WORKSHOP MODULES FOR PROFESSIONAL DEVELOPMENT

Assessment in Primary School Science

EDITOR
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Foreword

This material 'Assessment in Primary Science: Workshop Modules for Professional Development' is a collaborative project between UNESCO and the Commonwealth Secretariat. It is a direct result of an earlier project in primary science which took place between 1985 and 1992. The first project was concerned with developing process-based learning in science in primary school. It was an initiative once again supported by UNESCO and the Commonwealth Secretariat which drew on some work in this area already undertaken by the Committee on the Teaching of Science of the International Council of Scientific Unions (ICSU). The project convened several international workshops and regional seminars which culminated in the publication of a new UNESCO handbook – the *'UNESCO Sourcebook for Science in the Primary School'* by Wynne Harlen and Jos Elstgeest, 1992. The sourcebook is now included in the UNESCO Teaching Pack distributed to Member States.

During the operation of the first project, concern was expressed about the assessment of pupils. The existing practices of assessment were inhibiting the changes in teaching style and learning objectives which were necessary for learning with understanding through the use of process skills. It was clear that the established ways of assessing pupils emphasised testing recall of information and paid little attention to the outcomes which were the aims of process-based activities. To promote this learning approach, it is necessary to ensure that assessment relates to achievement of understanding of the development of process skills and scientific attitudes.

These identified needs gave rise to the assessment project with the aim of developing activities and materials designed to improve assessment skills for use in the training of teachers and of others involved in education. It was recognised that changes are needed both in terms of formal tests and examinations, used to summarise achievement and sometimes to select and grade children, and in the ongoing assessment of teachers for training purposes. Thus the materials had to reflect these and also to be sensitive to the many different primary education contexts, including those where there are few resources, large classes and untrained or inexperienced teachers.

The assessment project began in 1992, at a workshop in Lagos, Nigeria. It brought together a small group of experienced science educators to plan the form which the materials might take, and to decide on the procedure for trialling and evaluation. Draft materials were then prepared by the project leader, Professor Wynne Harlen, and these were distributed for trialling in various countries, mostly the developing countries. The draft materials were used to run workshops for teacher-trainers, practising teachers and curriculum developers. Evaluation forms were provided and useful feedback received.

In March 1997, after a gap of four years from the time the project started, an international meeting was organised at the Southeast Asian Regional Centre for Education in Science and Mathematics (SEAMEO RECSAM), in Penang Malaysia, jointly sponsored by the UNESCO Principal Regional Office for Asia and the Pacific, Bangkok and the Commonwealth Secretariat, London. As a result of this highly successful workshop, the materials have been thoroughly revised and extended.

We are grateful to the many people who have collaborated in the various stages of the production of these materials. We cannot name them all, but in particular to Professor Wynne Harlen the Project Consultant; Dr Ved Goel of the Commonwealth Secretariat and Mrs Lucille C Gregorio of UNESCO-PROAP, Bangkok who worked closely with the consultant during the project and in editing this material, and to those who meticulously

tried out the materials and provided feedback, namely Kamala Peiris (Sri Lanka); Teherah Rastegar (Iran); William Toili (Kenya); Peter Glover (South Africa); Hafiz Muhammad Iqbal (Pakistan) and the late Joseph Yakubu.

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Introduction to the workshop materials

The workshop approach

The materials are described as workshop materials because of the approach to teaching and learning which they use and convey. A workshop approach is the term used for learning experiences in which the learner creates meaning and understanding through his or her own mental and physical activity in collaboration with others. What is provided as a stimulus for this activity can be objects or materials to investigate or to use, problems to solve, or evidence to examine and discuss. The outcome may be an artefact, a solution to a problem, a plan, a critique or the recognition of new relationships between ideas or things. Perhaps the most important product, however, is a greater understanding of the ideas involved. In the present case this means understanding of the roles of assessment in teaching and learning.

To apply a workshop approach in the context of assessment, requires that workshop participants engage with issues and problems of assessment and use evidence in arriving at solutions that make sense to them. Materials such as case studies, examples of tests, assessment procedures and recording methods are provided for discussion and tasks are defined so that the work is systematic and purposeful. The overall aim is to bring about changes in attitudes to, and understanding of, the ways in which assessment can be a means of improving education; this requires more than the knowledge of new techniques.

The materials in use

The materials are intended for use in courses of professional development led by a workshop leader. They are suitable for use with a wide range of participants: teacher educators, teachers, inspectors, curriculum developers, examination board staff and ministry officials.

In order for the use of the materials to achieve its aims, it is essential for the workshop leader to read and follow the Notes for Workshop Leaders on page 3.

The modular structure of the materials

There are many facets of assessment and they do not need to be tackled in any particular sequence, apart from beginning with general principles. Priorities and needs will vary from time to time. To allow maximum flexibility in the use of the workshop materials it was decided to adopt a modular structure. This provides free-standing modules from which courses tailored to specific needs can be created.

The amount of time required for each module will depend to a large extent on the discussion generated within the group using it, but it is expected to be about 3 to 4 hours. This means that each module is long enough to cover a particular aspect in some depth, thus counteracting one of the disadvantages of a modular structure, that it can cause fragmentation in learning.

The first module is introductory, so any course should begin with this and then move to the priority focus for the participant group. This may be formative (ongoing) assessment or the creation of formal, summative tests, or the keeping of records, or management of assessment, etc.

The modules and their aims

A. Assessment: principles and approaches

Aims:: This is an introductory module which aims to introduce participants to the whole course and then to share preconceptions about assessment as a basis for developing a wider understanding of the nature and roles of assessment.

B. Assessment and Learning

Aims: The activities in this module aim to provide an opportunity for discussion of the role of assessment as part of teaching, and of how planning and the identification of criteria assist in using assessment to help teaching. The involvement of children in their own assessment is also discussed.

C. Methods of ongoing assessment by teachers

Aims: The activities of this module aim to promote discussion and understanding of methods which can be used by teachers to conduct ongoing, formative assessment of pupils, that is, to carry out assessment and to use the results as part of teaching. The interpretation and use of the results is the focus of Module D. In Module C the main methods for assessing skills and ideas are discussed.

D. Interpreting children's performance and using the results

Aims: The activities in this module are designed to promote discussion of how information about children's skills, attitudes and ideas is used in teaching. Through discussion of specific examples, general strategies for improving the development of skills, attitudes and ideas are identified.

E. Keeping records and summarising achievement

Aims: The activities in this module aim to promote discussion of records of ongoing assessment and how they can be summarised to provide information for the purpose of summative assessment. The use of informal tests or tasks for this purpose is also discussed, whilst the use of formal testing is the subject of Module F.

F. Formal Testing (double module)

Aims: This double module aims to develop an understanding of testing for the purpose of summative assessment. It is particularly concerned with the development of items which go beyond testing the recall of information. It considers the features of items which test process skills and the understanding of concepts.

Notes for workshop leaders

Numbers and grouping of participants

The ideal number of participants for a workshop is between 20 and 25. If there are more than 30, the workshop leader will require assistance.

All modules require participants to work in groups during some tasks. Thus the workshop leader should be prepared to form groups of four or five participants (six if really necessary, but never more than this). Generally mixing people of different backgrounds in groups is best, but this will depend on local circumstances.

The workshop materials

There are three kinds of materials:

- **Workshop leader's notes** and **background information**
- **Tasks** (for workshop participants – teachers or trainees)
- **Resources** (for use in undertaking the tasks)

For each module there is material of all three kinds, but whilst the workshop leader's notes and the tasks are specific to each module, some of the resources are used for tasks in different modules.

Each participant should have a copy of the tasks and resources, which are distributed at times as indicated in the workshop leader's notes.

Workshop leader's notes and background information

(i) It is essential that these are studied carefully before the module is used in a workshop and that the necessary preparation is done, including copying the required resources and tasks. (The workshop leader's notes include a copy of the tasks for the convenience of the workshop leader; copies for participants should be made from the separate sheets.)

(ii) The workshop leader's notes give detailed guidance on:

- the organisation of the tasks
- the way in which participants report the outcome of the tasks
- points to emphasis in the plenary discussion after each task has been completed.

(iii) The background information must be read by the workshop leader beforehand as it will be necessary to bring in certain points from it during the discussion. However it is advisable not to provide copies of the background information to participants before they have worked through the module. It may be helpful to copy parts, or all of it, for consolidation of learning after the module has been completed, but this is for the workshop leader to decide.

There are various ways of helping the participants to have access to the background information which depend on the format of the course. For example:

- If the course runs for several ways, then sections of the background information could be given for reading overnight either for consolidation or for preparation. The next morning might begin with a discussion of points for clarification or elaboration.
- If the course is a series of weekly meetings the whole of the background information could be given for extended study after the module has been completed. However reading or discussion of it should not replace the activities on the tasks and the generation of ideas by the participants themselves.
- In certain circumstances the workshop leader may convey the essence of the information in discussion rather than in the written version, or may create notes with a few main points for the participants.

The tasks

The tasks are the heart of the workshop materials. Do not omit them, thinking that time can be saved by telling the participants about the likely outcome. This would be to waste time, not save it.

The indicated time for each task is an estimate of what is likely to be required and in most cases it will be the minimum. It is for the workshop leader to judge when more or less time is preferable. The value of the tasks is in sharing ideas within a small group and with the whole group of participants. The workshop leader should therefore always ensure that this collaboration takes place, by observing the groups and joining in as necessary, to explain how to engage with the task.

The resources

The workshop is essentially an active and interactive experience for participants – active mentally and interactive with other participants, with the workshop leader and the resources. The resources serve the purpose of ensuring that ideas are developed through thinking and discussing concrete examples. Note that:

- The examples and case studies chosen for the some of the resources have been gathered from different countries and so cannot reflect the context for everyone; some will inevitably seem strange.
- Where this may detract from the usefulness of a task the workshop leader should substitute a local example which has the same form as the one provided. For example:
  - for Resource 1, an account of classroom activities in which children's ideas were first identified and then investigated. The account should include the actual work of some children.
  - for Resource 8, children's drawings which show how they understand certain things to work and which have been annotated to explain the drawing, should be included.

Glossary

Assessment is a process in which information is gathered about a child's performance and some judgement is made about the extent of the child's achievement.

Criteria are statements of some standard in achievement which are used as the basis of comparison for judging information gathered.

Criterion-referenced assessment indicates how a pupil's performance matches criteria describing a particular understanding, ability or other achievement.

Formative, or ongoing assessment, is assessment aimed at helping the teaching and learning process; it takes place regularly and is used for making decisions about ongoing work.

Diagnostic assessment is formative assessment which has a sharp focus on a particular aspect of learning and may use specially designed tests to explore a particular difficulty. When it is not concerned with special difficulties it can be regarded as the same as formative assessment.

Evaluation is a term that can be used whenever a value judgement is made about something. As in assessment, information is compared with some criterion or standard and judged against it. The two words can be (and are sometimes) used interchangeably, but practice which avoids confusion is to use the term assessment in relation to pupils' achievements and evaluation in relation to other matters such as books, curriculum materials, teaching and administration.

Monitoring means that repeated assessment of the same kind takes place to find out whether changes are taking place. Since the interest is not usually in individual pupils, a random sample can be used to represent the population being monitored.

Pupil-referenced (ipsative) assessment judges a pupil's performance against the same pupil's previous achievement. It indicates improvement or decline for the particular pupil, regardless of achievement against more general standards.

Reliability is the term used to express the degree of accuracy of the result of assessment ie, if the assessment were to be repeated, the extent to which the second result would agree with the first.

Summative assessment is assessment which summarises where a child has reached at a certain time. This information may be gathered through a test or examination or through summarising records of ongoing assessment.

Tests are specially devised activities, designed to assess knowledge and/or skills by giving precisely the same task to pupils who have to respond to it under similar conditions as envisaged by those who devised and trialled the test.

Validity refers to the extent to which what is assessed really reflects the behaviour it was intended to assess. For example, a multiple-choice test of knowledge about materials that conduct electricity would not give a valid assessment of understanding of a simple electric circuit, although it would be an assessment of quite high reliability.

Useful further reading

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Assessment: principles and approaches

WORKSHOP LEADER'S NOTES

Aims

This is an introductory module which aims to introduce participants to the whole course and then to share preconceptions about assessment as a basis for developing a wider understanding of the nature and roles of assessment.

Objectives

1. Understanding of the meaning of assessment in various learning contexts.
2. Knowledge of the various purposes of assessment.
3. Awareness of the range of information and ways of collecting it that are useful for assessment in various contexts.
4. Understanding of the concepts of reliability and validity.
5. Recognition of various issues, such as gender bias, in assessment.

Introduction to the course

- Give the participants an overview of the topics that will be covered in the modules selected for their course. Use the notes on page 2 for this purpose.
- Tell them that the way they will work is through workshop activities, which means that they will be undertaking tasks, mostly in groups, and discussing ideas about assessment through studying examples. There will be no lecturing; they will have access to background information at various points which they may read between sessions.
- As part of each workshop task there is some kind of reporting to others, and groups will be asked to bring their ideas together in a form that can be shared with others.

