out about children's thinking provides the basis for further work.

To be fair it must be
the same car and the
slope must be the same
length, That way it will be fair.

Children can also write about their own investigations. The example here was taken from a description of an activity in which a car was allowed to roll down different slopes.

This child recognizes the need to control variables in order to conduct a 'fair test'.

When long-term changes are being studied, teachers involved in SPACE research found it useful to establish a class log book. This was placed next to whatever was being investigated. A log book was used, for example, in studies of plant growth and of evaporation.

Children were encouraged to write their observations periodically during the relatively lengthy time involved. Drawings could also be 'entered' in the log book instead of or as well as writing. Children could put their own ideas in, dated and identified, as and when they felt they had something to say.

The class log book should thus be distinguished from an individual or even class diary. Contributions are not a matter of compulsion but need to be encouraged. As in the case of annotated drawings, log books are a basis for further discussion.

Here is an extract from a class log book.

22/10 Today the bean sprouts have grown much
bigger and they have leaves coming out.
The Bean sprouts have grown a sprout and there are
leaves at the end of it.
22/10 The leaves have grown and they are sticking
out of the top of the jar.
22/10 They have lots of leaves an small seeds
with long tails.

Helping children to develop their ideas

How does the teacher start?

Strategies to help children develop their scientific thinking are described in this chapter. The methods have been evolved by teachers who developed the work of the SPACE project in their own classrooms. They all found that the new methods of working were a challenge. However, those who took up that challenge found the methods a source of excitement and inspiration, not just in science but across the curriculum.

The procedures which teachers must use to encourage the initial expression of children's ideas have already been discussed in Chapters 13, 14 and 15. In those discussions it has been argued that the teacher's work includes:

- ◆ providing a climate to encourage children to express their thoughts;
- ◆ being receptive and encouraging, but not passive;
- ◆ while listening, trying also to interpret what the child understands in order to guide the dialogue further;
- ◆ avoiding the temptation to impose 'correct' ideas.

Having established starting points, the teacher's role is then to use a range of techniques to encourage children to move their thinking along. Teachers may find it difficult to switch from a technique which helps to find out existing ideas to one designed to develop understanding. It is important for the teacher provisionally to accept where children are in their thinking while simultaneously looking for opportunities to help them develop those ideas.

To 'accept' an idea implies simply that one is realistic about children's starting points. A teacher should not dismiss a child's position out of hand. Children's views often turn out to be carefully considered, and it is also well established that such ideas may be held with a conviction which is hard to shift.

How can children's ideas be built into investigations?

When children test their own ideas, the power of direct experience is coupled with the motivation arising from ownership of the ideas to be tested. The interplay between conceptual understanding and the use of process skills is of crucial importance when children carry out their investigations. This interplay, already discussed in Chapters 8 and 10, will be considered further at this point.

The first problem which teachers may encounter is that of persuading children to voice any ideas at all. This problem, and ways to overcome it, has already been discussed in Chapters 13 and 14. In trials, it was found that patient encouragement was often rewarded because the improved interaction had its effect in many other

parts of the curriculum. It was also a common experience for teachers to feel a sense of recognition coupled with exhilaration when the ideas exemplified in the teachers' guides began to emerge from children in their own classes.

The second problem is to help children to restate their ideas so that they can be tested. Their first reaction may be to try to show that their ideas are right rather than to test them scientifically. Moreover, investigations are often conducted with little thought about whether the test is fair. Children might, for example, compare how well two makes of paper towel soak up water without ensuring that they use comparable pieces of the two makes or that they follow exactly the same procedures in the two tests.

On occasion, everyday notions of what is fair may conflict with what is fair in a scientific test. Children may, when urged to make sure that a test is fair, simply ensure that everyone involved 'has a turn'.

Accurate observations, accurate measurement and recording, care with the procedures used, interpretations which are consistent with the evidence, all of these can be the subject of discussion. Opportunities for such discussion should be provided by arranging for children to report on their investigations to other children and receive comments from them. The difference between recounting reactions to a film or a football match and reporting the outcomes of an investigation have to be learned, through experience and the guidance of the teacher.

What other ways are there for helping children to rethink their ideas?

Problem-solving activities

Setting children practical problems which call upon their knowledge and power to apply science ideas is well established as a classroom technique. There are difficulties to be avoided here. The SPACE approach avoids the difficulties which arise from dropping a problem on a group of children 'out of the blue'. If teachers are using an integrated topic approach during which the opportunity to explore practical applications arises, then children can tackle the issue as a problem-solving activity starting with an understanding of the issue and some interest in pursuing it.

Another possible difficulty is that some children, and particularly girls, have an aversion to problems which have no meaning or setting or wider relevance. The notion of a problem being of purely intrinsic interest works for some children but not for all. It will help most children if teachers can ensure that all science work is presented in a context that has a clear personal relevance to children, for it does seem that if this is not done children will sooner or later turn off from science.

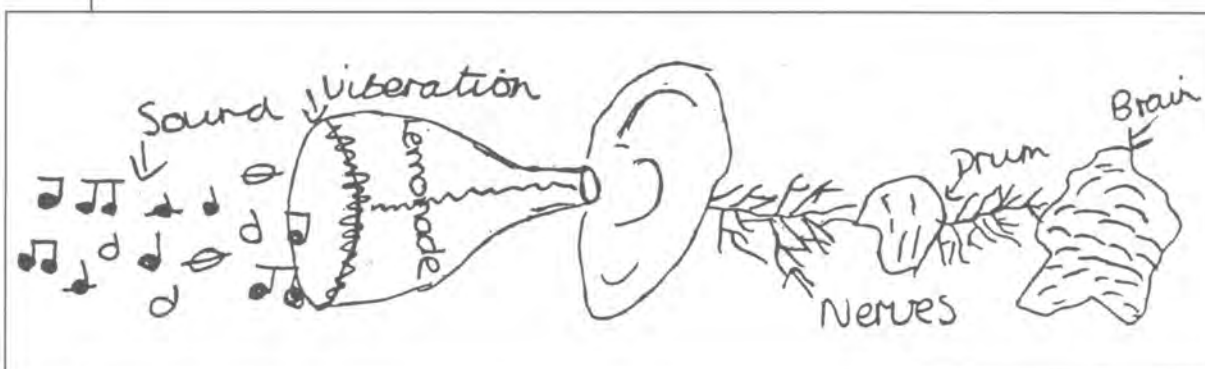
Social exchange of ideas

While direct experience is the touchstone for learning in the primary school, it is also true that many ideas are acquired, modified and developed during social interactions. Reporting ideas carries with it the discipline of putting together and expressing notions which may be barely formed. Justifying an interpretation to others requires that the evidence be made at least to appear as carefully weighed and judged. In a discussion, there may be opposing points of view, expressed and supported by differing interpretations of the evidence. The role of the teacher is to convene such discussions, ensure fair play, and ensure that children actually listen to each other's views.

There is research evidence that, in small groups, children gain more from interactions with children of differing views than from the support of those who share their ideas. It also appears that the influence of such interactions may be revealed only after some time. It may be that a period of reflection is required before new ideas from social exchanges are incorporated into an individual's view and made his or her own.

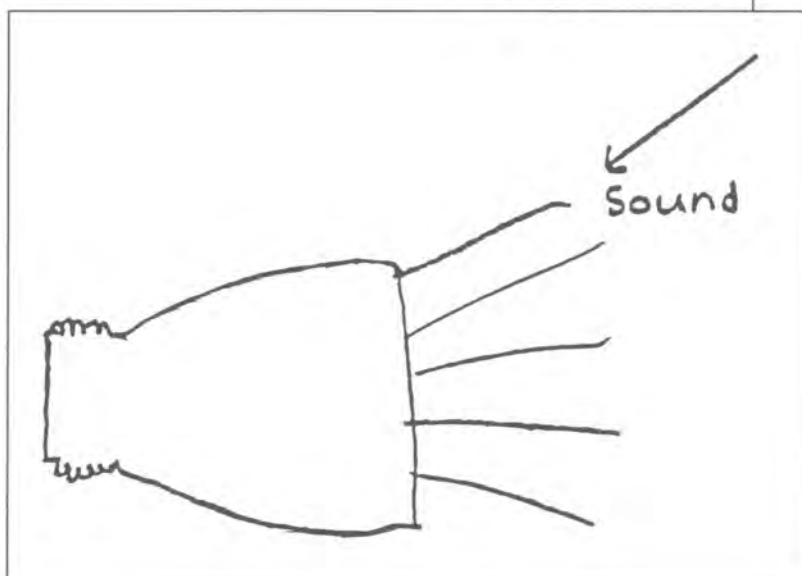
Representations of ideas

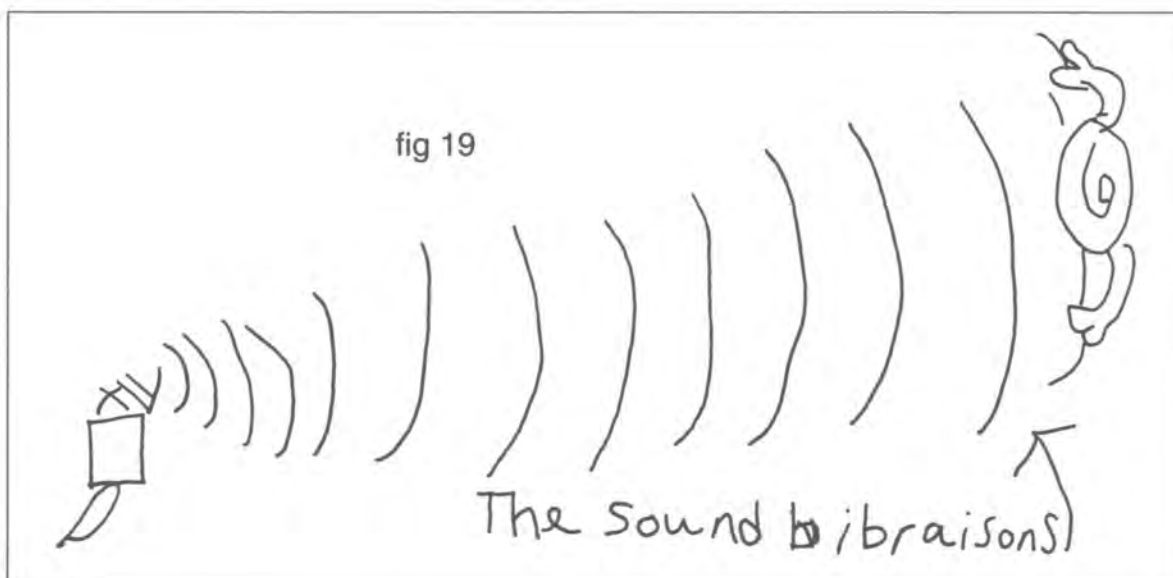
As pointed out in Chapter 15, drawings are an extremely useful way of making children's ideas explicit. In addition to the points made there, for example that children have to realize that drawings do not have to be artistic and that they can represent ideas as well as objects, it should also be realized that drawings can show us the various stages in a child's progress with a concept. For example, in the topic of 'sound' representations are essential because sound is an invisible phenomenon.