Note: The background information is for the workshop leader to read thoroughly before the module and to use in the discussion. Do not copy it for participants until they have completed the complete module. Then it may be useful for them to read sections or the whole to consolidate the points that have been made.

Introduction to Module A

- Indicate to participants the aims of the module, emphasising that it is introductory and that many of the aspects of the subject introduced can be studied in more depth in other modules later.
- Active involvement of the participants is important from the start, so keep the introductory remarks brief.

Task A1

This task provides an opportunity for participants to discuss basic points about the meaning and methods of assessment. It is important for every participant to consider his/her own ideas and to listen to others' ideas.

Organisation: Participants in groups of about five. Whilst they are working, walk round the groups and check for any misunderstanding of the task (for example if there is a query about kinds of information, give an example such as about the children's observation, use of measurements, co-operation, etc.). Make sure that there is discussion in the groups and that someone is making a record of points to report.

Materials needed: Task A1, Resource No 1.

Time: Allow at least 30 minutes for the task and 30 minutes for plenary feedback.

Instructions: Tell the participants to:

- Read the resource and the task.
- Make a list of aspects of the children's scientific development the teacher could gain information about in this sequence of events.
- For each one, note how the information would have been gained by the teacher.
- Ask themselves whether in their view these aspects were being assessed by the teacher.
- What else would the teacher need to do to assess these aspects?

Task A1

Read the account in Resource 1 of how an investigation about heartbeat rates was planned and undertaken by pupils in the fifth year of primary school. Then, working as a group:

(i) List all the kinds of information relevant to the children's scientific development that the teacher gained in the events described. (It may help to focus on one child, the one called J.)
(ii) Indicate how you think these kinds of information were gathered by the teacher.
(iii) What aspects of development were assessed in these activities?
(iv) What else would the teacher need to do to assess the children's achievements?

In each case note points about which there is disagreement as well as agreement within the groups. Prepare to report on your answers and discussion to other groups.

Plenary discussion

Ask one group's spokesperson to report on sub-task (i). Then ask other groups to add or to challenge what this group has reported, but not to report in full.

Discuss the list in terms of the evidence for the information which is claimed. If you disagree with an item ask, 'which particular event would give that kind of information?'

Then ask another group to report their response to sub-task (ii) and collect additional or differing responses from other groups.

Repeat this procedure for sub-tasks (iii) and (iv) introducing some of the following points at appropriate times.

Points to emphasise

Opportunities to underline these points are likely to arise during the feedback and discussion, but if not the leader should introduce them.

- Assessment is a broad term which is used to cover judgements about performance made both in informal classroom contexts and in more formal, test situations. (See background information for meanings of assessment).
- Some participants may only recognise as 'assessment' the more formal setting of questions at the end of the investigation. Ask them why. Is it because these concern the knowledge of the children rather than their investigation skills? Is it because asking for written answers is more formal than observing and listening to children? What other reasons?
- Gathering information, of itself, is not enough for assessment. Assessment is not just a description of what children can do but implies some judgement of it. All kinds of information are helpful for assessment, but assessment is more than information.

- Assessment means making a judgement as in: 'how well is this child doing in this aspect of development?' To make the judgement, the information has to be compared with something – 'how well . . . .' in relation to what? It could be:
  - how well compared with a specified type of performance (this is called criterion-referenced assessment) or
  - 'how well' compared with what that particular pupil could do at an earlier time (this is called pupil-referenced assessment) or
  - 'how well' compared with what is normal for pupils of the same age or stage to be able to do (this is called norm-referenced assessment).
- To summarise: all assessments involve some basis for judgement, thus:

  Information + basis for judgement —> assessment
- Use examples from the background information to underline the importance of using an appropriate basis for judgement. However, the next task takes up this matter in a specific context.

Task A2

This task provides an opportunity for further reflection on the meaning and of assessment and on the bases for judgement which might be used in particular instances. The task is open and there is no 'correct' answer since much will depend on the context and on the purpose for which the teacher was carrying out the assessment.

Organisation: Participants in groups of about five.

Materials needed: Task A2; Resource 2.

Time: Allow at least 20 minutes for the task and 20 minutes for plenary feedback.

Instructions: Tell the participants to:
- List the information as quickly as possible (this is similar to what was done in Task A1 and is just a necessary step for getting to sub-task (ii).
- Consider the pros and cons or each basis for judging the information that is gathered. (Ensure that the meaning for pupil-referenced, norm-referenced and criterion-referenced are understood.)

Task A2

Resource 2 is an account of an activity deliberately devised to provide opportunities for assessing pupils' work in science. Put yourself in the position of the teacher and, with your group, answer these questions:

(i) What kinds of information would the teacher be able to collect about the pupils?

(ii) What basis for assessing their performance would be the most appropriate? Consider each of these:

Pupil-referenced – comparing the information with what that particular pupil could do at an earlier time

Criterion-referenced – comparing the information with a specified standard of performance

Norm-referenced – comparing with what is the norm (or average) for pupils of the same age or stage.

Plenary discussion

For sub-task (i) collect responses by writing them on a board or large sheet of paper, taking one item from each group in turn and asking them not to repeat what others have said, until all the responses have been collected.

Sub-task (ii), collect 'votes' for each of the three possibilities – pupil-referenced, criterion-reference, norm-referenced. Ask those choosing each one to justify their choice.

Points to emphasise

- Clearly, the teacher who devised the task intended to assess things which it was not easy to assess in other ways, as well as to make the whole process fun for the children. Thus it is important to include items such as *questioning, curiosity, ability to communicate information orally*, in the list.

- There is no 'right' answer to (ii), since the basis for judgement will depend on what *purpose* the teacher had in mind for the assessment:
  - If the teacher was looking for progress made by each pupil, then pupil-referencing would have been appropriate.
  - If the teacher wanted to see what the children could do, using a standard which was the same for all the children, then it would be preferable for this to be based on the criteria of performance, ie the assessment would be criterion-referenced; it could hardly be based on a norm.
    - There is no place for norm-referenced assessment in teachers' assessment of the kind described in this example. Norm-referencing can only be used where a large number of pupils have been given the same task so that an average performance has been identified.

- The discussion of using criteria raises the question of 'which criteria?' Module B aims to introduce and give practice in using some criteria, so discussion of this point should be delayed. For the moment there is the important matter of the reliability and validity to consider.

Task A3

This task is a quick one to do, but leads to discussion of important matters relating to reliability, validity and gender bias.

Organisation: Participants in groups of about five.

Materials needed: Task A3, Resource 3.

Time: Allow 10 minutes for individual work, 15 minutes for sharing in the groups and 20 minutes for the plenary discussion.

Instructions: Tell the participants to:
- Answer the questions (i) to (v) individually and quickly.
- Share answers in the group and note points of agreement and disagreement, reasons.
- Be prepared to report the group's answers.

Task A3

Read the three tasks, A, B, and C in Resource 3 which assess in different ways children's ability to investigate.
Then answer these questions and give a reason for your answer in each case.
Do this individually and then share your views with the group.

(i) Which task (A, B or C) do you think is the closest to assessing how well the children can investigate something?
(ii) Which one gives a result that would be most likely to be judged in the same way by different teachers?
(iii) Which is the most interesting from the point of view of the children?
(iv) Which is the most convenient for the teacher?
(v) Which task would be best for finding out what the children would do to investigate, even if the teacher can't let them do it?

Don't forget to give the reason for your choice!

Plenary discussion

Ask one group for its response to question (i). Note any disagreement from other groups. Ask another group for its response to question (ii) and so on. Introduce the following points during the discussion.

Points to emphasise

- In relation to the reasons given in answer to (i), introduce the idea of *validity*. This word is used to describe the extent to which what the children were asked to do, really gives them the opportunity to show the skills or idea, or whatever was being assessed (see background information). So, Task A asks the children to *recognise and select* what would be the best test for bendiness, but they do not produce the ideas themselves. Task B asks them to plan, but not carry out the investigation, so it assesses planning only rather than ability to investigate. Task C enables the children to show how they would investigate and so would be the most valid assessment in this case.
- Discussion of the answers to question (ii) provides an opportunity to introduce the word and concept of *reliability*. Reliability relates to the accuracy of the assessment and means how closely the result of the assessment would be the same if the assessment were repeated. In the case of the assessment tasks in Resource No 3 it means the extent to which different teachers would make the same judgement of the pupils' answers. Since the 'correctness' of the answer can be unambiguously judged in Task A this has the highest reliability. Task B might be next, since all the information is written down. Assessment of Task C would depend on observing actions as well as reading what has been written.
- Note that reliability and validity *don't* go together. There usually has to be a trade-off of one against the other. What this is will depend on the purpose of the assessment. For assessment which is intended to be diagnostic and help teaching and learning, validity is paramount and reliability of less importance. But if the assessment is to be used for selection or comparison of children, then reliability is important and has to be increased as far as possible without infringing validity too much. (There is more about this in the background information for Module E).
- In discussing answers to question (iii), note that interest is not a trivial matter. If a task is enjoyable to the children this means that their attention and effort are likely to be engaged and so this adds to validity. When the attractiveness is different for groups of children, such as boys and girls, the result may be biased in favour of one group. The subject matter of the task is thus important, even if direct knowledge of it is not required. For example, if the activity about camouflage in Resource 2 had been about camouflage

of soldiers in war rather than about animals it might be less interesting to girls than to boys (see background information).

- In the discussion of question (iv) note that good multiple-choice questions are not easy to write, although they may seem most convenient to use. Example A is not a good question since there is more than one right answer. (The pros and cons of multiple choice questions are taken up in background information for Module F).
- In discussing question (v) note that it is not always possible to use practical items, even if this is preferred and thought to be the most valid. The important point is not to interpret the result as if it were the result of practical activity when it is not. Points from the section of background information on *interpreting results of assessment* can be brought in here.

Background information

Meanings of assessment

It is generally agreed that assessment in the context of children's achievements in school is a process of making judgements about the extent of these achievements. The judgements are reached on the basis of information which has been gathered about performance and which is compared with some kind of expectation. The various ways in which information is collected and the various bases for judging it, create the variety of different kinds of assessment. These include, at one extreme, standardised tests, where information is gathered whilst children are tackling carefully devised tests under controlled conditions and, in contrast, ongoing assessment, carried out almost imperceptibly during normal interchange between teacher and pupils.

The major distinction within assessment methods is between tests (and examinations) and other forms of assessment. Indeed some use of the term 'assessment' excludes tests and means only various forms of informal assessment usually devised by, and always conducted by, the teacher. Tests are specially devised activities designed to assess knowledge and/or skills by giving precisely the same task to pupils, who have to respond to it under similar conditions as envisaged by those who devised and trialled the test. However the distinction between tests and non-test assessment is not always not very clear. Some 'tests' can be absorbed into classroom work and look very much like normal classroom work as far as the children are concerned and so they cannot always be regarded as formal. To be more useful, the distinction should go beyond methods to include purposes. The main purpose of tests is to check up what children have achieved, although in some cases they also serve a purpose of feedback to help learning.

Evaluation and assessment

The terms 'evaluation' and 'assessment' are used differently in different countries. In some cases both are used interchangeably in relation to pupils' achievements. However, in other cases the word 'assessment' is used in the context of making judgements about pupils' achievements, and 'evaluation' when making judgements about other things, such as the curriculum, teaching materials and methods. In these materials we follow the latter convention and talk about assessment of pupils, rather than evaluation.

Purposes of assessment

The range of purposes of assessment of can be organised under headings such as the following:

- formative, or ongoing, to help teaching and learning
- summative or summary, to indicate achievment at a certain point
- selection or certification
- school evaluation
- national monitoring

Assessment in each of these categories requires information which fits its purpose. The full list is given for completeness, although our main concern is only with the first two.

Formative assessment is aimed at helping the teaching and learning process; information gathered regularly is used for making decisions during ongoing work. It assists teachers in adjusting the challenges given to children to match their existing ideas and skills, to help rather than to grade children. It is usually informal in that the child is not aware that it is taking place.

The term **diagnostic assessment** is sometimes used as if this were different from formative assessment. Diagnostic assessment has a more specific focus, being concerned with

examining in depth a particular area of performance. But this is only a slight variant of formative assessment and can be considered part of it.

Summative assessment, as the name suggests, means a summary judgement or a summing up of where a child has reached at a certain time. Quite often the information is obtained by a test (or examination) at the end of a term, year, or of a certain section of work. But it is also possible to give a summative assessment as a result of reviewing records of ongoing assessment, as teachers frequently do in reporting to parents, either orally or in writing, at the end of a year.

Methods

Ways of collecting information about children's achievement of ideas, skills and attitudes can be categorised in terms of what the children are doing when the information is collected and how the information is collected.

The children may be engaged in:
- normal work (including both written and practical work)
- special practical tasks (including tests)
- special written tasks (including tests)
- self-assessment

and the teacher may be:
- observing, but not interacting with, the children (including watching and listening)
- interacting with children (as well as watching and listening)
- using a check-list
- marking tests
- reading or marking class work
- gathering general impressions.