The first two drawings show ways that children might use. The first is often used in comics and gives a visual impression of transmitted melody; the second gives a visual impression of loudness and impact. Both might serve their purpose in

comics, but neither corresponds to any testable idea about how sound travels. The drawing opposite shows lines coming from the source and directions of travel, but does not show the pulsing or vibrating character of sound. The drawing at the top of the next page is nearer to a scientific model – the small arcs could be thought of as representing areas of high and low pressure





which spread out alternately from the source. Thus, a change from the first two drawings to the third to the fourth drawing would be evidence of progression towards more scientific ideas about how sound travels.

When children first make their drawings, it is likely that they will pay little explicit attention to the representation they use. Teachers should try to make this a more self-conscious exercise, perhaps by encouraging children to compare their drawings with the attempts of other children and to discuss the differences which emerge. Drawings, just like spoken language, have the capacity to communicate understanding. Like spoken language also, some representations 'work', perhaps because they use an imagery which communicates ideas with power and economy. Thus drawings are not just a second-best method for those who cannot write prose; they can enrich the development and sharing of understanding in a unique way.

Generalizations

Throughout childhood, conceptual development evolves through the accumulation of experiences. Exposure to one specific instance of a science idea is only a beginning; generalization from the first specific context to a wider range of examples is essential. Activities in the Nuffield Primary Science materials will help to start this process and it is important that it be supported by calling on a wider range of examples than those explored in the classroom (see also Chapters 9 and 11). Children's ability to relate experiences within the classroom to the outside world are reflected in the following teacher's comment :

'I found a lot of generalizations came from children themselves through making comparisons or relating to other situations. This occurred on countless occasions throughout the work.'

Attempts to generalize often arise out of class discussion. The process can go too far, with children's suggestions having to be carefully considered before accepting whether or not they are examples of the class of things under consideration. Teachers have seen some valuable discussions amongst groups of children attempting to reach consensus on such issues.

A child's ability or willingness to make generalizations is often determined by the focus of interest. Thus, in one classroom, children associated their beliefs about the forces acting on a toy car with their experiences in the playground:

'They were aware that in skating, playing with toy cars, and cycling there was a force either pushing or pulling.'

This teacher commented that she believed the generalizations were at a superficial level. Nevertheless the children had begun to make connections between their accumulated experiences.

Similarly, children who were exploring evaporation, following discussion of what had happened to the clothes they had washed, were asked to think of other instances. Suggestions included a kettle boiling dry; drops of water in a paddling pool; paint drying on a palette. Incorrect generalizations were also proposed, e.g. milk disappears in cereals and water disappears in plants. These ideas showed that children were confusing the processes involved in clothes drying with absorption, the apparent relationship being the 'disappearance' of the water. These incorrect generalizations can provide the teacher with valuable information about the child's current level of understanding and with signposts about how learning might proceed.

Many SPACE teachers have commented on the ease with which children given the opportunity can associate learning in the classroom with other contexts. This contrasts with reports from secondary education which suggest that children tend to keep school learning about science quite separate from personally acquired views about how the world works. It could be that the SPACE approach can help to avoid this kind of split.

Generalization work provides useful assessment information. Problems in new contexts cannot be tackled by factual recall alone, so that a child has the opportunity to show understanding in applying a learnt idea in a new way. Indeed, the gradual accumulation of experience in using an idea enables children to identify and extract its critical attributes, so leading to a higher order of conceptual development.

Extending children's experience

Young children are strongly influenced by what they can perceive directly. However, many of the things which we are concerned to understand in science are not directly observable. Energy is observable only in its effects. We cannot see gravity or sound. Other phenomena are imperceptible because they are outside the human scale. For example, we cannot see evaporation of a liquid, or plant and animal growth, actually taking place. Is there any way in which we can make these types of phenomena accessible to children?

In the case of evaporation, there are occasions when we can sense that it is taking place, for example when we smell perfume. Admittedly, parallels with evaporation of water from a fish tank might not be obvious to children, and it might not help to take over the children's discussion and assert the similarity of the situations. However, the experience of 'smelling evaporation' could be set up as a thinking activity to start off new ideas in children's minds. Unless such bases are laid, a demonstration lesson on the particle model of matter might fail to make any contact with children's understanding.

The rate of change is the problem with growth. One approach is to use plants which can grow very quickly. A more accessible method is to use time-lapse photography, a process which records changes over a long time and then plays the record back at a much faster rate. However, if this is within the scope of teachers to use at all, it is unlikely to relate to the plants which children themselves have studied. Used in the

right context, it could broaden children's understanding of aspects of growth which they have managed to perceive directly.

Experience can also be extended through secondary sources. The pupils' books have a function here by providing information which children may use in testing their ideas in their minds. The books also expose children to different ideas and ways of looking at things, promoting reflection and the need to justify their own ideas.

What if ideas cannot be investigated directly?

There are many aspects of the world which children cannot investigate or observe directly. Examples are the spherical shape of the Earth, the extinction of species, the interior of the human body, and the Earth's crust.

It may sometimes be possible to go part way with investigation. Fossil remains may be looked at as evidence of past life-forms, and observations in quarries, caves, or holes dug in the ground can be used to develop ideas about what is under the ground. However, secondary sources such as books, films and videotapes will have to be used if children are to be able to study some topics adequately.

Children have to make sense of ideas they find in such sources. It is important that they learn from them in an active way; that is, they should use them to seek evidence in relation to their own ideas and questions. It is also to be hoped that children will seek to understand how the information they find was first established.

There are also occasions when secondary sources may usefully supplement first-hand exploration. When children explore the variety of living things, they should observe as many plants and animals as possible, but this experience can be widened vastly by use of other sources. The pupils' books will help here. Their ideas will develop if they approach such sources with their own questions. For example, having seen the way that some animals look after their young, they might want to find what other animals do.

Words, words, words

How do children use scientific terms?

It was clear in the SPACE research and development work that children sometimes used both technical and non-technical words in a manner which was idiosyncratic and not necessarily in agreement with conventional meanings. Children used the words scientists use to describe events yet often without the meaning that scientists attach to them.

How can we help children towards a better understanding of the scientific terms they use?

In order to develop children's understanding of the vocabulary they were using, teachers devised a number of activities which would encourage children to think carefully about what they understood by particular words. As far as possible words were discussed in a concrete context – if 'vibrations' were being discussed, children had direct experience of vibrations to call upon. The intentions of the activities the teachers devised were to:

- ◆ clarify the more precise meanings and usage of words in the children's everyday vocabulary which have a more precise meaning in a scientific context;
- ◆ collect examples of alternative words which children used to mean the same thing, so that the nuances of related words, in both scientific and everyday vocabulary, could be drawn out;
- ◆ help children to use more accurately the scientific terms which emerged as they tried to describe their science activities. (Scientific vocabulary was introduced only when children had evidently identified an idea or process for which they lacked a precise label.)

Some examples of these activities were as follows.

Children frequently used the words 'rough' and 'smooth' in connection with the surfaces on which toy cars were propelled. Several teachers developed activities to clarify the children's understanding of these terms. Comparisons were made between different surfaces, for example the playground surface and the floor of the hall. The children made rubbings of rough and smooth surfaces. They collected objects and sorted them into rough and smooth groups. These groups exemplified particular words and enabled the children to use the words more accurately and in a relevant context.

Words like 'grip' and 'stick' were used by children in the context of car wheels and their contact with the road. Practical activities were generated to examine chil-

dren's understanding of these words. Children moved around the hall in bare feet, in socks and wearing shoes. Their attention was focused on the stopping action which they used, such as pushing toes into the floor.

The children predicted which would grip best on the floor. Further investigations considered which foot covering would be best for climbing up a slide. Which would grip best?

This teacher had recognized that words like 'stick' and 'grip' were within the children's experience and were perhaps acceptable approximations (or at least, as close as the children concerned were likely to approach) to the idea of friction between surfaces.

Generating other contexts in which the word was used emerged as a useful strategy for developing understanding, particularly amongst infants. One teacher asked children to think of instances where they had heard the words 'melt' and 'wet' used.

Candles melt on a cake.

Chocolate melts in your hand.

A towel dries you when you are wet.

Wet clothes dry.

Wet paint dries on paper.