Common combinations of items from these lists describe identifiable 'methods' of assessment such as tests, continuous assessment and ratings, but there is clearly a range of other possibilities. Some methods are more suited than others to collecting information about achievement in particular subject areas and so here we focus on methods particularly appropriate for performance in science and technology.

Basis of judgement

This refers to the reference point used in judging information. It may be illustrated in terms of an example (from Harlen, 1996):

> Suppose, as a hypothetical example that a teacher wants to assess a child's ability in 'knocking nails into wood'.
>
> The teacher may have some expectation of the level of performance (knocking the nail in straight, using the hammer correctly, taking necessary safety precautions) and judge the child's performance in relation to these. The judgement is made in terms of the extent to which the child's performance meets the criteria; that is, it is *criterion-referenced*.
>
> Alternatively the teacher may judge in terms of how the child performs at knocking in nails compared with other children of the same age and stage. If this is the case there will be a norm or average performance known for the age/stage group and any child can be described in relation to this as average, above average or below average, or more precisely identified if some quantitative measure has been obtained. (The result could be expressed as a 'knocking nails age' or a 'hammer manipulation' quotient!) The judgement arrived at in this way is called a *norm-referenced* assessment.

A third possibility is that the teacher compares the child's present performance with what the same child could do on a previous occasion – in which case the assessment is *pupil-referenced* (or ipsative).

It is important to recognise these different bases for judgements in assessment and apply them appropriately. They each have their value in the right context, but each have drawbacks outside these contexts. Pupil-referenced assessment is appropriate for formative assessment, for providing encouraging feedback to pupils, particularly slower ones who, if compared with criteria or with others' performance would always be seeming to fail, but can recognise progress in terms of their own previous performance. But it must be realised that it leads to one child being praised for work which, from another child, might be received with less approval. This is no problem as long as no comparisons are made between children, but where comparisons are being made, or performance in terms of external standards has to be reported, then one of the other bases for judgements must be used.

Interpreting results of assessment

Results of assessment have to be interpreted in the knowledge of the kind of information gathered and the basis of the judgement made. There is always some implied generalisation of the result, for we assess only a sample of behaviour and act on it as if it applied to more than this sample. Indeed unless we are assessing simple recall of facts, we have the expectation that the result will tell us more than just about the particular performance assessed. However, it is important not to generalise beyond what is justified by the information. But how is this limit to be identified? The problem can be put in this way: if a child has shown evidence, either in a test situation or in regular work, of using patterns in findings to make predictions, to what extent does this mean that (s)he is able to do this on all other occasions where it is possible?

It is known from research evidence that context influences performance, but to an unknown extent. Assessment results must therefore be interpreted cautiously, as guides to what children can do, but not as indicating any kind of certainty about it. No assessment can be used predictively with certainty; it is best treated as a hypothesis, a tentative finding, to be modified by further evidence of the child's performance.

Cautious interpretation should avoid labelling children, which results from over-generalisation of assessment results. When an assessment is interpreted as if it describes the whole child and not just certain performance this can affect teachers', parents' and the child's view of what (s)he is able to do, often needlessly limiting expectations.

Bias relating to gender

An important consequence of the influence on performance of the context and the subject matter is that it can disadvantage certain groups of children. Some children may be less motivated than others by the subject they are asked to think about. Some may anticipate failure in certain activities because of their self-image and so make failure more likely. The poor performance of girls, in some activities involving ideas of physics, can be explained to an extent by the context and topics relating more to boys' interests and triggering the reaction in girls 'I can't do this' before they even try.

There is also evidence that, in tests and examinations, boys perform better on multiple-choice questions than on ones where an open response must be written and that for girls the reverse is the case. Girls have also been rated as less willing to undertake investigations and so may achieve less well in a practical context than boys, particularly if they have, in class, been used to taking a passive role in science and technology activities.

Reliability and validity

There are two concepts in assessment which describe how dependable an assessment is. These are its reliability and its validity.

Reliability is the term used to express the degree of accuracy of the result of assessment ie, if the assessment were to be repeated, the extent to which the second result would agree with the first. The reliability of assessment of a child's skill in writing is likely to be less than the reliability of a test of addition and subtraction sums, mainly because it is far easier to mark the latter consistently.

Validity refers to the extent to which what is assessed really reflects the behaviour it was intended to assess. For example, a multiple-choice test of knowledge about materials that conduct electricity would not give a valid assessment of understanding of a simple electric circuit, although it would be an assessment of quite high reliability.

The highest possible level of reliability and validity is always the aim, but since neither can be 100% and since the requirements of one sometimes conflict with those of the other, a compromise has to be accepted. The requirements in terms of relative emphasis on detail, and on reliability and validity will vary with the purpose of the assessment. For example, for formative, ongoing, assessment, it is more important that the result has a high validity, indicating what the child is and is not yet able to do. For the purposes of selection, or wherever children are compared one with another, it is important that the assessment is reliable, whilst at the same time being valid in terms of the abilities being assessed.

Assessment and learning

WORKSHOP LEADER'S NOTES

Aims

The activities in this module aim to provide an opportunity for discussion of the role of assessment as part of teaching, and of how planning and the identification of criteria assist in using assessment to help teaching. The involvement of children in their own assessment is also discussed.

Objectives

1. Understanding the value of assessment at part of teaching.
2. Recognition that it is necessary to plan how to assess ongoing work just as much as it is necessary to plan learning activities.
3. Awareness that having criteria in mind for assessment enables information to be gathered and used more efficiently in assessment.
4. Knowledge of ways of involving children in the assessment of their work.

Task B1

This task illustrates the importance of ongoing assessment to reveal a child's thinking and guide teaching.

Organisation: Participants in pairs.

Materials needed: Task B1

Time: Allow at least 20 minutes for the task. After 10 minutes encourage pairs to move on to part (ii) and 20 minutes for plenary feedback

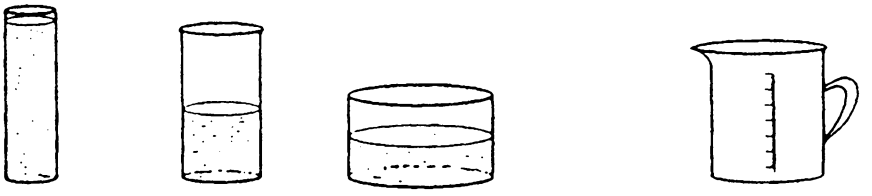
Instructions: Go through the task and tell the participants :

- After reading the episode, imagine that the assessment had ended when the answers were marked and compare that with what happened.
- In part (ii) identify precisely how the extra information gained by questioning the child could be used in teaching.

Task B1

First read this episode

An 8-year-old child was given three containers, A, B, and C, as shown and a measuring jug. The child was asked to label them 1, 2 and 3 according to the amount of water in them, giving 1 to the one containing the most and 3 to that containing the least.



A B C Measuring jug

The child's answer was: A = 1, B = 2, C = 3.
The teacher marked A = 1 as correct but the other answers as wrong.

The teacher was puzzled that only the first answer was correct.

She asked the child: "Why do you think all your answers are correct?"
The child replied: "Because I did the same for all of them, I looked at the height of the water level in each one and numbered them."

(i) Suppose the teacher had not questioned the child to find out why only one answer was correct, what could have been the consequences for the child's immediate learning?
(ii) If you were the teacher in this situation how would you react to the child? Work with a partner and take turns to role-play the child and the teacher. Write down what you think is the best way of reacting to the child.

Plenary discussion

Begin plenary feedback by asking one pair what they saw as the main 'moral' from this tale. Collect responses from others if they have different points to make.

For sub-task (ii) ask another pair to report. Insist on a statement of what the teacher would actually do or say rather than a general indication. Collect alternatives from other pairs. (**Note:** there is more about using assessment information to help learning in Module D).

Points to emphasise

- It is not enough for the assessment to be concerned with the product of work, this will not necessarily reveal the child's thinking.
- The teacher is in a much better position to help children's learning when appropriate formative assessment is used. (Refer to background information for Module A to reinforce the meaning of formative assessment.)
- Asking children to explain their reasoning orally is as much assessment as is asking for written answers.
- This kind of assessment does not come at the end of teaching, just to check on what has been learned, but guides the teaching and is part of it.

Task B2

This task draws attention to the value of having some criteria in mind expressed in terms of what children will be doing when they are using various process skills or displaying attitudes or ideas. It asks participants to consider, before referrng to examples of criteria, what could be assessed in certain situations and then to do the same with criteria in mind. Thus it is important that the criteria (Resource 5) are not distributed before part (i) has been completed.

Organisation: Participants in groups of four to six.

Materials needed: Task B1 and Resource 4. Resource 5 to be distributed after completion of part (i). Sheets of flip chart paper and felt-tip pens.

Time: At least 75 minutes in all. Allow about 20 minutes for part (i) of the task, 10 minutes for reading Resource 5, then another 25 minutes for part (ii), with 20 minutes for plenary feedback.

Instructions: Introduce the task and tell the participants:

- For part (i), read the four episodes in Resource 4 and brainstorm the information that the teacher could obtain by assessing in the ways indicated. Complete the table indicated on a large sheet of paper. Put this on display before starting part (ii).
- Then (and only then) read Resource 5.
- Use the criteria to list the process skills, ideas and attitudes that might be assessed in each episode. Use the reference numbers in Resource 5 for the process skills and attitudes. Present findings in the form of a large chart.

Task B2

(i) For each episode in Resource 4, write down what the teacher would be able to assess using the information (s)he could collect in these situations. Brainstorm the ideas in your group onto a chart like this:

Situation	Information obtainable
A	
B	
C	
D	

(ii) Now consider the examples of criteria for assessing skills, attitudes and concepts of primary children in Resource 5. List the criteria that might be used for assessing in these situations. Complete a chart of this kind:

	Process skills	Ideas	Attitudes
A			
B			
C			
D			

Plenary discussion

Display the charts and allow a few minutes for reading. Look across the displayed answers to part (i). Where it is not obvious, ask the group to explain how certain information could be obtained.

Do the same for answers to part (ii). Compare responses to the two parts. It is likely that there is more detail in answers to part (ii). Ask participants why they think this is.

Points to emphasise

- In all four situations there is a great range of information to be gathered, especially about skills and attitudes.
- Each situation provides opportunities for only a few ideas to be assessed, but they all provide an opportunity for a number of skills and attitudes to be assessed.
- Teachers can use many ways of collecting the information. (Details of these are taken up in Module C).
- Reading the criteria helps in recognising the range of information that could be collected.
- The value of having criteria in mind is felt before making an assessment, not just afterwards in making judgements.
- In practice, to be useful, criteria have to be carried on the head, not written down as a list on paper. There are other practical matters relating to this ongoing assessment that have to be considered. This links to Task B3.

Task B3

At first it seems quite impossible to collect information at the level of detail suggested for all pupils in a class. This task is concerned with matters relating to the practicalities of assessing during teaching.

Finding solutions to these problems requires a further look at what is being assessed. A key points is that in an active science programme, process skills will be used frequently and there will be several opportunities for their assessment. On the other hand, concepts are tied to the particular subject matter in each activity and have to assessed when this is being considered.

Organisation: Participants in groups of four to six.

Materials needed: Task B3.

Time: Allow at least 30 minutes in total for the three parts of task.

Instructions: Tell participants to:

- Work out specific questions for part (i).
- In parts (ii) and (iii) suggest one or two alternatives, indicating whether or not the ideas are based on practice.

Task B3

First read this episode

One week before a test, 7-year-old children are asked to observe a living spider closely and told that the test will be such that they can answer it well if they have observed the spider well. The children will answer orally or on paper (as a picture or using words).

Working as a group:

(i) Write five questions to assess how well the children have observed the spider.

(ii) Imagine you are the teacher. How will you arrange for the assessment to take place? How will you plan the session when the children are giving their answers so that each one can be assessed?

(iii) Suppose the teacher wants to assess children whilst they are investigating some materials. How could (s)he do this with at least eight groups of children?

Plenary discussion

For reporting sub-task (i), proceed as follows:

- pretend you are the child and ask one group to ask you the five questions they have prepared
- answer the questions as well as you can, noticing whether the answer really depended on having observed a spider or not
- after responding to all the questions, discuss any questions that you thought did not depend on observation
- ask other groups to review their questions in the light of the points made.

For part (ii) collect responses from two groups and then ask for any additional points or comments on what has been said. Remembering that the children are aged 7, it is likely that a child's drawings needs to be discussed with him or her. A possible approach is to ask all the children to make drawings at the same time and then, at a later time, to discuss each drawing with the child and to ask probing questions. Older children might help in an assessment of this kind (see Task B4).

For part (iii) collect responses from two different groups and ask for comments from others. Assumptions have to be made about the situation; some suggestions might be feasible in certain circumstances and not in others. Keep the discussion to general strategies. Particular difficulties have to be accommodated in applying the strategies.

Points to emphasise

- When questioning children, it's important to have in mind what you want to assess and to make sure that the questions do require them to use or have used the particular skill or idea.
- The key to solving the practical problems is planning what to assess at the same time as planning the lesson.
- It's useful to think in terms of priorities for the limited amount of 'on the spot' assessment that a teacher can do with a large class. Observation of practical skills has to be done in this way, but fortunately not for all the children at once. There should be several opportunities for this if the children are often involved in practical investigations. Thus the assessment can be spread over several lessons, with focus on one group at a time, as suggested in the background information.
- For assessing ideas, it is usually possible to use a combination of questioning during discussion of their work and setting some written tasks that are designed to reveal their ideas and which can be answered by writing or drawing. (There is more about this in Module C.)
- The children can often help. This bring us to the next task.

Task B4

Involving children in assessing their own work has many advantages for their learning. To obtain the benefits, however, the involvement has to go beyond having children mark their own or each other's answers right or wrong. Taking part in assessment can be a means of positive and helpful feedback to the children, enabling them to understand the learning objectives. All of this requires planning and takes time. This task helps teachers to decide the benefits of spending time in this way.

Organisation: Participants in groups of four to six.

Materials needed: Task B4 (also B3 if not already available) flip chart paper and pens.

Time: Allow at least 30 minutes in total for the three parts of the task.

Instructions: Introduce the task by telling participants :

- For part (i) consider what is desirable and not just what is current practice.
- Part (ii) will mean thinking about real situations.
- For part (iii) consider the circumstances where there are advantages and disadvantages.
- In part (iv) gather ideas are based on practice.

Task B4

(i) In the episode in B3 in what ways might the children take part in assessing their own work and/or each other's work? How might your answer differ if the children were 10 years old instead of 7?
(ii) How would practice have to be modified in very large classes?
(iii) What advantages and disadvantages do you see in children taking part in assessment?
(iv) What examples of children taking a role in their assessment can you give?

Plenary discussion

Ask one group to give responses to (i) and list these on a flip chart. Ask other groups to give ideas which add to the list. For (ii) list advantages and disadvantages on a flip chart, taking points from each group. For (iii) the examples should be taken from practice; avoid going over possibilities gathered in (i).

Points to emphasise

- Involving pupils in assessment provides them with feedback on their achievements, but the more important aim is to enable them to understand the objectives of their learning. Unless this happens, the process becomes mechanical and will not help to motivate learning.
- Avoid children being involved in giving themselves marks and comparing them with others.
- Pupil self-assessment is helped by teachers explaining what sorts of things they are looking for in children's wok and discussing the assessment of it in these terms.
- Children should be given an opportunity to comment on their work, that is, to say what they like and don't like about it and how they might improve it.

Background information

Assessment as an integral part of teaching and learning

There are three important points:

- Opportunities for children to develop and use their ideas and skills and for positive attitudes to be fostered should arise frequently in children's activities. Thus these same activities provide opportunities for assessment of the ideas, skills and attitudes.
- Teachers need to know where children are in their development in order to provide activities which are to help their progress and not be too far out of their reach, nor too easy and so boring.
- It is important to keep in mind that the purpose of ongoing assessment is to gather information which can be used to help learning *at the time*, and which can contribute to a record of performance which will inform longer term planning. Gathering information to be used in teaching is the aim to emphasise, since if it is carried out thoroughly, the creation of a record is a straightforward matter (see Module E). However, the reverse is not true: the collection of information for a record does not necessarily mean that it helps teaching and learning.

Seen in this way, good teaching *requires* assessment to be part of it, and not added on as an after thought. Thus planning for assessment becomes part of planning for teaching.

Planning assessment as part of teaching

Gathering information when the appropriate opportunity is there – and thus avoiding having to set up special tasks – means planning the assessment as part of the lesson planning. The plan should take account of the frequency of opportunities for assessing different aspects and the potential for using the information.

Opportunities (should) arise frequently for children to use process skills. Most science activities should involve children in thinking and doing and thus provide the teacher with opportunities to assess the children's process skills. All activities should involve children in thinking and using most of the process skills. If this is so then it means that it is not necessary to assess all children at a particular time. It is better to observe a small number of children thoroughly throughout an activity so as to achieve a detailed picture of their skills than to attempt to cover a larger number more superficially.

It may take two or three months to complete the observation of all the children in the class, and it will mean that different children are assessed when carrying out different activities. This is not a problem in the context of ongoing assessment for two main reasons.

- Since no comparison is being made between children then, providing the activities give an opportunity for the skills to be used, one activity context is as good as another. (If the purpose were to assign a grade or label to the children then the variation in content of the activities would be a source of error in the results, but when observations can be repeated and the purpose is to help the children's learning, it is not a problem.)
- The skills we are concerned with are ones which are assumed to be generally applicable and so, again, it is the case that one context is as valid as another, given that they provide similar opportunity for skills to be used. This is not to deny the context-dependence of the use of skills, however, and with this in mind it should be emphasised that no one activity alone is sufficient to give a reliable assessment. Observations should be made during various activities over a period of time.

When it comes to assessing children's ideas, the opportunities are far less frequent. Ideas are

linked to the subject matter and particular ideas will tend to be expressed in activities relating to the appropriate subject matter. Thus the opportunities to assess ideas have to be taken when they occur. This means assessing as many pupils as are working on that subject matter at any one time. Fortunately it is far more feasible to use the products of children's work for assessing ideas than it is for assessing process skills. Children's reports, other writing and drawing and other products can be collected and studied after the event. This is not to deny the importance of the context, which should be noted, and the added value that comes if the work can be discussed with the pupils.
Note: The study of specific methods of assessing skills and ideas is the subject of Module C and is not pursued further here.

Involving children in assessing their work

Involving children in their assessment means that they must know what are the aims of their learning. Communicating these aims for science is not easy, but the rewards of successfully attempting it are quite considerable, not only for help in assessment, but the potential for self-direction in learning. Direct communication of complex learning objectives and criteria of achievement is unlikely to be successful. For example, children may not be able to *define* what it means to draw a conclusion from evidence, but at the same time they will be able to do it, to draw conclusions from evidence in the course of their activities. Such things are understood by children through experience and examples.

Ability in self-assessment has to be developed slowly and in an accepting and supportive atmosphere. It takes time to work through several stages before children are able to apply to their work anything like the criteria which their teacher would apply. Teachers communicate what is valued and expected in their comments on children's work. Children pick these up and use them implicitly in judging and making comments on their own work. This being so, it is important to ensure that such comments reflect what is of real value to children's learning.

There are two main strategies which can be used in combination to work towards more explicit discussion of criteria for judging work and using the results to improve achievement. They both take up some class time and this has to be justified in terms of the benefits.

1 Starting from the children's judgement of their work

The process can begin usefully if children from about the age of eight are encouraged to select their 'best' work and to put this in a folder or bag. Part of the time for 'bagging' should be set aside for the teacher to talk to each child about why certain pieces of work were selected. The criteria which the children are using will become clear. These should be accepted and they may have messages for the teacher. For example if work seems to be selected only on the basis of being 'tidy' and not in terms of content, then perhaps this aspect is being over-emphasised by the teacher.

At first the discussion should only be to clarify the criteria the children use. 'Tell me what you particularly liked about this piece of work?' Gradually it will be possible to suggest criteria without dictating what the children should be selecting. This can be done through comments on the work. 'That was a very good way of showing your results, I could see at a glance how quickly each plant grew', 'I'm glad you think that was your best investigation because although you didn't get the result you expected, you did it very carefully and made sure that the result was fair.'

Through such an approach as this children may begin to share an understanding of the objectives of their work, and will be able to comment usefully on what they have achieved. It then becomes easier to be explicit about further targets and for the children to recognise when they have achieved them. This then turns into the second strategy.

2 Starting from the teacher's objectives

This can start in a simple way as when a teacher might say, 'I will be looking for... in your work today'. Following on from this it may well be a good use of learning time to discuss different ways of going about a task to achieve what the teacher wants and what the children think would be the best way to tackle something and why. A class of 9-year-olds readily came up with the home truth (about a project on the planets) that 'if we just copy the book, we don't really understand it' and proposed that they should read first and then put down what they thought. The teacher added to this, 'Yes, then you will also be more careful to understand what you read in a book and that will help you whenever you use books to find information'.

It is not easy for anyone to stand back from specific learning to examine the *process* of learning itself and young children are not often able to do this, but a gentle move in this direction can help them realise the point of what they are doing. Teachers of older pupils can more explicitly share with them the criteria they use both in assessing practical skills and marking written work. One science teacher, for example, did this by writing his own account of a class investigation and distributing copies for the pupils to mark, looking for particular features. It led to lively discussion and a keener understanding of what was expected in their own accounts.

Benefits for the children's learning

Self-assessment, when children are judging their own work, gives them immediate feedback on what they have achieved. They do not have to wait for their teacher to tell them or for their work to be marked.

The communication of criteria for judging their work, by one strategy or another enables them to see what they should be aiming for, i.e. to realise implicitly or explicitly the learning objectives.

Information of this kind also helps in encouraging children to share responsibility for their learning. For this they have to be aware of what they are expected to achieve in their work.

Sharing responsibility for learning necessarily means that the teacher has to be aware of how the children feel about their work. Interest in children's feelings and views on their learning has to be sincere. Children are not taken in by the superficial interest of their teacher, for it will be betrayed by manner and tone of voice as well as by whether anything happens as a result. A genuine interest creates an atmosphere in which children's own ideas are encouraged and taken as a starting point, where effort is praised rather than only achievement, where value is attached to each child's endeavours. In this atmosphere, a child who does not achieve as well as others will not be ridiculed. The range of activities available makes allowances for differences in the ability of the children, and the teacher's interest and approach results in the involvement of children in their work and their own learning.

Methods of ongoing assessment by teachers

WORKSHOP LEADER'S NOTES

Aims

The activities of this module aim to promote discussion and understanding of methods which can be used by teachers to conduct ongoing, formative assessment of pupils, that is, to carry out assessment and to use the results as part of teaching. The interpretation and use of the results is the focus of Module D. In the present module the main methods for assessing skills and ideas are discussed.

Objectives

1. Identification of the advantages and disadvantages of using a checklist of criteria for observing pupils during practical work.
2. Recognition of the types of question that teachers can ask to assess pupils' ideas.
3. Consideration of how drawing and writing can be used for ongoing assessment.
4. Recognition of the value of collaborative group work and of the possibility of group assessment.

Task C1

This task considers observation as a means of gathering information for assessment. For science, observation has an important role in assessment, particularly for process skills. However it has disadvantages in practice and so should be used where no other way of assessing is as useful. In this task the use of observation is considered for assessing two aspects of scientific achievement – pupils' skill in *observing* and in *investigating*. The task also enables participants to consider the value of using a checklist (from Resource 5) to assist in the assessment.

Organisation: Participants working in groups of about five.

Materials needed: Task C1, Resources 5 and 6.

Time: Allow at least 20 minutes for participants to work in groups to produce agreed answers to the questions and then 30 minutes for a plenary discussion.

Instructions: Tell participants to:

- Imagine they were the teacher of the class described in Resource 6 and consider what information they could obtain by observing the children, using sections on *observing* and *investigating* from Resource 5.
- Consider whether using the criteria in Resource 5 as a checklist is of help in assessing by observation.
- Consider the advantages and disadvantages of using observation for assessing science, including the problems of very large classes.

Task C1

Working as a group, answer questions (i), (ii) and (iii) and be prepared to share your answers with other groups.

(i) Read the account in Resource 6. Imagine you are the teacher. By observing the children, what would you be able to find out in relation to the sections in Resource 5 on *observing* and *investigating*?
(ii) To what extent do you think the lists of criteria would help you, as the teacher, in assessing the children's process skills by observation?
(iii) What are the advantages and disadvantages of assessing children by observing them?

Plenary discussion

Ask one group to report answers to question (i) and others to add points not already made. Repeat with other groups for (ii) and (iii).

Points to emphasise

- The focus has been on two process skills only in order to reduce the burden in the task. However it is useful to note that information relevant to all the skills can be collected in the same way, although some can be assessed through pupils' records.
- Look at the attitudes in Resource 5. Note that it would be difficult to assess these except through observation and discussion with pupils.
- The main value of having the list of statements of what pupils do, as in the lists in Resource 5, is to give a focus to observation, to indicate what to look for. Without this, observation by the teacher will be less efficient. At the same time the lists should not blinker the teacher to other aspects of the children's behaviour.
- Among the disadvantages of using observation will be the time needed to use a checklist of criteria in practice. For this reason the checklist is best seen as a way of preparing oneself for what to look for and it should, with a little practice, become internalised as a mental checklist, not one on paper.
- When starting to use this as a method for assessing it is wise to select a few skills and attitudes only. When these have become routine, in the head rather than on paper, then others can be added.
- Observing is not just looking, but listening. It can be enhanced by asking certain kinds of questions so that what is heard reflects children and skills ideas. This takes us to the next task.

Task C2

The two parts of this task take up the subject of the kinds of questions that the teacher might ask pupils in the context of assessing to help learning. This means that interest is in what the pupils think, whether correct or not. Once this is known, then the teacher can take some action to help children develop their ideas. So questioning is an important aspect of assessment.

Organisation: Participants in pairs for part (i) and in groups of four to six for part (ii).