These suggestions were turned into activities, after which children drew pictures of their observations and discussed the outcomes. This provided the opportunity for children to make some distinction between what had 'melted' and what was simply 'wet'. By using this method, the normally haphazard acquisition of word meanings which occurs probably every day of children's lives was subjected to some control. The two essential aspects were:

- ◆ shared and unambiguous direct experience through which every child involved was able to agree the characteristics of the phenomenon;
- ◆ shared use and discussion of particular vocabulary. If we are to communicate effectively, we have to make considerable efforts to establish conventional meanings.

How should children be introduced to scientific vocabulary?

On occasions the words children used as synonyms revealed a lot about their understanding of a concept. While working on the Growth topic, a significant number of children used the word 'stretch' as an alternative to the word 'grow'. In an attempt to clarify children's understanding of these words and ideas, a Year 3 teacher selected a group of objects which would elicit children's ideas about these words. A spring, a balloon filled with water, treacle toffee and knitting were all produced, following children's suggestions.

The children's notion of grow and stretch became increasingly confused as these objects challenged their understanding. A consensus view seemed to be that growth was a permanent state whereas stretch would go back. There was also a belief that growth involved adding on to, like building a wall or knitting.

Similarly, 'wobble' and 'vibrate' were used interchangeably. An agreed working definition was established for these words through discussion. For instance, a jelly wobbles and you can't hear it, so a wobble moves up and down slowly; vibrations

are usually smaller and faster movements which produce a sound we can hear.

During children's investigations into evaporation there were further instances of children using words that were imprecise. 'Dissolving', 'crystallizing' and 'absorbing' were used by children freely but it was clear that they did not all have the same understanding of the words: for instance, the water was said to have 'dissolved' into the sugar, and to have 'melted' into the dried milk.

The difference between dissolving and absorption was exemplified by providing instances of each – sugar and salt in water, a handprint on an absorbent towel. The activities enabled children to clarify and develop their initial understanding of scientific labels. This kind of clarification is essential and it helped these children to understand that some words are science related and are applied only within the science context.

A number of children used the word 'soaked' in connection with condensation on the window. Did they really think that the water soaked into the glass? (The assumption that condensation on the outside of an iced drink is water from the ice which has passed through the glass has been encountered frequently, so interviewers were on the alert!) On this occasion, children were using 'soak' in the sense that they might describe themselves as 'soaking wet'. A very imprecise usage that might convey a very clear meaning in an everyday context sowed confusion in a scientific context.

Careful exploration of the words children use may reveal underlying ideas about what is happening which are strange or even confused. Direct experiences, discussion and drawing can have some impact on children's understanding of the words they use, but it has to be recognized that linguistic development is a gradual process enhanced by encountering a range of different experiences. As one teacher said:

Many children will need reinforcement activities over months and years to develop their understanding.

This comment demonstrates the importance of sensitivity and understanding in identifying the needs of individual children in order to determine the appropriateness of a conventional scientific term. The experience of teachers involved in the SPACE project has been that merely supplying a child with a scientific label has not facilitated understanding. Children have either not used the technical term because they did not know enough, or have used it inappropriately.

On the other hand, children may well use alternatives to the technical terms with which they are completely satisfied and which work perfectly satisfactorily for their level of understanding. These alternatives have been constructed and refined from previous experiences, and so children are likely to find them much more helpful in expressing their ideas. Therefore, we need to value the words children use to describe their ideas as well as the ideas themselves. In consequence the major task in language development in this context is to judge accurately the point at which the children themselves feel the need for additional or alternative words.

Knowing when and where to stop

Does a difficult start justify stopping early?

Knowing where to start with helping children to develop their ideas should pose no problems, for within the SPACE philosophy the starting point is children's current thinking and understanding. On the other hand, teachers have sometimes found it a problem to know where to stop. It might be helpful to think first about where not to stop.

Occasionally, teachers have commented that some children in their classes simply 'do not have any ideas' about the subject under consideration. They would therefore like to stop, in a sense, before the children have started. As suggested in Chapter 13, it should always be possible to encourage children, even those in reception groups, to express some comment about an object, event, photograph, or whatever. This may be no more than a basic descriptive observation, but that is, at least, a start. It means that children have begun to engage with the subject matter at some level. To stop before this point is likely to be a mistake, since every child with intact senses is capable of an observational comment of some kind. To stop before such a comment has been elicited is to run the risk of engendering a sense of failure, for children will be aware that a question has been posed to which they have failed to make any response. An open question should be posed on which a child can comment at his or her own level.

If it emerges that nothing beyond the most basic observations are likely to be forthcoming, then the point to stop is after there has been an opportunity to experience and explore a range of direct sensations and basic manipulations offered by the initial activity. Such direct experiences sow the seeds for reflection and discussion at some later point, without necessarily offering the teacher much scope for immediate development.

Should children be stopped before a topic has been fully covered?

Another landmark to avoid as a stopping place is that point of weariness and exhaustion, 'the bitter end'. In the science curriculum, it may be tempting to try to take children through a whole AT, or a whole level within an AT, so as to be able to achieve a sense of completeness, from the teacher's point of view. This could easily turn into one of the clearest manifestations of teaching being distorted by assessment considerations, the so-called 'assessment-driven curriculum'. Naturally, teachers will make every effort to support conceptual progression in such a way that children develop their understanding as far as they can take it. When they have carried out all the preparatory groundwork, they will make every effort to maximize the possibilities of new learning. However, it would be counter-productive to dwell too long on what seems to be a difficult idea for a child to grasp, to force a point.

The risk is that a sense of frustration or boredom may be induced. The tempo of a child's learning may dictate that it is more realistic to stop between the National Curriculum bench-marks, the Statements of Attainment. It is necessary to adopt a long-term view of conceptual development, which is, after all, a life-long process. Children need some time for incubating ideas and reflecting on new experiences; an overview of progression might enable teachers to take a more relaxed view and a more evenly paced approach.

A contrasting case is that in which, as sometimes happens, a child becomes captivated by some subject matter or other, almost to the point of obsession. Teachers have always had to deal with this sort of situation, particularly if they have used a topic-based approach. Indeed, one of the virtues of working on a topic basis is that a wide span of activities may be encouraged and sustained by the contextual interest. The SPACE approach emphasizes the role of the child in helping to set the learning agenda by defining the starting point and by bringing a personal motivation to the learning situation. It then becomes possible for the teacher to interact with these factors brought by the child in a responsive but active role, guiding, influencing and shaping activities and outcomes. When a teacher's planning determines that it is time to turn attention to another area, it should be possible to shape a child's interest and motivation towards other areas within the science curriculum, or to develop cross-curricular aspects which exploit the special interest. When these possibilities have been exhausted, an invitation to indulge the passion in the child's free time might be a possibility. To put on the brakes when interest and motivation are running at a high level is not usually necessary.

How do teachers tell the best time to stop?

Decisions about when to stop will, for most children, not involve these extreme situations. The sorts of judgements which teachers tend to make on a daily basis in this respect are of a cost-benefit nature: 'How much is she or he getting out of this activity?' Since the SPACE approach lends itself to fairly continuous formative judgements about where children are in their thinking and what the next conceptual step is likely to be, it should soon become apparent when a child has achieved as much as is likely to be gained. This is the obvious point at which to stop, and for most children on most occasions it is likely to be fairly self-evident. It follows that a good stopping point may be one where it is clear that the children still have incorrect ideas; as long as these are reviewed in later activities it is far better to leave them than to impose the 'right' ones in desperation.

In considering when to bring activities to a close, the general consideration to bear in mind is a fairly common-sense one: that the teacher should control the situation in such a way that children do not end on a 'low', with a sense of failure or frustration. The drive which enlivens children's thinking is their own interest, curiosity and exploratory motivation. This must be nurtured, sustained and protected by the teacher, and judgements about when to change tack will be one of the most important of the teacher's functions.

Equal opportunities for all pupils

How does the SPACE approach provide science for all pupils?

In providing learning experiences for the National Curriculum, one of the criteria to be met is that they should:

'appeal to both boys and girls and those of all cultural backgrounds'

(NCC Non-Statutory Guidance, 1989.)

It is also important that, as far as possible, children with special educational needs should have the same science experience as others.

The Nuffield Primary Science materials have been developed with these requirements firmly in mind. Indeed, since the SPACE approach to teaching and learning is designed to give each child encouragement to build upon and develop her or his own skills, it can be used successfully across a very wide range of levels of development. In addition, the relationship between the ideas children hold and the way in which these are developing means that children are operating at different levels but within the same curriculum. Consequently those children with particular difficulties do not become isolated because of their differences.

Providing for equal opportunities for learning essentially means taking action to avoid unconscious discrimination. So in considering the three main reasons for unequal opportunities we will look at the circumstances which are associated with bias, then at how it is possible to avoid them and how the SPACE approach helps.

What can be done to avoid gender-related bias?

That there are gender differences in participation and performance in science has been well documented. These differences appear in all western countries where they have been studied, mainly at the secondary level. However, it is not difficult to realize that the problem has its roots at primary level and indeed the APU findings showed that trends for boys to perform better in physical science were already evident at the end of primary school. It is not uncommon in primary schools for girls' participation in activities more often to take the form of watching or writing and for boys to be dominating the 'doing'.

The several hypotheses which have been put forward to account for these differences fall into two groups: biological and social. The biological have included a nineteenth century idea that females were constitutionally unsuited to science and the more recent theory which relates to sex differences in visual-spatial ability. However, there is overwhelming evidence (particularly from non-western countries) that there is no inherent sex difference in related skills.

The hypotheses relating to social influences, including the school, suggest that differences may be due to the overall differences in personality characteristics between males and females, to the established order of scientists as being chiefly male, to the view that scientific activity is masculine rather than feminine, to gender differences in interests, and to methods of teaching science. All these are linked to the way science is presented and this seems to provide the key to how to counter them.

When presented as an objective view of how things are, as facts already known and as relationships governed by immutable laws, divorced from human imagination and creativity, science appeals more to the masculine than the feminine personality. Since science has been traditionally presented in this way both within schools and, even more so, perhaps, in the public image, it is not surprising that the very large proportion of those succeeding in and practising science are male. This has added confirmation to a self-fulfilling prophecy and to the image of science as a male preserve.

This view of science is now seen as deficient. Philosophers, scientists and educators alike recognize science as a human endeavour to make sense of the world around, through testing and changing theories whose origins may depend upon imaginative leaps of thinking as well as on rigorous application of a 'scientific method'. Such a view of science is much less gender-biased than the clinical, objective one which has been traditional for so long. It allows for a range of interpretations, for testing alternative ideas and for change in ideas; it requires maintaining an open mind; it includes creativity and open discussion in considering evidence.

It is this view of science which underpins the National Curriculum, as made explicit in the NCC's Non-Statutory Guidance: 'Scientists are curious; they seek explanations There is also an important place for imagination, for inspirational thinking and the receptive mind' (para 3.1). Later, science is described as 'a human construction' (para 3.2).

In closely reflecting this view, the SPACE approach helps children to choose from their own ideas in trying to understand what they find, to test their ideas and to take part in the 'human construction' of knowledge. It has, therefore, the characteristics which are likely to reduce gender bias. However, children are influenced by their many out-of-school experiences, so teachers still need to be watchful that girls are encouraged to participate equally with boys in all aspects of the activities. Only through experiencing science for themselves will girls overcome prejudices which are still fed by social pressures and the media.

It is also important to take into account the differences in interests of girls and boys. The origin of these, in cultural expectations, role models in the home and represented in literature and the media, gender-differentiated toys and so on, have generally been very effective in producing quite distinct – and traditional – sets of gender-related interests from an early age. Although these different interests affect all areas of the curriculum they have particular relevance to science. Boys' tendency towards things mechanical means that they readily engage in activities relating to forces, electricity and magnetism, and energy (AT4). Girls' interests take them away from mechanical things and towards activities relating to living things (AT2). Thus it is necessary to make a special effort to engage both sexes in these areas particularly. Otherwise the lack of experience will lead to lower performance which itself creates dislike of things 'I'm no good at', and the events which lead to under-representation of boys in biology and girls in physical science gather momentum.

How can the SPACE approach help to avoid bias relating to cultural background?

Just as pupils can feel excluded if the subject of activities does not interest them, so they can experience the same reaction if it bears no relation to their cultural experience. This is a matter which is curriculum-wide and calls for sensitivity. The purpose of an activity may be entirely missed or engagement may be resented if inappropriate assumptions are made. This happened when a six-year-old was making a reindeer, as were all her classmates, just before Christmas. All the others were going to take theirs home to hang on their tree, but this little girl was Jewish. She worked very reluctantly. In science, cultural background may not be thought to be a problem, just because science is about the same world around all of us. But daily experiences, from which so many science activities start, may be quite different for children with a family background and a tradition from other countries. The most obvious example is the discussion of food. If this deals exclusively with traditional English fare, some children may be unable to relate this to their own daily lives. Moreover they may receive the message that science does not concern them.

It is not only content but the way pupils are encouraged to behave in science – touching, questioning, challenging – which may distance certain children. It may take considerable persuasion to prise out their own ideas from children who expect the teacher to be the source of all ideas. Often this is compounded by gender and the way girls are expected to behave.

The approach of beginning from children's ideas may have to be introduced carefully to children who may find it unnatural to put forward any ideas which do not derive from some authority, such as a book or the teacher. Rather than a direct approach it is often best to include these children in groups where other children's ideas are freely given and used. This legitimates the expression of their own ideas more effectively than compelling them to say something before they realize why this is useful. But this is essential in avoiding bias due to cultural differences: when children express their ideas, work on them and discuss their experiences, the danger of unconsciously excluding them is minimized.

How does the SPACE approach help children with learning difficulties?

Often children who experience difficulties in other curriculum areas, where language skills may hold them back, show unexpected understanding in science. At the same time there will be children who experience difficulties in science. Children with sensory disorders may be limited in the observations they are able to make. Collecting resources or making accurate measurements may pose problems for some physically handicapped youngsters. There will also be children who have difficulty articulating their ideas, because of communication disorders and lack of confidence. Children might also experience difficulties developing investigations, working co-operatively, or drawing conclusions from their observations.

Children who have experienced difficulties in the classroom are often regarded as unresponsive, reticent or simply lacking any ideas. An aim of the SPACE approach is that children confidently express their ideas. This confidence can only be achieved by creating an atmosphere within which children are willing to express their ideas. There are several ways in which this can be done.

An initial activity which takes account of children's own experience and allows them to explore real objects within their own capabilities is crucial. This direct and

concrete experience provokes thought and may reveal hidden depths of understanding.

The full range of techniques for expressing their ideas (see Chapters 14 and 15) allows children to communicate, independent of individual abilities. Some children may discuss their ideas more willingly on a one to one basis while others may be more responsive in small groups. Allowing children to represent their ideas in drawings, which can be annotated by the teacher, ensures that children with writing or communication difficulties can express their ideas. By offering a range of ways in which ideas can be expressed, all techniques become equally valued. As a result participation in science is not dependent on possessing specific skills.

Since children's own ideas form the basis of future activities, the SPACE approach ensures that learning activities are closely matched to a child's individual abilities. All children have the opportunity to complete a purposeful task and to experience success. This positive outcome raises children's confidence and levels of motivation. Teachers have reported that as children's interest in a topic is sustained, they spend more time on a task and are less likely to become distracted.

Catering for children's individual abilities does not mean providing a whole range of different practical activities, almost at the level of one for each child. Children can engage with an activity at several levels and starting from their ideas enables each to make an individual response within the framework of the same activity.

Neither is catering for individuals differences incompatible with promoting co-operative learning; indeed, quite the opposite is the case. An infants' teacher reported how a child, David, with severe communication difficulties expressed and explored his ideas about floating and sinking. David himself made a boat with a bridge that held the front and the back sections together. He was convinced it would float, even when the other children suggested it might sink because of the hole between back and front sections. David himself went on to test his boat and was pleased when he proved it would float. Another child offered an explanation, claiming that it floated because it was more even. This led another child to begin generating theories about why the boat floated and a co-operative attempt to find the best explanation resulted. Experience during development work for the Nuffield Primary Science materials was that children began to recognize as valuable the contribution of their less able peers. They responded by including these formerly less popular children in their investigations. This increased co-operation results in increased self esteem, which may transfer to other learning and social situations.

Teachers adopting the SPACE approach have indicated a number of ways in which the needs of children who experience difficulties in science can be addressed. These can be summarized as follows:

- ◆ an emphasis on direct experience challenges children's thinking and understanding whilst at the same time placing learning within a meaningful and purposeful context;
- ◆ establishing a classroom which values and responds to children's ideas will increase confidence and willingness to express ideas;
- ◆ providing a range of ways for expressing ideas means that all can become involved;
- ◆ providing a range of ways of working from children's ideas leads to the experience of success, which creates enthusiasm for science.

Organizing SPACE work

Are any particular classroom organizations better than others?

The SPACE approach can be employed in various ways provided that the organization allows the essential features of the approach to be put into practice. These are that at various times there has to be opportunity for:

- ◆ teachers to listen to individual children speaking in a one-to-one situation, within small groups and in whole-class discussions;
- ◆ children to discuss with their teacher and with other children;
- ◆ children to express their ideas, prompted by exploration of real things;
- ◆ children to try out their ideas in practical investigations which they devise for themselves.

As long as the curriculum organization makes these things possible the SPACE approach imposes no restrictions, although some arrangements will certainly make this easier than others. For example, it is important for children to have opportunities to talk to other children about their work and to exchange ideas. In this way they learn that there are alternatives to their own ideas and become more ready to look at things from a different view point. This exchange is not feasible if children have not shared similar experiences at least as starting points for their activities.

What has been done in practice?

Descriptions of various approaches for working with children can be found in Chapters 13, 14 and 15. Here additional points are made by drawing on the experience of teachers who have used the SPACE approach.

Class discussion is a useful method of establishing children's ideas at the beginning of a topic, in monitoring the progress in children's ideas, or in concluding a topic. The teacher's role is to maintain the discussion and encourage all children to express ideas. This may necessitate changes in order to adapt to a non-directive teaching style. As one teacher explained:

I needed to spend far longer listening to each child. I hadn't realized before that they wanted me to tell them what I wanted to hear.

The SPACE approach therefore requires that teachers spend much longer listening to all responses in order to create an atmosphere where pupils feel confident in expressing ideas.

Teachers who have used class discussion have been encouraged by the range of ideas expressed.

It was a real eye-opener. Responses and ideas did not match my expectations. Good ideas sprang from all age-groups.

In order to recall the range of responses made, one infant teacher suggests:

I always make sure I have a notebook on hand to record the date and who said what.

This type of record can be used to determine which children share similar beliefs and therefore can be used to determine groups for investigations; it can also provide a record of any change in children's ideas.

Some teachers who helped in the development of the SPACE approach spent too long on whole-class discussions – perhaps because these were so fascinating – so that there was a danger of science being something more talked about than experienced actively. At the same time it is important to avoid constant practical activity without literally sitting back to think and talk about it.

Although class discussions are easy to organize, there may be children who feel reluctant to express ideas in a class situation:

I felt the discussion was enlightening. The children had come a long way, but there were several who didn't take part at all.

Ideas from these children may be gleaned through individual discussion. Teachers did find that opportunities for individual discussion with specific children could be planned in a busy classroom. As children were engaged in representing their ideas in drawings, some could be asked to talk about their drawings on an individual basis. Comments which emerge during these conversations can be added to the drawings and may even contribute to an assessment record. Similarly, during investigations opportunities may arise for individual discussions with targeted children. Teachers in the research found that activities left in the classroom encouraged children to discuss their observations not only with peers but spontaneously with teachers.