Materials needed: Task C2, Resource 7, a sealed matchbox with two small objects inside – one for each pair.

Time: Allow at least 30 minutes in total for the two parts of the task.

Instructions: Tell participants to:

- Work in pairs for part (i). Each person in turn is to handle the matchbox *without talking* and decide what might be inside. Then they each think up three questions which they will ask the other to try to find out what the other person *thinks* is inside.
- They ask each other their questions in turn and then discuss which questions were best for finding out the other's idea.
- In part (ii) consider the questions in Resource 7. Divide them into two groups : those you think more helpful for assessment as part of teaching and those less helpful for this purpose.

Task C2

(i) Divide into pairs. Each pair has a sealed matchbox. Neither of you knows what is inside the matchbox. Handle it and form your own ideas of what is inside *without saying anything*. The idea is to find out by questioning what the other person *thinks* is inside. Each person should devise three questions and then take turns to ask each other their questions. Then decide which question(s) were most productive in finding out the other's idea.

(ii) Work as a group with Resource 7. Read the examples of questions asked of pupils by teachers. Divide them into groups of different *kinds* of questions (ignoring the subject matter). Do this in any way you think makes distinctions between questions that are helpful for the purposes of ongoing assessment and those not so helpful. Be prepared to say what it is that makes some questions more useful for this purpose. Record your result using the numbers of the questions and write these on a large piece of paper.

Plenary discussion

Go straight into the feedback from sub-task (ii) since points arising from (i) will be included in the discussion. Ask each group to display their results using the numbers of the questions in Resource 7. Invite everyone to look for patterns across the lists. Where there are large difference, ask one group to explain the basis for their division of the questions.

Points to emphasise

- The purpose of asking questions in the context of ongoing assessment is to get an answer. Therefore there is no point in asking questions in such a way that children are unable to answer. Thus the form of the question is important as well as the content.
- If there has been a separation of questions into those which require more than a single correct answer and those which ask for one answer, introduce the distinction between *open* and *closed* questions. eg 6, 8 and 13 are closed whilst 5, 7 and 15 are open.
- Similarly, point out the difference between questions which ask for 'what the pupils think' and those which require them to know the right answer. For example, questions 2, 7, 9, ask for what the children's ideas are and can be answered whether or not the 'right' answer is known. These can be called 'person-centred' questions. Questions 5, 12, and 14, although open, cannot be answered unless you think you know the right answer. Children often give no answer when they feel that they have to give the right one and may not know it. (See background information.)
- It is important to ask open and person-centred questions to find out what children are thinking so that the teacher knows where they are in developing ideas. Thus the questions will be the most useful for assessment purposes.
- Sometimes children can draw things which they can't explain so well only in words. This leads to the next subject and task.

Task C3

Drawings can be a good way of enabling children to express their ideas, particularly if they are annotated and if possible discussed with the children. This task gives participants an opportunity to explore the use of drawing both in their own experience and through discussing children's drawings.

Organisation: Participants in pairs for part (i) and in groups of four to six for part (ii).

Materials needed: Task C3, for each group a clockwork toy or home-made elastic band cotton reel 'tank', Resource 8 to be distributed *after* sub-task (i) has been completed.

Time: Allow at least 30 minutes in total for the two parts of the task.

Instructions: Tell participants to:

- Work in pairs at the start. Watch the clockwork toy or 'tank' after it has been wound up and then, without discussing it with anyone, make a drawing which shows how you understand the way it works. Don't write any words on it.
- Exchange drawings with your partner and ask each other questions to help you to understand the other's ideas about the mechanism. Then annotate your drawings with labels to answer the questions you were asked.
- Show your drawing to another pair and look at theirs.
- For part (ii) look at the drawing in Resource 8 and, working as a group, answer the questions.

Task C3

(i) Wind up the toy or 'tank', set it moving and watch it for a short while. Then, working alone, make a drawing to show what is happening to make it move in the way it does. Don't label the drawing. Now exchange your drawing with that of your partner. Ask your partner questions to help you understand his/her drawing of how the toy is moving. Now let your partner question you about your drawing. Then add labels and annotation to your drawings that answer the questions you have been asked. As a pair, exchange your annotated drawings with another pair and see how well you can understand their drawings from the start after they have been annotated.

(ii) Look at the examples of children's drawings in Resource 8. What can you tell about the children's ideas from these drawings? Discuss how you would set up the tasks for these children so that they annotated their drawings to show their ideas.

Plenary discussion

There is no need for plenary feedback for part (i). For part (ii) collect the results from one group about what ideas are revealed in the drawings. Ask other groups to add anything. Then ask another group to say how they would set up the tasks so that the children annotated their drawings in a way which showed their ideas.

Points to emphasise

- The use of words enables the teacher to be clear about what the drawing means. In drawing 1 the child appears to see that a 'line' connects the cogs to each other. If this were not stated explicitly it might be difficult to interpret the line between the cogs as indicating the child's idea about how one cog makes another go round. In drawing 2 the

labels only give the names of the parts, whilst the description above indicates that the child has begun to develop ideas abut energy being used and used up in movement. Drawing 3 is another example of an added description revealing the child's ideas. The drawing itself indicates that the child is aware that vibrations pass along the string. But in the writing it becomes clear that the child considers the sound travelling as vibrations only along the string and being 'transferred back to a voice' in the yoghurt pot.

- The main point to note is that the drawing task needs to be set so that the child tries to explain what is happening and not just to represent what can be seen. For example, the child who drew the telephone may not have included the vibrations if (s)he had been asked just to 'draw the string telephone'. This drawing was made in response to the request: 'make a drawing to show how you think the sound gets from one end of the telephone to the other'. There is a small but important difference between these requests.
- The points made about questioning in Task C2 are also relevant to setting drawing tasks. It should be made clear to the child that the teacher wants to know what the child thinks is happening.

Task C4

Children's writing will always be an important vehicle for assessing their ideas and skills. It also has a valuable role in helping the child to clarify ideas and for communication between pupils as well as between pupil and teacher. This task gives an opportunity to consider this and goes on to discuss the implications for assessing group effort.

Organisation: Participants work alone for part (i), in pairs for part (ii) and in groups of four to six for part (iii) to (v).

Materials needed: Task C4.

Time: Allow 5 minutes for sub-task (i) about another 5 for sub-task (ii) and then about 30 minutes for the rest of the task.

Instructions: Tell participants :

- For sub-task (i) spend exactly 5 minutes working in silence and alone.
- Then exchange papers with a partner and reflect on whether you gain anything from his/her ideas.
- Discuss as a group the implications for how children's writing can be used to assist their understanding and development of ideas.
- Turn to the subject of group working more generally in sub-task (iv) addressing each of the questions it poses.
- On the assumption that there are benefits from collaborative group working consider the implications for teaching and assessment as part of teaching.

Task C4

(i) Working alone, for no more than 5 minutes, write down your ideas about the answer to this question: *Why do you think our hearts beat more quickly during and just after exercise?*
(ii) Exchange your writing with that of your neighbour. Consider whether this helps your own understanding and answers any of your questions.
(iii) Discuss as a group the implications of this for asking children to write in science and the use made of their writing in class activities.
(iv) Reflect on the experience of working in a group in the tasks in this module:
- How well did the group work together?
- What were the reasons for this (working well or not)?
- How did you feel when working alone at the beginning of this task compared with sharing ideas?
- What was achieved by working with others that could not have been achieved by working alone?

(v) Discuss the implications of the group interactions for the performance and learning of individuals. Is there a case for assessing a group of children as a whole in a particular activity?

Plenary discussion

Briefly ask one pair to share views on sub-tasks (i) and (ii), avoiding details of the content, but asking about the impact of having to write down ideas. Ask them to say:
- Did they feel that they found out anything about their own (mis)understanding of the subject?
- Did it raise questions which they would now like to have answered?
- Were they surprised that they did/ did not know something?

Ask one group to report on sub-task (iii) and add ideas from other groups, creating a list of ideas for using children's writing in science. After discussion ask another group to comment on the outcome of sub-task (iv) and take points of disagreement or expansion from others. Repeat for sub-task (v).

Points to emphasise

- It is important to pay attention to the way writing tasks are set for children. As in drawing, the task should be set so that it asks the children to give their own ideas.
- Asking for writing as a routine but not *using* the writing, can be a deterrent to some children's enthusiasm for science. Thus the writing should have a clear purpose for the children, and an evident intended readership (see other points under *communication* in the background information for Module D).
- Task (iv) is a brief one which asks participants to reflect on their own thinking and actions and then to consider an equivalent situation affecting children in class. It is not intended to be a basis for criticism of any of the groups.
- Note the big difference between collaborative working in groups, when all members combine efforts to produce a single outcome, and sitting in a group with others but working on a task individually. In schools real collaborative learning is rare, partly because teachers are afraid that some children will be doing all the work and others none. This is a major issue to be overcome.

- When there is group work going on, teachers usually have little difficulty in assessing the contribution of individuals to the work whether collaborative or individual. However in certain contexts, where genuine collaborative work is going on, it is worth questioning whether it is always necessary to assess individuals. If the purpose is to help the group along then the group might well be the focus of the assessment for formative purposes. This could be particularly relevant where there are very large classes. The purpose of the assessment has to determine how it is carried out, of course, and when it might be appropriate to assess children as groups and when it would not be.

Background information

Teachers' questions

Productive and unproductive questions

Some important distinctions between different kinds of question are made by Jos Elstgeest, drawing attention to the timing as well as the content of the questions. He gives the following example of an unproductive and a productive question:

> A child was reflecting sunlight onto the wall with a mirror. The teacher asked: 'Why does the mirror reflect sunlight?' The child had no way of knowing, felt bad about it and learned nothing. Had the teacher asked: 'What do you get when you stand twice as far away from the wall?' the child would have responded by doing just that, and would have seen the answer reflected on the wall.
>
> (Elstgeest, 1985, p36)

The teacher's reason for asking this question is not clear and may not have been thought out. Many questions of this kind emerge from what Elstgeest calls the 'testing reflex'. The impulse to ask such questions has to be controlled and the purpose of questions more clearly worked out. Elstgeest suggested dubbed the 'testing' questions as *unproductive* and suggested the following sequence of *productive* questions, which roughly correspond with the order in which they could be used to encourage a child's investigation:

- *Attention-focusing questions*, which have the purpose of drawing children's attention to features which might otherwise be missed. 'Have you noticed...?' 'What do you think of that?' These questions are ones which children often supply for themselves and the teacher may have to raise them, only if observation is superficial and attention fleeting.
- *Measuring and counting questions* – 'How much?' and 'How long?' take observation into the quantitative and lay a foundation for the next type of question.
- *Comparison questions* – 'In what ways are these leaves different?' 'What is the same about these two pieces of rock?' draw attention to patterns and lay the foundation for using keys and categorising objects and events.
- *Action questions* such as – 'What happens if you shine light from a torch onto a worm?' or 'What happens when you put an ice cube into warm water?' are the kinds of question which lead to investigations. There are also some useful action questions suggested in Harlen and Jelly (*Developing Primary Science*, Longman, 1997).
- Asking *problem-posing questions* gives children a challenge and leaves them to work and how to meet it. Questions such as 'Can you find a way to make your string telephone sound clearer?' 'How can you make a coloured shadow?' require children to have experience or knowledge which they can apply in tackling them. Without such knowledge the question may not even make sense to the children. It is in relation to this point that the matter of the right time for a question arises.

Elstgeest uses this anecdote to illustrate the importance of choosing the right moment for a particular type of question:

> I once asked a class of children, 'Can you make your plant grow sideways?' For a short time they had been studying plants growing in tins, pots, boxes and other contraptions made of plastic bags. I was just a little too anxious and too hasty and, quite rightly, I got the answers, 'No we can't'. So we patiently continued with scores of 'what happens if...' experiments. Plants were placed in wet and dry conditions, in dark and in light corners, in big boxes and in cupboards, inside collars of white and black paper, upside down, on their side, and in various combinations of these. In other words, the children really made it 'difficult and confusing' for the plants. Their plants, however, never failed to respond in one way or another, and slowly the children began to realise that there was relationship between the plant and its environment which they controlled. Noticing the ways in which the plants responded, the children became aware that they

> could somehow control the growth of plants in certain ways... When the question 'Can you find a way to make your plant grow sideways?' reappeared later there was not only a confident reaction, there was also a good variety of attempts, all sensible, all based on newly acquired experience, and all original.
>
> (Elstgeest, 1985, p39-40)

Open and closed questions

Open questions give access to children's views about things, their feelings and their ideas, and promote enquiry by the children. *Closed questions*, whilst still inviting thought about the learning task, require the child to respond to ideas or comments of the teacher. For example these questions:

'What do you notice about these crystals?'

'What has happened to your bean since you planted it?'

are more likely to lead to answers useful to both teacher and pupils than their closed versions:

'Are all the crystals the same size?'

'How much has your bean grown since you planted it?'

Closed questions suggest that there is a right answer and children may not attempt an answer if they are afraid of being wrong.