These unplanned individual conversations provide an insight into the ideas held by more reticent children. One child, who usually had very little to say, had been investigating a car rolling down a slope. He revealed ideas about gravity as he explained to the teacher: 'It is something that pulls everything down into the earth.'

Occasionally individual discussions are frustrated by the competing demands of a classroom, even where there has been meticulous planning. It may be easier to use group discussions where a smaller group of five or six children discuss their ideas and develop investigations. These smaller groups encourage children who are reluctant to express ideas in a class discussion to make a contribution. They also enable children to challenge each other's thinking much more quickly than in a class discussion. Initially teachers had reservations about the viability of this strategy, since children often had little or no experience of working in groups. Teachers believed that without the guidance of an adult the group would not maintain the focus of interest. The experiences of those teachers showed that the children developed an ability to cope with the new groups and to work without constant teacher intervention.

I was very impressed at how children work much better without supervision. They carry out their investigations and discuss what is happening, and there is very little talk about what was on television last night.

A plenary session where groups report to the whole class provides the opportunity for children to communicate their experiences to the class. These group reporting sessions enable teachers to assess individual contributions. They also encourage the groups to develop their investigative skills as their peers inquire: 'Did you make sure you have the same push?' 'How long did you do that for?' and so on. Clearly group discussion and group activities require careful planning. The teacher needs to decide if all the class will be engaged in science or just some of the children. This may be dictated by the focus of study or by the personal demands of the teacher.

Does the whole class have to work on science together?

Inevitably, as they try out their own ideas, children will be involved in different investigations, but in pursuit of a shared experience. A common focus is thus very desirable, but this does not mean that they must work at the same time as each other. The nature of some work demands that groups must work at different times, while in other cases the whole class can be involved if the teacher wishes.

Teachers' individual preferences are important. One teacher said: 'I couldn't cope with them all doing different things. It's just the way I work. They all work on science at the same time.' Clearly this teacher felt more confident when her attention was focused on one curriculum area, even if the children were following different ideas within that area.

Teachers who have preferred all the class working in science together have usually presented children with a common experience in order to elicit a range of ideas. They have then organized children into groups, and the groups have explored their ideas in different ways.

I left them very much to their own devices listening in and only asking the odd question. On Monday we shall get together as a class and discuss what we did, using a spokesperson from each group. Then we will probably extend their investigation using ideas noticed about the shape of the foil, the objects' weight and the speed of sinking.

This teacher's report demonstrates the extent of her planning. She has closely monitored the group tasks, and has planned for a class discussion to take place. During this discussion she has anticipated the kinds of ideas which will emerge and is using the discussion as a means of developing children's ideas and helping them to extend their investigative skills. The teacher has planned that further investigations will take place, building upon the ideas expressed during the exploratory activities and during the discussion.

On the other hand some teachers may find monitoring four or five groups simultaneously too demanding.

Ideas were being expressed so thick and fast I couldn't cope. Next time I'd stick with a group and give the other children something which didn't need my attention for 10 minutes. This way I could be sure I was really establishing what their ideas are.

This strategy was commonly adopted by teachers of younger children. The teachers often planned a range of different activities for children to engage in, which needed lower levels of teacher support, enabling teachers to focus their attention on a particular group. One Year 2 teacher produced a box of home-made instruments

designed to elicit ideas about where sound was coming from. The children produced ideas which were explored by asking further questions: 'Can we make the sound different?' 'What will happen if ...?'

Children concluded the group activity by drawing one of the instruments and showing how it makes a sound. Their representations revealed ideas about sound travelling and reception as well as sound production which could be pursued in the next session. Teachers resolved the difficulties of spreading themselves around different groups by carefully planning to spend specific amounts of time with a particular group while other children were engaged in different activities.

Clearly, adopting the SPACE approach will have implications for planning. Class discussions require the involvement of all children, whereas group activities may involve some of the children and occasional periods of teacher support. There are critical times, such as when probing children's ideas or when children are turning their ideas into investigations, for which it is necessary to plan to be with specific groups. At these times other groups should engage in activities which need lower levels of teacher attention.

Teachers in the research found that initially this approach to science placed heavy demands on their organizational skills. Nevertheless they realized that children do gradually develop the ability to work both independently and in groups and then make fewer demands on the teacher.

Science and other subjects

Are there opportunities for unified teaching of National Curriculum subjects?

While the National Curriculum is specified in terms of subjects, it does not follow that these subjects have to be, or even ought to be, taught in isolation from one another. There are many common elements, both in the Programmes of Study and in the Attainment Targets, which might well be treated together. Some examples are:

- ◆ The emphasis on communication skills in the first paragraphs of the Programmes of Study for science means that some aspects of English are required in the teaching of science.
- ◆ The targets in mathematics on Handling Data and on Using and Applying Mathematics overlap strongly with elements of the Scientific investigation target.
- ◆ The discussion in the Programmes of Study of Design and Technology and the reference there to the use of science in that subject again set out positive requirements for overlap.

More detailed examination of the overlap has been provided in the Non-Statutory Guidance which the National Curriculum Council has prepared for each of the foundation subjects.

What are the advantages and disadvantages of teaching science within a cross-curricular topic?

If electricity is introduced as an activity involving children in connecting light bulbs, batteries and wires, it will interest some children. It would become much more meaningful, and interest more children, if it were set in the context of a project in which they were involved, such as a working model of a fairground or a model theatre. Both of these projects would provide opportunity for cross-curricular work in addition to the science.

Children need to be clear about the purpose of the scientific activities in which they are involved. For this to happen, their work in science has to relate to their everyday lives and to the existing ideas which they have. If children have a genuine problem to solve, such as making a working model of a lift involving a pulley system for design and technology they will have a clearer idea of what pulleys are for and how they work than if they learnt about them in isolation.

Children need also to learn to draw on the scientific knowledge which they have.

Cross-curricular topics can help provide opportunity for children to apply their knowledge and skills in a variety of contexts. For example, in a topic on 'litter', children may think about how rubbish is recycled and use their knowledge of magnets to work out how iron and steel may be separated from other materials.

To sum up, if science can be taught within a cross-curricular context, then teachers can:

- ◆ draw on a range of interests and backgrounds so that more children will be fully involved;
- ◆ give children a sense of purpose in their science work and help them to relate it to their everyday lives;
- ◆ help children to apply their scientific knowledge in a variety of contexts so enabling them to make generalizations about scientific ideas.

There are two main pitfalls to watch out for when teaching science within a cross-curricular topic:

- ◆ The science may become lost among the many other activities and therefore lose its focus; this has happened in the past when the scientific aspects of a broad-based topic appeared on planning charts but became, in practice, a minor feature of the work.
- ◆ The topic may cover a number of Attainment Targets so that no one area of science is covered in any depth; children's learning will at best be superficial; and children may become confused when faced with learning several different concepts at the same time.

How can Nuffield Primary Science materials be used?

Each teachers' guide and pupils' book follows closely the content of one or more strands of the science National Curriculum. Comprehensive coverage of an Attainment Target comes from using the ideas from several guides. The exception is AT1, which occurs throughout all the teachers' guides. The diagram on page 7 shows how Attainment Targets 2, 3 and 4, and the strands within these Attainment Targets, are related to the teachers' guides at KS1 and at KS2. Within each guide the activities are set out so that teachers have the maximum flexibility to use the ideas to fit in with their own preferred way of working.

Thus the material in the guides ought to be regarded as a kit of parts to be assembled by teachers in their own design of a curriculum. The science may therefore be presented to children as part of an integrated topic, as part of a science-based topic, or as a specifically science topic. A teacher may well use all three modes at different times.

When selecting suitable topics for cross-curricular work, a teacher might start with the area of science which is to be covered and think out topics in which it may be applied or to which it could be relevant. Alternatively, it may be more productive to think first of other topic or subject areas, and to see how science ideas and skills can be included in the work.

What is to be done about Information Technology?

Information Technology is specified as a component in Technology and is intended to be cross-curricular in nature. The idea is that children should become familiar

and confident with the various aspects of Information Technology through using it in the work of various subjects when opportunities arise.

There is extensive overlap between the requirements of Information Technology and the Programmes of Study in Science, although the two are not identical. Guidance on how this target, and the broader aims in Information Technology, may be met is given throughout the teachers' guides. Within their own schemes of work, teachers may find opportunities both to apply Information Technology experience acquired in Science to subsequent work in other subject areas, and to use work initiated in other areas within Science.

Planning the teaching of science

How can science be included in the school curriculum?

The Nuffield Primary Science curriculum materials have been designed to allow schools and teachers to incorporate science in their curriculum in a manner which meets their specific needs. The teachers' guides are structured in terms of the concepts of the themes of Attainment Targets 2, 3, and 4 of the National Curriculum, so the information is readily accessible and easily fitted into the common patterns of curriculum organization or a combination of them. Thus, where the Nuffield Primary Science teachers' guides are being used, science may be included:

- ◆ as part of integrated topics, where work in science and other curriculum areas such as maths, English, history, geography, art, technology, music etc. is carried out as it arises;
- ◆ through the study of more restricted science-based topics, where science may lead to activities in other subjects but not vice-versa;
- ◆ as specific science sessions where the activities have their own cohesion independent of work in other areas.

With regard to topic work it is useful to keep in mind the caution pointed out by HMI in their report 'Teaching and learning: primary science' (1989):

Some caution is needed about this [the topic] approach since the least effective work is often associated with topics where far too much is attempted and – as a consequence – too little is achieved in depth of knowledge, understanding and the acquisition of skills in the constituent subjects. (DES, 1989, paragraph 74.)

The Nuffield Primary Science materials help to avoid this situation by clearly defining the processes and concepts of science related to each of the themes. In addition each teachers' guide indicates how the identified science themes fit into a number of cross-curricular topics and provides an example of how planning for this might be carried out.

How can a school ensure that all the Programmes of Study and Statements of Attainment are covered?

This question addresses a problem which goes across all areas of the curriculum, and requires careful planning throughout the school. The Nuffield Primary Science teachers' guides help in a number of ways:

- ◆ the structure allows them to be used in a range of curriculum contexts (as explained above);
- ◆ there is clear guidance about how the science concepts in each guide are related to Programmes of Study and ATs;

- ◆ the identification of themes within ATs provides well-defined manageable units which can be incorporated into the curriculum at different stages. (See also Chapter 3.)

What about 'revisiting' an Attainment Target?

Concepts are not learnt as a result of a single event or activity. They are developed through a variety of experiences over a period of time. The SPACE approach recognizes this, and therefore the materials allow for themes to be revisited at different times during a child's studies. There is no guarantee that any particular experience, however well chosen, will bring about a specific shift in understanding. In fact children often use new experiences to reinforce their existing ideas rather than to challenge them. It is not so much the activity that determines the developmental impact but rather how the child interprets it.

Children need time to reflect on their experiences in order to come to terms with evidence that challenges their previous ideas. Planning for science in the curriculum should therefore ensure that the themes are included on two or more occasions, preferably in different contexts. Each occasion should provide opportunities to identify the children's existing ideas followed by experiences designed to help the children towards a deeper understanding of the concepts involved. The teachers' guides encourage this by presenting examples of activities appropriate to different stages of development as well as indicating how children's ideas might progress.

How can the Nuffield Primary Science materials be used in planning for science?

Each teachers' guide provides suggestions for planning science within a specific topic, but this is only one aspect of planning. Some consideration should be given to:

- ◆ the provision of opportunities for children to develop the skills and processes of science alongside their understanding of scientific concepts;
- ◆ the nature of and possibilities for assessing and recording children's progress (see Chapters 23 and 24);
- ◆ classroom organization and management (see Chapter 20).

The following is an example of how such planning might be organized.

TOPIC: MATERIALS AND THEIR USES

CREATING THE CLIMATE

Teacher tasks	Children's involvement	Core activities	Assessment	Classroom organization
Provide stimuli – questions	Children bring in materials	INTERACTIVE MATERIALS DISPLAY	Gain initial ideas from children	Set up display area
Set context	Children explore materials available		• log book • discussion	Provision of materials
Consider own thoughts on concepts	Record/discuss general thoughts		(class and individuals)	Make time for children to interact with display
Familiarize with PoS and ATs				

FINDING OUT IDEAS				
Teacher tasks	Children's involvement	Core activities	Assessment	Classroom organization
Decide emphasis for investigation	Children carry out activities	SELECTION OF STARTER ACTIVITIES	Determination of existing ideas on properties of materials (note others)	Provision of materials
Find out children's ideas	Record using e.g. annotated diagrams and lists	e.g. to consider properties of materials	Match to ATs where appropriate	Arrange children in groups
Identify starting activities			Note demonstration of skills especially observations	Determine times for activities to be carried out
Prepare exploratory activities			Record responses	

HELPING CHILDREN TO DEVELOP THEIR IDEAS				
Teacher tasks	Children's involvement	Core activities	Assessment	Classroom organization
Help/guide children in investigations	Devise and carry out tests on materials	EXPLORING THE PROPERTIES OF MATERIALS	Note skills of:	Provision of likely resources
Introduce additional ideas	Identification of similarities and differences		- hypothesizing - predicting - measuring - planning and carrying out investigations - recording	Arrangement of resources
Question				Determination of group size and timing of activities
Consider lines of development			and ideas emerging	
Provide supplementary activities				

CONCLUDING THE TOPIC				
Teacher tasks	Children's involvement	Core activities	Assessment	Classroom organization
Note areas covered	Bring findings together	PRESENTATION OF FINDINGS	Confirmation/clarification of points with individuals	Prepare space for display of findings
	Prepare report	- display - class discussion		Arrange time for class discussion

Assessment and the SPACE approach

How does assessment fit into the SPACE approach?

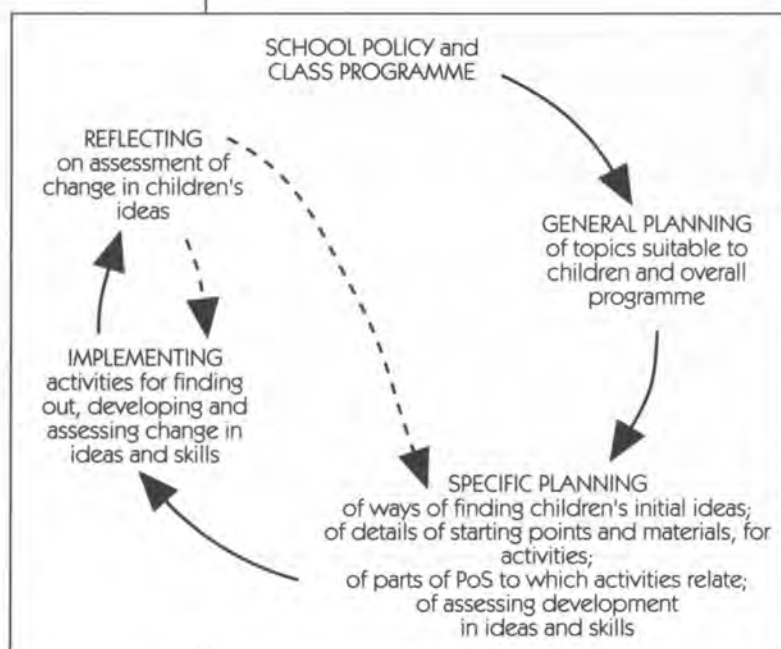
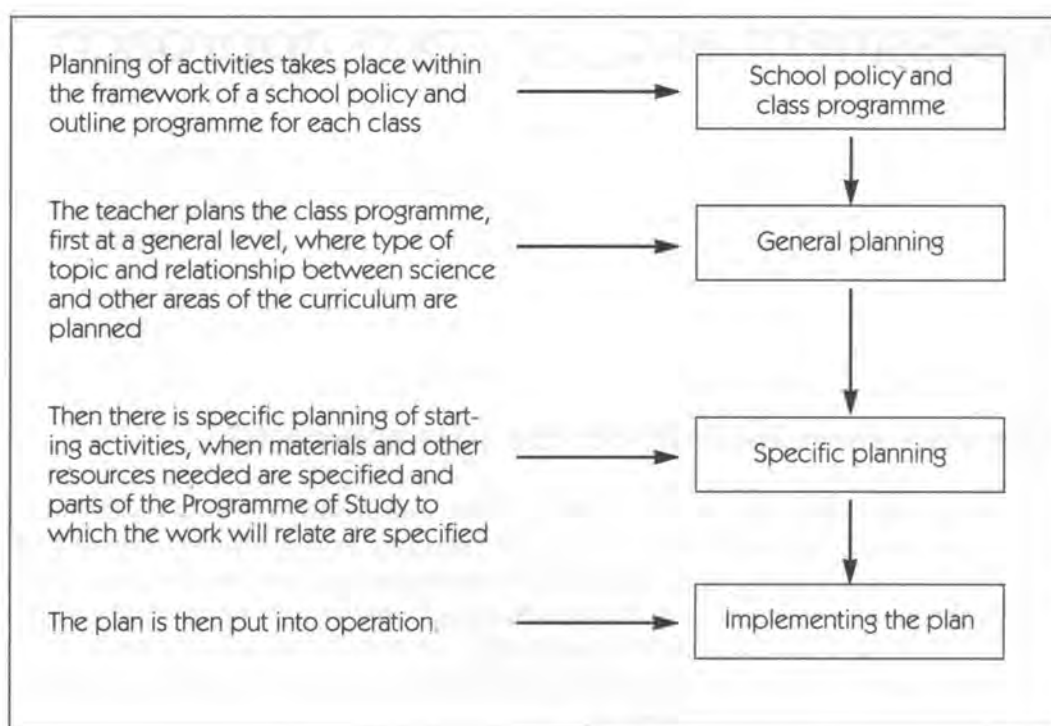
Collecting and using information about children's ideas and skills is an essential part of the SPACE approach to teaching and learning. It can also be argued that knowing about children's starting points is important for any teaching, for only then is there any chance of providing experiences which build upon what a child can already do and understand. The reasons for and the importance of starting from the child's ideas in the SPACE approach have been clear: they form the basis of the rationale for this approach to learning.

Assessment of change in children's ideas automatically follows from the regular gathering of information to establish children's ideas at any particular time. Finding out what children understand about a topic before embarking on some activities is a necessary first step in guiding the provision of activities; finding out what they understand after the activities indicates not only what changes have taken place, but also the starting point for further experiences.

If these regular probes into children's ideas were to be carried out through any formal methods of assessment, such as by tests or special check-up activities, the intrusion into time and continuity would be intolerable. Therefore, it is important for the process of assessment that this purpose should be an integral part of the activities. What this means in practice is that teachers consciously seek, by listening, watching, open questioning or studying what has been produced, to gather information which helps them to understand a child's thinking whilst carrying out the normal interactions of teaching. For instance while discussing with a child how she thinks a paper dart can be made to stay in the air for longer, a teacher was able to discover this girl's ideas about why things fall.

This informality must not be taken to imply any lack of rigour and comprehensiveness, however. In fact, the more informal the methods of assessment the more conscious attention there needs to be to ensure that at some time during the course of their activities information is gathered about each one of the children in relation to all the aspects of their learning. Without this attention it often happens that teachers notice *some* aspects of *some* children's ideas (usually the ones who achieve well above or well below the others). To ensure that the necessary information is obtained to help the learning of all the children, the process must be systematic and rigorous. This means giving thought not only to what information is to be gathered but to how it is to be gathered. Planning and records of the accumulating information are obviously essential.