Person-centred and subject-centred questions

Another way of avoiding the 'right answer' deterrent is to recognise the difference between a *subject-centred* question, which asks directly about the subject matter, and a *person-centred* question which asks for the child's ideas about the subject matter. Subject-centred questions are such as:

'Why do heavy lorries take longer to stop than lighter ones?'

'Why did your plant grow more quickly in the cupboard?'

which cannot be answered unless you know, or at least think you know, the reasons. By contrast the person-centred versions:

'Why *do you think* heavy lorries take longer to stop than lighter ones?'

'Why *do you think* your plant grew more quickly when it was in the cupboard?'

can be attempted by anyone who has been thinking about these things (and we assume the questions would not be asked unless this was the case) and has some ideas about them, whether or not they are correct. Where there is interest in children's reasoning, person-centred questions are clearly essential, but at other times they are a more effective, and more friendly, way of involving children in discussions which help in making sense of their work.

Examples of questions for finding out children's ideas

The following questions were designed to be used by teachers to find out children's ideas. These particular question were used when children had been involved in handling, observing and drawing sprouting and non-sprouting potatoes:

'What do you think is coming out of the potato?'

'What do you think is happening inside the potato?'

'Why do you think this is happening to the potato?'

'Do you think the potato plant will go on growing?'

'Can you think of anything else that this happens to?'

They can readily be seen to be open, person-centred questions, giving children every encouragement to express their thoughts so that the teachers would know the children's initial ideas before investigation of the growing potatoes began.

Assessing groups or individuals?

In science pupils are generally working in groups and the composition and coherence of the group influences what is achieved. Teachers generally have no difficulty in identifying the separate contributions of children even when they are combining their ideas and skills in a group enterprise. However, we might question whether, *for the purpose of ongoing assessment for informing teaching*, it is necessary always to assess individual pupils. If the information is used to make decisions about the activities and help to be given to children *as a group*, then assessment of the group is all that is needed for this purpose. There is research evidence that in heterogeneous groups all pupils benefit when they are encouraged to share ideas and skills. Thus a group assessment may be considered to be all that is necessary in certain circumstances. However this would not apply to summative assessment or when a record of individual achievements is being made.

Interpreting children's performance and using the results

WORKSHOP LEADER'S NOTES

Aims

The activities in this module are designed to promote discussion of how information about children's skills, attitudes and ideas is used in teaching. Through discussion of specific examples, general strategies for helping the development of skills, attitudes and ideas are identified.

Objectives

1. Further recognition of how formative assessment can be used in teaching.
2. Knowledge of ways of using assessment to help children's development of scientific process skills and attitudes.
3. Knowledge of ways of using assessment to help children's development in understanding scientific ideas.

Task D1

This provides an example of a practical activity in which the teacher sought to set up the work so that he could find out the children's ideas and skills and then develop these.

Organisation: Participants working in groups of about five or six.

Materials needed: Task D1, Resource 9.

Time: Allow at least 25 minutes for participants to read Resource 9 and to work in groups to produce agreed answers to the questions. Then allow 30 minutes for a plenary discussion.

Instructions: Tell participants to:

- Make lists of the process skills, attitudes and ideas that the teacher attempted to gather in each of the three phases of the lesson (eg children's skill in observing, raising questions).
- Identify where the teacher used the information, if he did, either at the time or in his planning for the future.
- Consider whether there were opportunities missed and what other information could have been collected.

Task D1

The lesson on fabrics in Resource 9 is described as having three phases:
exploratory phase
investigation phase
reporting and reflecting

(i) Identify the information relating to assessing skills, attitudes and understanding that the teacher could gather about the pupils in each of these phases.

(ii) Identify where the teacher used information from assessment immediately in the progress of the activity and in his planning.

(iii) What other information might the teacher have gathered and used during this lesson?

Plenary discussion

Ask one group to report their answers to sub-task (i) for each phase of the lesson. List the skills and ideas reported down the left hand half a large sheet of paper:

Phase	Information about	How the information was used
Exploratory phase	.....	
	.....	
	..... etc	
Investigation phase	.....	
	.....	
	..... etc	
Reporting and reflecting phase	.....	
	.....	
	..... etc	

Add to this list from other groups. Discuss any patterns in the information in each phase. Then go to another group and complete the right hand column of the chart with answers to sub-task (ii). Ask a different group for answers to sub-task (iii) and add to the chart as necessary.

Points to emphasise

- There are likely to be overlapping types of information gathered in each phase, but there are patterns which can help in planning to gather information, for example:

	Children's ideas about the fabrics
Exploratory phase	Skill in explaining (hypothesising) Skill in raising questions Skill in predicting
Investigating phase	Skill in observing Skill in planning and conducting investigations Skill in interpreting (drawing conclusions)
Reporting and reflecting phase	Children's ideas about the fabrics Skill in communicating

- If not raised by the participants, ask what opportunities they think there were for assessing attitudes? There is a point to make about being very tentative about assessing attitudes from one lesson. Attitudes are shown in the consistency of behaviour on several occasions. However, this does not mean that information should not be gathered about attitudes, rather that it should be considered in the light of what the children do on other occasions.
- Raise the matter of feasibility of the approach used by this teacher in different contexts. Would it be possible to teach in this way with a very large class, for example, leaving aside for the moment the extra materials that would be needed?
- It was partly to keep the description of the lesson from becoming too long that there is not much information abut what the teacher actually did in using the information. The next two tasks take us into this detail.

Task D2

Organisation: Participants working in groups of about five.

Materials needed: Task D2, Resources 1 and 5. Large sheets of sugar paper or flip-chart paper and marker pens.

Time: Allow at least 45 minutes for participants to work in groups to produce agreed answers to the questions and then 45 minutes for a plenary discussion.

Instructions: Tell participants to:

- Read or look again at the account in Resource 1 (if they have already used it in Module A) and at Resource 5.
- Draw up a table, as in the task handout on a large sheets of paper.
- Decide whether there is evidence of achievement of child C in relation to each skill and attitude in Resource 5 and, if so, identify roughly what C has achieved. Use the labels of the statements in Resource 5 as a short-hand to put these in the table.
- Don't spend too much time on (i) since (ii) is the main task.
- Where there is evidence, consider what the teacher might do to help the child's further development in these skills and attitudes.
- Complete the table by entering suggestions for action by the teacher.

Task D2

(i) Read Resource 1 (or look at it again if you have already done so) and decide what you can tell about child C's achievement in the skills and attitudes in Resource 5. If you don't think there is any evidence, leave a blank. Complete the first column of a table such as that below.

(ii) Suggest what the teacher should do to help C's development of the skills and attitudes for which there is information about achievement. Give as much detail as you can.

	Achievement shown	Action by the teacher
Observing		
Explaining (hypothesising)		
Predicting		
Raising questions		
Planning and conducting		
Investigations		
Interpreting (drawing		
conclusions)		
Communicating		
Respect for evidence		
Flexibility		
Critical reflection		

Plenary discussion

Ask groups to display their posters and allow time for each group to consider the other groups' work and to look for similarities and differences. To start this off suggest they ask themselves questions, such as:

> *Are there similarities in what people have suggested for developing observation for developing interpretation.....etc.*

Then use these in structuring the feedback, considering each skill in turn. Introduce points from the background information during the discussion, as indicated below.

Points to emphasise

- Not all practical activities give an opportunity for all the process skills to be assessed. In practice a teacher has to look across several activities to assess the full range. If some are never found, then the teacher should look at the activities and see if they are providing oportunities for development of all the skills. (For example, are the children often following instructions and so never having the chance to plan an investigation for themselves?)
- The identification of patterns in developing process skills helps teachers to have strategies at hand that (s)he can apply in any activity. Thus it is important to think in general terms. (The background information summarises these and if possible the participants should be given copies to read after completing the module)
- If the detail for each skill seems too much to deal with at once, there are general points which apply across all the skills about what teachers can do to help development:
  - Providing opportunity to use process skills in the exploration of materials and phenomena at first hand.
  - Providing opportunity for discussion in small groups and as a whole class. (Tasks which are designed to require children to share their ideas, to listen to others, to explain and defend their ideas necessarily involve them in thinking through what they have done, relating ideas to evidence, considering others' ways of approaching a problem in addition to their own.)
  - Listening to their talk and studying their products to find out the processes which have been used in forming their ideas.
  - Encouraging critical review of *how* activities have been carried out. (During and after completing activities children should discuss how they have carried out parts of, or the whole of, an investigation and be encouraged to consider alternative courses of action and the extent to which these may be improvements.)
  - Providing access to the techniques needed for advancing skills. (In order to increase the accuracy of observation and measurement, for example, the use of instruments needs to be taught as the need for them arises. Other techniques, such as those used in the drawing of charts and graphs, and the knowledge of conventions in diagrams, are required for communication. Knowing how to use these instruments and conventions is not the same as using them appropriately, so there is more to using these skills than the basic knowledge.)

Task D3

This task focuses on the assessment of the pupils' understanding of scientific ideas and on how to develop it. It is parallel to task D2 and is conducted in a smiliar manner, but with a focus on ideas rather than skills.

Organisation: Participants working in groups of about five.

Materials needed: Task D3, Resource 10.

Time: Allow at least 20 minutes for participants to work in groups to produce agreed answers to the questions and then 30 minutes for a plenary discussion.

Instructions: Tell participants to:

- Study carefully each example and agree the extent to which there is evidence of achievement of the understanding which is indicated in the stated aim.
- Be very specific about what action the teacher should take. Say exactly what questions might be asked or what particular further activity would be provided (avoid vagueness such as 'give more examples...')

Task D3

Look at the examples of children's writing and drawings in Resource 10.

For each one consider:

- the evidence in relation to whether the child has understood the idea that is stated as the aim
- what action the teacher should take to help further development.

Complete the following table

Example	Evidence related to aim	Action by the teacher
A		
B		
C		

Plenary discussion

Ask one group to give their responses for Example A. Ask other groups for points of difference. Resolve conflict in relation to the evidence by asking for reasons. Question the group closely to provide a detailed indication of what the teacher's action might be.

Repeat with different groups reporting for the other examples.

After collecting all the specific ideas, bring them together and draw out the strategies that could be used in other situations (see below).

Points to emphasise

- It is not just children's 'wrong' answers that provide information to help in teaching. Both the child's correct answer in Example A and the unusual one (the horn) should be followed up by questioning to find out the child's reasoning.
- There are too many ideas to list a separate action for each one so it is important to identify general strategies that can be appied across the range of ideas. These are described in the background information under the headings:
  Helping children to test their ideas
  Extending children's experience
  Discussing words
  Providing alternative, more scientific ideas
- Although these suggestions have been made in relation to individual children or pairs, the strategies suggested can be used in relation to groups and large classes.

Background information

Using information to help children's process skill development

At a general level, the following are some of the main ways of helping children to develop their process skills:

- Children have to use process skills in order to develop them; to use their own senses and to gather evidence from which to raise questions, form hypotheses based on existing ideas, and so on. Being told about what it means to observe, interpret or investigate is not the same as doing these things.
- It is useful to design activities which require children to share their ideas, to listen to others, to explain and defend their ideas. This necessarily involves them in thinking through what they have done, relating ideas to evidence, considering others' ways of approaching a problem in addition to their own.
- During and after completing activities children should discuss how they have carried out parts of or the whole of an investigation and encouraged to consider alternative courses of action and the extent to which these may be improvements. This will enable the children to recognise the skills which they need to improve.
- In order to increase the accuracy of observation and measurement, for example, the use of instruments needs to be taught as the need for them arises. Other techniques, such as those used in the drawing of charts and graphs, and the knowledge of conventions in diagrams, are required for communication.

The further points below look in more detail at what can be done in relation to particular skills.

Observing

Opportunity to use the senses as ways of finding out requires objects to explore objects and phenomena. An 'interest' or science table in the classroom is one way of providing this as well as serving other purposes. It is always a good idea to set out objects relating to a new topic two or three weeks ahead of starting it in order to create interest. During the topic work items can be added to the display. The table enables children to use odd moments as well as science activity time for observing and so increases an important commodity in the development of this skill. Time is significant here more than perhaps for other skills. Children need time to go back to things they may have observed only superficially or when a question has occurred to them that suggests something they want to check.

Some children also need invitations to observe. Cards placed next to objects or equipment displayed can encourage observation and action. 'Try to make this bottle make a high and a low sound' placed next to a bottle three-quarters full of water encourages interaction. 'How many different kinds of grass are there here?' placed next to a bunch of dried grasses encourages careful observation. The correct use of a magnifying glass can also be taught through a card with a drawing on it.

When observations have been made, there should be opportunities created for them to be shared. Making a point of spending a few minutes in whole class discussion of what has been noticed about things on the science table, for example, may draw the attention of some children to things they have missed and emphasise the role of the table in the class activities.

Raising questions

Whilst the aim of the development of questioning skills in science is to help children raise questions which are investigable, the starting point towards this is raising questions of any kind. To indicate too soon that science is concerned with certain kinds of questions and

not others might deter the raising of questions. So the teacher should see asking questions of any kind as the first step to progress in this skill. These may be questions which ask for names, for information, for explanations; they may be philosophical or may address aesthetic values, or they may be answerable by investigation or be capable of being turned into questions which can be investigated. It is important to take all the questions seriously and to indicate to the children which ones can be answered if they do something to find out.