When planning for assessment, it is useful to consider the whole context of planning of activities.



Working with the SPACE approach adds importantly to this series of planning steps. It requires the planning for gathering information about the children's ideas as part of the specific planning step, and the implementation of this information gathering in the following one. It also adds a further step of reflection (aided by record keeping), leading to feedback into earlier steps. The process becomes cyclic as a result of the feedback, and each time assessment is used to give information about any change in ideas it is also giving information about the starting point for further activities.

Assessment of initial ideas and of any change in them is represented here as part of the activities in both planning and implementation. It is not added as an after-thought or seen as requiring different activities; it is part of the activities in which learning is planned to take place.

How does assessment in the SPACE approach fit in with the National Curriculum assessment?

In any assessment the information gathered about what a child can do or understand is compared with some expectation or standard. This is true of informal assessment as much as of formal testing. When a teacher responds to what a child does or says with a smile or a frown, with a verbal pat on the back or an admonition, these apparently spontaneous reactions are the result of comparing what happened with an expectation. Meeting the expectation leads to one type of response

and not meeting it to another. In the case of informal assessment the standard or 'expectation' may be one for that particular child; the same behaviour from another child might be judged differently. This is quite acceptable when the purpose is to provide feedback to the children about progress in their own individual terms. However, if information is required in more widely applicable terms, it is desirable to use the same standards or expectations as bases for judgement for all the children.

Teachers' assessment of children's progress in the National Curriculum involves comparing information about what children can do and understand with the Statements of Attainment for each Attainment Target. The Statements of Attainment are the common basis, or criteria, for the judgements made in the assessment.

One way of using the Statements of Attainment is to pose the question: 'Does the child have this knowledge/understanding/ability?' and to seek evidence relevant to this. In the assessment described as integral to the SPACE approach, however, the questions posed are more open: 'What ideas/understanding does the child have about ...?' 'How does the child go about ...?' So, for example, instead of: 'Do the children "know the basic life processes common to humans and other animals"' (AT2, 3a), the question would be 'What ideas do the children have about basic life processes?'. The question serves a wider purpose than just deciding whether or not the children have the ideas conveyed in the statement: it does this but more besides, indicating the starting point for extending and perhaps changing the children's ideas.

Working with the Nuffield Primary Science teachers' guides the teacher will be assessing the children's ideas and skills at the start of the topic and then gathering information at later points in the activities. This provides all the information that is necessary for applying the National Curriculum criteria. All that is needed further, at times when this is required, is to express this information in terms of the levels of the National Curriculum. In each teachers' guide there is a chapter which is designed to help in this process. It provides commentaries on examples of children's work which help to show how the general principles apply in specific cases. These chapters emphasize that the kind of activities described in the guides provide all the evidence that is needed without giving the children special tasks or tests.

Do the children always fit into levels?

Applying the Statements of Attainment to the children's work is easier said than done. In practice it is not at all straightforward. It is necessary to come to terms with using this messy information.

An important thought to keep in mind is the purpose of the assessment, which is not to be able to label children as being able to do this or that but to help their learning through finding out about their skills and ideas. Often equivocal information is the most useful in this respect. If a child can do something in one context but not in another, or gives an answer which suggests that he or she thinks that some seeds are living, but not others, then this gives a clue as to how to help. Which contexts favour the more scientific performance; what is different about these from other contexts? Which seeds does the child think are alive, and which not? What other ideas does the child have about these two different kinds? What experiences might challenge these ideas?

Assessing ideas and process skills

What techniques are there for assessing children's ideas and process skills?

In terms of techniques for gathering information it is useful to think in terms of sources of information and then of how information is gathered from these sources.

There are really only two sources of information for the assessment we are concerned with:

- ◆ children's actions: what they do or say;
- ◆ children's products: what they write, draw, make or set up.

The important difference between these sources is the relative permanence of the information they provide. This feature is significant because it relates to the time the teacher has for considering and reconsidering what the child has done. It has implications for planning to collect relevant information from all children in a class. Clearly what children do or say does not have a permanent record (unless it is video- or audio-taped, which is unlikely to be routine) and so this information has to be used in making an assessment at the time. It is unlikely, though, that this can be done for more than a few children at any one time. When there is a longer lasting record, however, it can be stored, pored over at a later time, compared with other products of the child and discussed with those who were not there at the time it was created. Moreover, the products of many children can be considered.

Before we turn to how the information can be gathered from these sources, it may be worthwhile making clear that ideas are not necessarily assessed from products and skills assessed from actions, even though this is a tempting association to make. Both products and actions can be used in assessing children's ideas and both in assessing process skills. Where possible both sources should be used, for it is not difficult to realize that either source alone is insufficient. For example, it is not always possible to be sure from what children do whether their action had the purpose we might ascribe to it but this can sometimes be clear from a written account or an end product. Similarly, what children mean in their drawing or writing is not always clear and it is extremely helpful to discuss it with them and possibly annotate the product for later reference (see Chapter 15).

For example, whilst this description of results of an investigation with a string telephone has ambiguities in it, it indicates a situation in which there is ample potential for a range of skills and ideas to be assessed:

We went into the corridor and took the beaker telephone with us. We held the beaker tightly and we spoke into the beaker and we could hear very clearly and when we bent we could not hear properly.

There would seem to be some information about the child's ability to 'use their observations to support conclusions and compare what they have observed with what they expected' (AT1, 2c) but it is not quite clear what 'we bent' means (round a corner or just letting the string go slack?) and whether or not other factors were kept the same when 'bending' was tried. If there were observation of the event, or discussion with the child to recap the event, then not only could this point be cleared up but there would also be information about whether the child had suggested questions which could be tested (AT1, 3a), had recognized the need for a 'fair' test (AT1, 3c) or knew that sound can travel through different materials.

We have a reminder here of the importance of being prepared, of planning to gather information for assessment, of having in mind the criteria to be applied in making judgements. In this way opportunities to gather the information are not missed.

How can practical work be assessed?

Much of the information for assessing children's practical work has to be collected by observation and needs on-the-spot judgements. This is particularly important for young children, whose products are unlikely to convey the full story of their interaction with materials.

An example is the best way of illustrating the approach. A class of middle infants was involved in studying seeds. The children and their teacher had collected a very wide range of different kinds, from fruits they had eaten, from trees and hedgerows, from their kitchen shelves and from seed packets. These formed a daily increasing display in the classroom. Groups had been working at various times on sorting and comparing the seeds, measuring them, making patterns with them, planting them in various conditions and carefully opening them to look inside.

The parts of the programme of study for Key Stage 1 to which these activities related were:

that pupils should undertake activities which

promote at first hand the exploration of materials (living and non-living) and events ... encourage the sorting, grouping and describing of materials and events in their immediate environment, using their senses and noting similarities and differences. (AT1)

and that ...

They should sort living things into broad groups according to similarities and differences using observable features. Over a period of time, pupils should take responsibility for the care of living things, maintaining their welfare by knowing about their needs and understanding the care required. (AT2)

Each session with the seeds lasted no more than half an hour and it was not possible to gather information about all the children in that time. The teacher selected five children to observe in any one session. These children were unaware of being chosen and the teacher interacted normally with all the children whilst making particular (mental or actual) notes about the 'target' five. He was guided by a list of questions for which he sought answers for each of the five:

Did the child:

Make at least one relevant observation (e.g. find a way in which seeds were different)?

Ask questions and suggest ideas (e.g. about why some seeds are bigger than others, have different colours, etc.)?

Make related observations (e.g. about the size of the seedlings in relation to the size of the seed)?

Make an interpretation based on the observation or investigation (e.g. that water was needed to make the seeds grow)?

Know that the seeds were part of living things?

Know that the seeds needed certain things to remain alive?

Know that the seeds would grow into plants of the kind which produced them?

Realize that certain plants grow in certain places and that some seeds (e.g. spices) do not normally grow in this country?

Treat the seeds and seedlings with appropriate care?

These questions relate very closely to some of the Statements of Attainment for AT1 and AT2. We have kept to levels 1 and 2 in this example, but clearly statements at other levels could be added. Some of the questions could be answered by observation, but others depended on discussion with children. In these discussions the teacher framed more open questions which would give more information about the children's ideas, for example:

What differences do you notice between these seeds?

Where do you think these seeds came from? How do you think they were created?

[If the children think they are alive] How can we keep them alive and make sure they don't die?

What do you think these will grow into?

This information was gathered as part of the teacher's regular teaching, that is, between visits to other groups, where he may well have asked similar questions. He did not, however, attempt to overload his memory by trying to recall all the responses and check systematically on all the children except for the five targets. The only difference in his behaviour in respect of the five targets was in his deliberate attempt to take in information whilst interacting normally. He did not stand over them with a check-list or ignore children from other groups who needed his help.

Having gathered as much as possible of this information about these five children, the teacher would record it immediately after the session, perhaps noting, for his own use, the evidence on which he decided whether the child did or did not do what was expressed in the question.

In later sessions, other children would be selected as targets for observation. In the case of the statements relating to AT1 it would not matter if the observations were made when children were working on investigations of things other than seeds, which is why these questions were expressed above in general terms and 'translated' into the seeds context in brackets. Over the year the teacher would observe all the children in detail in several different activities and so would be able to judge the extent to which skills were being used generally. For the AT2 statements, clearly the subject matter has to be living things and so the gathering of information has to be planned to take place for all the children when they are working on this material.

Keeping records

How do I keep track of children's activities?