Children will readily ask questions in terms of 'how' or 'why' which are often not easy to answer. 'How do worms move without any legs?' 'Why are wood lice (slaters) hard on the outside and soft in the middle?' By helping the children to turn these into investigable questions by such means as posing related questions ('Well, can we find out if the worms move as easily on different surfaces, very shiny ones or rough ones?') they gradually realise that these questions are more effective in obtaining answers. With encouragement and the example of the teacher they will gradually begin to realise that there are certain kinds of questions which are answered by investigation.

Thus the ways in which teachers can help children's progression in this skill include:
- taking children's questions seriously so that they see for themselves how each kind is answered
- posing questions themselves in investigable form in science
- helping children to clarify their questions so that they can see how to find an answers
- giving invitations for children to raise questions ('What would you like to find out about ...?')

Hypothesising

A hypothesis is an attempt to explain some observation, happening or relationship. There are things to avoid as well as to encourage in helping the development of this skill. To be avoided is the idea that a hypothesis has to be 'right', that is, it depends on knowing all about what is happening. This impression can be conveyed through the questions which are asked of children. If the question is framed as 'Why do some leaves turn brown in autumn?' then it is difficult to answer unless you know, or think you know the reason. On the other hand, the questions 'Why do you think some leaves turn brown?' or 'What do you think could be the reason for leaves turning brown?' stimulate the generation of an explanation from existing ideas. (See Module C on teachers' questions)

The development of confidence in ability to suggest explanation is helped by asking for several possible alternatives in situations where there is not necessarily an obvious answer. For example, why are there patches of different coloured grass on the field? There are multiple possible reasons, which could be brought out by asking 'what else could be the reason?' as each suggestion is accepted. Each one has to be possible in terms of the evidence: different kinds of grass; something in the soil under the patches; drainage varying from one place to another. But a suggestion that more rain fall on the patches might be rejected because of evidence that there is nothing to cause such difference.
Trying to explain a shared observation such as this enables children to feel that they have the ability to make sense of the things around them. Which of the suggestions may be most likely, would require more evidence and investigation, but their ability to attempt explanations is not dependent on the result.

Young children's hypotheses will be in the form of attempts to explain specific events in their experience rather than in terms of broad statements of principles which explain a whole range of phenomena (such as referring to the conditions needed for the growth of plants to explain the patches in the grass). However, the ability to suggest explanations in specific terms is the foundation of later development in applying broad principles and theories. Meanwhile the skill of using existing ideas, limited though they may be, in attempting explanations plays an important role in testing and developing these ideas.

Predicting

Opportunities to make predictions can be created both in relation to patterns found in observations and in relation to hypotheses which are put forward to explain observations.

In the case of *patterns found between two variables* the prediction is based on the evidence of some association between one thing and another, but without necessarily assuming that it is an association of cause and effect. The simple relationship between hand size and foot size is an example of association where there is no sense in suggesting that one thing causes the other, that having large hands causes large feet; rather there is another variable which is causally related to both of them. Nevertheless, the association, whatever its basis, can be used in predicting (within limits) the foot size of someone from their hand size.

Not all patterns are simple and the process of predicting from them is best encouraged through the more obvious relationships such as the sound that is made when a thin strip of wood (or a ruler) is held at one end and twanged at the other. The note varies with the length which is free to vibrate. Once observations have led to the pattern being established, children can predict whether a particular length will give a higher or lower note and then try it out. In such situations it is useful for them to discuss how they make their predictions since this helps them to become conscious of using the pattern they have noticed in the observations. They should recognise that this is different from a guess.

Predictions based on hypotheses depend on previous experience and ideas derived from it rather than the interpretation of findings from an investigation or observed events. Hypotheses do suggest explanations in terms of cause and effect and constitute some theory of why things are as they are. It is the test of a true theory that it can be used. For example the hypothesis that the leaves turn brown 'because of the cold' is a theory that cold brings about the change. Although not quite accurate, this theory can be used to make a prediction about the circumstances in which leaves will turn brown, which is a test of the hypothesis and the idea on which it is based. Again, it is important for children to be helped to make predictions in simple cases and think about the way in which they arrive at a prediction.

Children often implicitly use patterns or hypotheses in making predictions but fail to recognise that they in fact do so. A girl who had investigated how far a wind-up toy travelled after different numbers of turns, asked to make a prediction of how far it would go for a certain number of turns said that she guessed. Further probing, however, led to her explaining, 'I thought that it would be a bit more than for 3 and a bit less than for 5', suggesting that she was implicitly using a relationship of 'more winds means further'. Becoming aware of the pattern she was using enabled her to predict other distances with more confidence and indeed satisfaction. Discussion played a central part in bringing about this awareness.

Investigating

The process of investigating is taken here to be what happens between having a question to investigate or a prediction to test and obtaining observations or data to be interpreted. Too often children's experience of these steps in answering questions is of following instructions such as:

> "*(To find out if ice melts more quickly in air or in water a room temperature) you'll need to use the same sized ice-cubes. Make sure you have everything ready before you take the ice cubes out of the tray. Put one cube in the water and one close to it in the air. Then start the clock...*"

Here the children will have no problem in doing what is required, but they will have no idea of why they are doing it. If they did, they might challenge the need for a clock in this activity!

A diet weighted with such activities does not give children the opportunity to carry out planning and thinking about what they are doing. There must, therefore, be opportunities for children to start from a question for investigation and to think out and carry out their own procedures for answering it. This is asking a great deal for young children and for older ones unused to devising investigations and they will need help which subsequently can gradually be withdrawn.

Young children's experience should include simple problems such that they can easily respond to 'How will you do this?' For example, 'How can you find out if the light from the torch will shine through this fabric, this piece of plastic, this jar of water, this coat sleeve?' Involving children in planning is part of setting an expectation that they will think through what they are going to do as far as possible.

For older children, help in planning can begin, paradoxically, from reviewing an investigation which has been completed (whether or not the children planned it themselves), helping them to go through what was done and identifying the structure of the activity through questions such as

- What were they trying to find out?
- What things did they compare (identifying the independent variable)?
- How did they make sure that it was fair (identifying the variables which should be kept the same)?
- How did they find the result (identifying the dependent variable).

When planing a new investigation the lessons learned from reviewing can be recalled, where perhaps variables were not controlled or initial observations taken when they should have been. Planning continues throughout an investigation and indeed the initial plan may change as the work progresses and unforeseen practical obstacles emerge. However it is important for children to recognise when they do change plans and to review the whole planning framework when a change is made. Writing plans down is a useful activity because it requires forward thinking, actions carried out in the mind. Children become more able to do this the more experience they have to think through and call upon in anticipating the results of certain actions. The teacher's role is thus to provide time and a structure for planning and gradually to set the expectation that children think through what they do even it they do not write formal plans on paper for every investigation.

Interpreting results and drawing conclusions

For children to develop ideas as a result of collecting information and evidence to test their ideas they have to interpret what they find. That is, they must go further than collecting individual observations and to look for patterns, relate various pieces of information to each other and to ideas. For example, children measuring the length of the shadow of a stick placed in the ground at different times of the day children must go beyond just collecting the measurements if the activity is to have value for developing ideas. Important outcomes of this activity are recognising the pattern of the decreasing and then increasing length of the shadow and the possibility of using the pattern to make predictions about the length at times not measured, or the time of day from the measurement of the shadow, and the development of ideas about how shadows are formed. They all depend on *using* the results the children obtain, so the development of the skills required is important. The central part of the teacher's role is to ensure that results *are* used and children don't rush from one activity to another without talking about and thinking through what their results mean.

It was noted earlier that children often make predictions on the basis of patterns without apparently being conscious of doing so. Teachers can help to foster this consciousness by discussing simple patterns, such as the relationship between the position of the sun and the length of the shadow (or the equivalent in a classroom simulation using a torch and a stick). The starting point must be the various ways in which children will express their conclusions, including:

'The shadow is shortest when the sun is highest'.
'The shortest one is when the sun is high and the longest when it is low'.
'Its length depends on where the sun is'.
These are working towards recognising that:
'The higher the sun the shorter the shadow'.
Which says all that the previous statements say and more besides. Time for discussion of how to express a pattern is essential for the development of this skill.

Communicating

In the course of their science activities there is the potential for children to experience a range of different kinds of communication for different purposes and audiences. These should include:

Modes:	writing, speaking, drawing, making, keeping notes and listening, reading, looking
Audiences:	for themselves, other pupils, their teacher, other adults
Purposes:	in order to sort out ideas, tell others about what they have done present observations, findings and conclusions.

This is a wide range to cover and clearly not all will be part of every activity. It is useful, however, for a teacher to plan this part of children's activities so that all are included appropriately and regularly. 'Appropriately' means that it should serve the purposes of the activity and not become meaningless ritual. The routine 'write about what you did' can kill any creativity in communication, as well as being a deterrent for some children.

A personal note-book can be a very helpful aid to recording and to later interpretation and reporting. At the least it is an aid to memory and at best a means of having a dialogue with oneself which assists reflective thinking. It is useful for children to use a note-book but they will need help. The help has to be given very subtly, though; if there is too much checking-up on what is written, the note-book becomes just another exercise book which is 'marked' by the teacher.

Discussion of the best way to present information is the opportunity to introduce techniques for graphical representation or to talk about how to select the best way of presenting information. Work already displayed on the wall can be used as examples of how to and how not to do this. Children are usually willing to criticise their own work after some time has elapsed. It is also a good idea to have one or two examples of commercial posters (such as those about the nutritional value of different foods or showing types of clouds) to show different ways of providing information.

Looking at posters and books is the other side of formal communication, that is, using secondary sources of information. Children need opportunity – suitable reference sources and time to use them – and some help in locating and selecting information.

Using information to develop children's ideas

These are suggestions for ways of meeting individual needs within a group context. They do not propose separate activities for individual children but support from the teacher which is based on knowledge of the development of the children. The ideas that children express and which we see as 'unscientific' need to be taken seriously because they are based on their own reasoning even though this reasoning may be limited and 'unscientific'.

The children's ideas may be:
- based on their inevitably limited experience
- expressed using scientific words but without a grasp of the accepted meaning of these words
- held because there are no alternative ideas which are more convincing to the children.

Consideration of their characteristics leads almost automatically to the action that a teacher may take to help the development of their understanding: helping children to test their ideas more rigorously (which implies the development of process skills); extending experience; discussing words; providing alternative, more scientific, ideas; enabling children to review past experience in the light of any change made in their ideas. We shall consider the teacher's role in relation to each of these.

Helping children to test their ideas

If we think about how children arrive at their ideas it is often the case that they have taken account only of certain evidence and ignored anything that is contradictory, or that they have not compared like with like.

An important part of a teacher's role in science is to set up the expectation that *all* ideas have to be tested, not just the children's but any the teacher proposes or ones found in books. If this becomes routine, then there will be no implied criticism in asking children to 'find a way to see if your idea works'.

Not all tests of children's ideas will be of the kind suggested in books of scientific activities and the teacher should be prepared to be as imaginative as the children in devising ways to address unexpected ideas.

Extending children's experience

It is not always the case that children have ignored evidence; often evidence that they might have used is just not available to them, as it is to adults. For example, it is reasonable to hold the hypothesis that rust may originate inside the body of a metal if a child has only ever seen the exposed surfaces of metal objects. Cutting through a rusted nail may be all that is needed to show that this in not the case. (This could be interpreted as testing the prediction that rust is found inside the metal; indeed all ways of extending children's ideas could be regarded as ways of testing ideas).

The teacher's role is to provide gradually extended experience as a matter of routine. This can be through classroom displays, which are added to as a topic proceeds; through posters and photographs mounted on the walls, information books at the right level, for reference in the book corner; through visits, visitors and full use of the school buildings as resources for observation and activity.

Discussing words

The introduction and use of 'scientific' words is often a cause of uncertainty. The teacher's role is to judge the right time to introduce an appropriate word to describe events or objects that children have already experienced and need to name.

However, children pick up words from other sources and take some delight in trying them out. When children use scientific words, from any source, it is necessary to find out what meaning they have in mind rather than to assume that it is the same as the accepted meaning. A useful way of doing this is to ask the children to show some examples of what the word means: 'Tell me about something that is melting....vibrating....evaporating....etc' . If the example is of something rather different from the meaning of the word (as when evaporating is confused with condensing, for instance) then the correct word can be introduced and the children should become involved in thinking up and demonstrating examples of both condensing and evaporating – or whatever words were confused. Encouraging children to challenge each other's use of words can sharpen their thinking at times when the teacher is not present.

Providing alternative, more scientific ideas

This needs careful judgement even though it may seem the most obvious role for the

teacher to take. The delicacy of judgement is required because it is all too easy to destroy children's confidence in their own thinking and reasoning if their ideas are swept aside by premature presentation of the 'right' ones. The best way of avoiding this is to ensure that more scientific ideas are introduced, not as being 'correct' but as alternatives worth considering, and that these are tested in terms of the evidence available so that everyone can judge the extent to which they 'work' in practice.