Teachers keep a variety of records in different detail for different purposes. In the past, records have been kept in other areas of the curriculum more commonly than in science. Now records have to be kept in all areas, and for many teachers this represents a considerable increase in work. The real danger of overload is an important factor in deciding on a recording system, for there is no one way of keeping records. Other factors are the preferences of individual teachers and what they are required to do in order to keep records compatible with what has been decided for the whole school, for if this is not done then the value of records as a means of communication is thrown into question. For these reasons we do not propose a specific form of record but offer some suggestions which may be taken into account in choosing or designing recording procedures and forms.

One kind of record is a record of planned activities. The following example includes planning of information to be gathered for assessment as well as the activities to be undertaken by the children and the parts of the programmes of study covered.

General topic: Time				
Date	Specific activity	Part of Programme of Study	Key ideas/skills	Information
Wb 15/1	Sundials	AT1 Investigation	Predicting Series of observations	What will happen to shadow?
		AT4 – Track path of sun using safe proc. – learn about motion of Earth – investigate formation of shadows	Daily movement of sun. Rotation of Earth about axis Position of shadow, object light source	Ask for expl. of why shadow is formed; why sun appears to move.

This has important uses, particularly if it is updated after the event, by adding things that happened but were unplanned and deleting those which did not happen. Depending on the organization of teaching, a column may need to be added to

indicate which children were involved in each activity. The information about what actually took place is input into planning of the next activities.

How can I record progress in learning usefully and efficiently?

It is important to distinguish between a record of activities and a record of achievement. Keeping an account of information about what children have achieved in terms of ideas and skills (and other attributes, such as attitudes, if desired) is important not only for deciding possible next experiences for children but for meeting the requirements of continuous assessment (teacher assessment) for the National Curriculum.

If teachers are not to be overwhelmed by the work of keeping records the process has to be kept in bounds, unnecessary detail avoided and transcribing from one form to another avoided or reduced to a minimum. The main issues to be decided are the pros and cons of detailed and necessarily voluminous records covering several pages as compared with more condensed records which provide a greater overview of more information at a glance though in a more cryptic form.

The voluminous record typically requires one set of sheets for each child, as shown below.

Name: <i>Zena Williams</i>				
Activity	Evidence	Attribute	Statement of Attainment	Date
<i>Sorting and comparing seeds</i>	<i>Asked how seeds get out of their pod</i>	<i>Asking questions</i>	<i>A71. 2a</i>	<i>16/1</i>
<i>Planting seeds</i>	<i>Said peas would grow into peas, with sun and water</i>	<i>Testable ideas, everyday experience</i>	<i>A71. 3a</i>	<i>2/2</i>
		<i>Conditions to sustain life</i>	<i>A72. 2a 3c?</i>	

Records for other subjects may be added to the same sheets or kept separately according to preference, but in either case it is obvious that several pages will be needed to keep a running record of this kind. These pages will have to be summarized at some point and so this cannot be the only record to be kept. Its advantages are, though, that it is open and flexible and that attributes, such as attitudes, can be recorded (as not all entries have to be related to an Attainment Target). It also gives a good picture of the development of a child across different aspects of achievement and so can be a sound basis for diagnosis and matching.

The condensed type of record inevitably has to make use of some sort of coding system, of which ticks are the most common. Colours, however, give an extra dimension, which could be used on the following Key Stage 1 example to indicate dates of entries.

Names		AT1	AT2	AT3	AT4
Cilla Heales	L1	■	■	■	■
	L2	■	■	■	■
	L3	■	■	■	■
Steve Jones	L1	■	■	■	■
	L2	■	■	■	■
	L3	■	■	■	■
L1		■	■	■	■

This type gives a clear summary for each child and for the whole class and could be drawn up from more detailed records. Some teachers, however, find it sufficient as a running record, particularly if accompanied by a detailed planning scheme/record of activities. Its disadvantages are that only predetermined achievement can be indicated, without qualifying comment, and many teachers have an aversion to tick-lists. However, in defence of the ticks it has to be pointed out that when related, as they are in this record, to statements of attainment they have as much meaning as if the statement were written in and a profile of each child was expressed in words. The ticks are not arbitrary in meaning, as might well have been the case in many such lists in the past, devised without agreed criteria attached to the items ticked.

Self-evaluation

How do I know if I'm doing a good job?

The purpose of this chapter is to provide some questions as an aid to reflection on those occasions when teachers want to ask themselves 'How am I doing?' At such times these questions may act as a check-list relating to aspects of classroom life to which attention should be paid and at the same time as criteria for evaluating them.

There is no intended formality in using these questions. They are here to be used in whatever way is felt best, although some sort of systematic approach should be adopted if one's evaluation is to be useful. The questions are framed so as to be relevant in most classrooms, but not all will be appropriate for the youngest children. It is clear that a positive answer is expected in every case where a question applies. If a number of answers are negative, some reorientation of the teaching may be necessary. There are certain chapters of this Handbook which might be reread in response to a negative answer and the numbers of these chapters are enclosed in brackets to help this process.

The questions in the list are in no particular sequence and there is no suggestion that some are more important than others.

The first list applies to the children. When you are away from the children and have time to reflect, think back over the science activities for a particular week (or two) and ask yourself these questions. Don't accept the answer 'yes' too easily; make sure you can give a specific example which justifies the answer.

During this time, have children:

- 1 Talked to each other in small groups about the things they were observing or investigating? [14]
- 2 Talked freely to you about what they think? [14]
- 3 Shown and explained their work to others? [14]
- 4 Listened to alternative ideas from others? [14]
- 5 Explained what they meant by a word? [17]
- 6 Agreed with a different view from their own on the basis of sound argument or evidence? [16]
- 7 Written down, drawn or made something which conveys their own ideas? [15]
- 8 Asked questions which indicated their interest in the way they were working or what they were finding out? [13,14]
- 9 Handled materials and made and expressed observations about them? [16]
- 10 Carried out an investigation which they had helped to plan? [16]
- 11 Suggested ways of testing their ideas? [16]
- 12 Expressed justified criticism of the way in which an investigation was carried out? [16]
- 13 Used measurement in setting up or finding results from an investigation? [11]

- 14 Asked questions which led to investigations? [11]
- 15 Made a prediction based on their own ideas? [10, 16]
- 16 Linked observations in one situation to a relevant previous experience? [11]
- 17 Shown absorption in their work or other signs that it is important to them? [11, 16]
- 18 Used sources of information to answer factual questions? [16]
- 19 Changed their ideas towards more accepted scientific ones? [9, 11].

The second list applies to the teacher's thinking and behaviour. In the same period of time, have you been finding out children's ideas? That is, have you:

- 1 Been aware of the children's ideas about the materials, objects and events being studied? [8, 9, 13]
- 2 Asked the children questions which invited them to talk about their ideas? [14, 16]
- 3 Asked for writing, drawings or other products in which the children expressed their ideas about why something happened or behaved in a certain way? [15]
- 4 Deliberately kept silent and listened to the children talking? [12, 13, 14, 20]
- 5 Made interpretations of the children's written or other products in terms of their ideas and skills? [15]
- 6 Been aware of knowing something about the ideas of every child in the class in relation to the topic on which they are working? [7, 12, 23].

Have you been helping children to develop their ideas? That is, have you:

- 7 Provided opportunities for children to explore/play/interact informally with materials? [16]
- 8 Encouraged children to ask questions? [13, 14, 16]
- 9 Provided opportunities and encouragement for children to talk informally in groups? [14, 20]
- 10 Provided opportunities for children to present ideas or to describe their investigations to others? [14, 16, 20]
- 11 Responded to questions by suggesting what the children might do to find out rather than providing a direct answer? [12, 16]
- 12 Noticed children working well without your help? [12, 20]
- 13 Become aware of changes in children's ideas from ones previously held? [9, 23, 24]
- 14 Provided sources of information suitable for the children to find out more about a topic? [16]
- 15 Challenged children to test and reassess their present ideas? [16, 24].
- 16 Kept records that help you to know what skills and ideas the children have developed? [24, 25]

Have you been personally surprised and interested? That is, have you:

- 17 Found the topics being studied interesting and intriguing? [7, 8]
- 18 Felt that your knowledge of the topics was sufficient? [7]
- 19 Been surprised at something the children have found out? [9, 16]
- 20 Been surprised by the ideas and skills shown by certain children? [11, 24]

Appendix

The Primary SPACE Project research reports

The reports describe the collaborative research conducted with teachers aimed at understanding the development of young children's scientific ideas. The titles in the series are as follows:

Electricity
Evaporation and condensation
Growth
Light
Materials
Processes of life
Rocks, soil and weather
Sound
Earth in Space
Energy
Forces
Genetics and evolution
Variety of life
Human influences on the Earth

The reports are published by Liverpool University Press. Copies are available from:

Centre for Research in Primary Science and Technology (CRIPSAT)
Department of Education
University of Liverpool
126 Mount Pleasant
Liverpool L69 3BX

Centre for Educational Studies
King's College London
University of London
Cornwall House Annex
Waterloo Road
London SE1 8TX

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'Start where the children are.'

NUFFIELD PRIMARY SCIENCE presents a radical new approach to teaching and learning primary science. It embodies the results of extensive research carried out by the SPACE project in classrooms with the help of teachers. The results showed that children can be greatly helped to learn about science by building on the ideas they bring with them to their science lessons. Nuffield Primary Science shows how teaching benefits when teachers value every child's ideas. It shows how development based on these ideas can give children a flying start in extending and changing their ideas to reach more useful scientific ones.

This handbook is essential preparatory reading for teachers about to embark on Nuffield Primary Science. It will make an invaluable tool for regular reference thereafter. It explains the underlying philosophy of the SPACE approach which is at the heart of the materials; it sets out how to use it to fulfil the requirements of the National Curriculum; it gives practical guidance about the planning and procedures of classroom work; and it describes the teachers' guides and pupils' books of Nuffield Primary Science and how to use them. Its arrangement is designed to make it easy for teachers to dip into it in search of help with specific questions or uncertainties.

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