As children progress in ways of thinking and experience they can be encouraged to consider alternatives by argument and information from secondary sources and not only from what they can experience directly. Thus, for example, models of the solar system can be used to introduce explanations of the apparent movement of the sun and moon which can over-ride the naive interpretations of direct observations.

Enabling children to review earlier experience in terms of new ideas

When early ideas that children have used to explain things to themselves are changed by the impact of investigating and thinking about new experience, it is important for there to be some review of their understanding of earlier experience. Without this there may be a residue of naive ideas which are still used to explain previous experience. For example, we can all probably recall believing in something like 'the man in the moon', but recognise that this belief was overtaken by more rational views. It would be illogical to believe in a man in the moon and the moon as understood more scientifically. To avoid the equivalent in children's growing ideas the teacher should help them to reflect on previous experience in terms of new ideas. It is helpful to be quite explicit about 'how your ideas about ... have changed' for this legitimises changing ways of understanding things, which is essential for the continued development of ideas.

Keeping records and summarising achievement

WORKSHOP LEADER'S NOTES

Aims

The activities in this module aim to promote discussion of records of ongoing assessment and how they can be summarised to provide information for the purpose of summative assessment. The use of informal tests or tasks for this purpose is also discussed, whilst the use of formal testing is the subject of Module F.

Objectives

1. Understanding of the limitations and strengths of different ways of recording formative, ongoing assessment.
2. Awareness of different ways of summarising ongoing records to produce a summative assessment.
3. Appreciation of some advantages and disadvantages of teachers' assessment and external assessments of children's achievements.
4. Knowledge of different ways in which teachers' summative assessments can be made more reliable.

Task E1

This task facilitates discussion of records kept for the purpose of keeping track of children's progress and helping teachers in planning work to match their achievements.

Organisation: Participants in groups of about four.

Materials needed: Task E1, Resources 5 and 11.

Time: Allow at least 45 minutes for the task and 30 minutes for plenary feedback.

Instructions: Tell the participants what they have to do:

- Look at the four kinds of record and answer the three questions in sub-task (i). Draw up a list of advantages and disadvantages in relation to a), b) and c) for each one.
- Groups can decide whether they complete the sub-task for each method for all the purposes or look at each one in relation to each purpose.
- Remember to give some time to questions (ii), (iii), (iv) and (v).

Task E1

Look at the methods of recording of Teachers 1, 2, 3, and 4, in Resource 11.
Working in groups of four:–

(i) Three of the main purposes of record keeping are:
   a) keeping track of the achievements of the children
   b) helping the teacher's planning to match the children's achievements.
   c) keeping track of the activities completed by the children.

Consider the advantages and disadvantages of the methods used by Teachers 1, 2, 3, and 4 for each of these purposes.

(ii) What advantages and disadvantages are there of involving children in keeping records? What part could the children have in keeping these records?

(iii) How might these records be modified to make recording practicable with very large classes?

(iv) Would these kinds of records be useful for other subjects in the primary school? What would be the advantages and disadvantages of incorporating science with other subjects in a single record?

(v) What other forms of record are used by members of the group? What are their advantages and disadvantages for purposes in a), b) and c)?

Plenary feedback

Ask one group to report on sub-task (i). Collect any disagreements or additions from other groups (not repetition of same points).
Ask a different group to comment on sub-task (ii), following this with contributions from other groups in the same way.
Repeat with a different group for sub-tasks (iii) and (iv).
For sub-task (v), ask for methods which differ substantially from those already discussed and encourage the users to be self-critical.

Points to emphasise

If not raised within the discussion, the leader should make sure that the following matters are discussed and these points raised or emphasised:

- The difference between recording the activities that children have carried out and the learning that they have achieved through it. Children can readily take part in keeping a record of the activities they have completed; participation in the assessment of achievement is important but is separate from teachers' records (see Module B).
- Keeping records is not the same as assessing. Assessing, which is making judgements about learners' progress and development, can take place without a written record. Records help us to reflect and make better judgements.
- It is important that the record provides the same kind of information about all the children, otherwise the information may relate to different aspects of learning for different children. (Teacher 2 does not do this, whilst Teachers 1 and 3 keep records of the same things for all).
- To help in the planning of future work the record should indicate what the children can and cannot yet do. (Teacher 1's records do not do this and Teacher 2's indicate only some aspects.)
- Records are time-consuming and should provide only the amount of detail that is needed. (Teacher 4 has retained all the detail and still has to analyse what the work means for what children can and cannot yet do. A portfolio doesn't provide 'at a glance' information).
- Records should be kept under control. If certain information is never used, it may as well not have been recorded. (Teacher 3 has reduced the burden by recording after a coherent group of activities rather than after every activity.)

- These points apply particularly with very large classes. Rather than not make any records, because the task is too great, the record could be streamlined by, for instance, only recording certain, carefully selected activities, but doing this for all the children.
- There is no perfect record. As can be seen from this discussion, each has its drawbacks; personal preference and style should also be considered.

Task E2

This moves the discussion onto using the information in the ongoing records for the purpose of reporting and recording what children have achieved at a certain time (summative assessment).

Organisation: Participants in groups of about four.

Materials needed: Task E2, Resources 5 and 11.

Time: Allow at least 20 minutes for the task and 25 minutes for plenary feedback.

Instructions: Tell the participants to:
- Look again at the four kinds of record in Resource 11.
- Consider the three questions in (i) in relation to each of the four records. (The matrix is just a reminder to do this systematically – it is unlikely that the full answers can be entered into it.)
- Make some practical suggestions for adapting records to be practicable with very large classes.

Check that the meaning of 'reliable' is understood. Take the opportunity to rehearse the difference between reliability and validity (see background information for Module A – or glossary).

Task E2

Consider again the records in Resource 11 but this time to decide how the information for each child could be summarised to provide an assessment of achievement at the end of term or of the school year. This is the summative assessment that would be the basis of an end-of-year report to parents and would be passed to the child's next teacher.

(i) For each of the records answer these questions:
a) How might the teacher go about producing a summative assessment from the ongoing record?
b) What form could the summative assessment take?
c) How reliable do you think the assessment would be?

	How to produce the summative assessment	Form of the summative assessment	How reliable?
Teacher 1			
Teacher 2			
Teacher 3			
Teacher 4			

(ii) Consider how the process of producing end of term/year reports could be streamlined to help teachers of very large classes.

Plenary feedback

Ask for the responses to a) for all the four records, followed by responses to b) for all four and on to c) for all four. This helps to focus on the process of summarising and avoids the danger of repeating points already made about each record. As before, take one group's responses, in turn; ask for comments and additions rather than full reports from others.

Points to emphasise

- The purpose of summative assessment is to show what each child has achieved by the end of the year, not an average performance across the year. Find out whether there is agreement on this point among the participants.
- The marks out of ten on the tests present a problem in relation to the intention of providing information about what children can do. It isn't possible to know what they mean in terms of achievement. Some might suggest using the general trend in the marks, to indicate 'excellent', 'good', or 'poor' performance but this is of little help if we don't know 'good at what'? Inevitably this means that Teacher 1's records are not very helpful. Significantly, they are the most common form of record kept.
- A useful form of summative record is a short profile of the areas of understanding, skills and attitudes. Some of these can be grouped together for this purpose, so that the information is not more detailed than can be grasped or used.
- It follows from what has been said earlier that the most useful assessment is criterion-referenced. For summative assessment it is important for the same criteria to be used in the same way for all the children since the results may be used to compare one child with another in order to select or group them.
- The official curriculum in some countries provides criteria in the form of performance indictors or targets arranged in levels of development. These provide convenient ways of recording children's progress, as long as those receiving the records know what the levels mean.
- In using criteria (or performance indicators) for summative assessment it is necessary to get away from an activity-by-activity assessment and to take a 'holistic' view all the information. This results in the 'best fit' to the criteria overall (see background information). Portfolios can be assessed holistically in this way as well as the information described in terms of developmental criteria.
- To serve its purposes summative assessment has to have a high reliability; in this context it means that the same judgement would be made whoever makes it. It is not always easy to apply criteria reliably (particularly when first starting) but teachers' meetings can be organised to compare judgements, identify areas of difference and bring the judgements of different teachers into line with each other.

Task E3

So far we have considered using only teachers' records of ongoing assessment. There are disadvantages of this which have probably been revealed in the discussion. This task provides an opportunity to consider alternatives. These have their advantages and disadvantages too.

Organisation: Participants in pairs, moving after 15 minutes to groups of four.

Materials needed: Task E3.

Time: Allow at least 25 minutes for the task (15 in pairs and 10 in fours) and 30 minutes for plenary feedback.

Instructions: Read the information about Teachers 5 and 6. Emphasise that when meeting in groups of four they should concentrate on the differences in their views.

Task E3

The Head Teachers of the schools where Teachers 5, 6 and 7 teach were not confident that a fair summative assessment could be derived from the records of ongoing assessment. They therefore obtained a collection of test items and practical tasks which could be used at the end of each year to provide the summative assessment. The test items and tasks had been tried out and analysed so that they could be labelled according to the skills and understanding of ideas they assessed.

In the school of Teacher 5, selections of the items and tasks were put together to make tests suitable for each age level. The tests were rather similar to the children's normal work and so there was no feeling of being tested. The children took the tests at the end of the year, the teachers marked them, using the mark schemes provided and the total score for each child obtained in this way formed the summative assessment.

In the school of Teacher 6, the Head Teacher told the teachers to use their judgement and their ongoing records to decide whether certain criteria had been met. They were then to select appropriate tasks and test items and use these as part of the children's activities, to check their own judgements. Where there was disagreement, teachers looked again at the evidence from both sources and refined their view of how to judge certain kinds of achievement.

In the school of Teacher 7, there was a combination of externally produced tests, marked by the teacher, and assessments based on the teacher's ongoing records. The tests were given 30% of the marks and the teacher's assessment 70% per cent.

In pairs:
a) List the strengths and weaknesses of the approaches used in the schools of Teachers 5, 6 and 7.
b) Identify the conditions in which you would use each of these approaches. Give your reasons.

Join with another pair and identify any points of disagreement. Be prepared to report these.

Plenary discussion

This activity is likely to pin-point differences in view of the relative confidence that participants have (or believe others to have) in teachers' assessments, on the one hand, and externally produced assessment tasks, on the other.

Begin by collecting areas of disagreement in relation to a). Ask each group for one point only until all the points have been raised. List them on a board or flip chart. Repeat for b).

Points to emphasise

- Teachers' records and judgements can potentially cover a wider range of achievement than a test. In this sense they are more valid than a test in reflecting the full learning that is aimed for.
- However the realisation of this breadth depends on the opportunities provided in the classroom and on the teacher's skill in assessment. If either or both of these are weak then there are advantages in giving a test so that children can show what they can do.
- Unless teachers have an opportunity to develop their skills in making summary judgements and to bring their judgements into line with those of others then their judgements may well be less reliable than we would wish. Therefore some means of checking their judgements will increase the confidence in the results of both the teachers and those who use the information (parents, head teachers, etc).

- Using externally devised tests to check teachers' judgements, as in Teacher 6's school, or to combine with them, as in Teacher 7's school, is a means of maintaining breadth and reliability. Moreover the feedback that the teacher receives in this process is a form of staff development.

Background information

Purposes of records

Records relating to individual children can serve three different purposes:

- to keep track of activities and experience
- to assist ongoing assessment by keeping track of children's achievements
- to provide summary information about what children have achieved at the end of certain periods of time.

It is worth emphasising that records of activities and records of achievement are not the same and have different purposes. Records of activities show what each child has experienced; records of achievement show what they achieved at that time, possibly as a result of the activities.

Records of activities

The purpose of a record of activities is to enable the teacher to ensure that all children, at various times, have the learning opportunities planned, in so far as this is possible, and to record gaps in children's experience where this has not been possible. A list of activities is created and the record would be completed by ticking those undertaken by each child; not an arduous matter and one in which the children can help. In many cases groups of children will have undertaken the same activities but keeping individual records means that absences and changes of group composition are taken into account. Certain activities will probably be regarded as equivalent to each other, whilst in other cases it may be that the context is so different that repetition is desirable. Taking these things into account, the teacher will use the record to keep an eye on the gaps in the activities of individual children and act on this, either in planning the next term's work or having one or two sessions in which children are directed to activities which they have missed.

Ongoing records of achievement

These are the most detailed of the records which have to be kept and it is inevitable that a fairly lengthy recording sheet will have to be used for each pupil. A compromise has to be struck, however, between a scheme which is so burdensome that it will not be maintained and too detailed to be easily used, and one which consists of ticks or other marks whose meaning is rather vague. In deciding which kind of record is most useful it should be noted that:

- The over-riding purpose is to help the teacher remember where each child has reached in development so that suitable activities and encouragement can be given.
- These records are for the teacher's own use and so the level of detail can be adjusted to suit the individual's ways of working.
- They will be summarised for other purposes, for school records passed from class to class and for reporting to parents.

Teachers vary as to how much information they can carry in their head and how much they like to write down. *However it is important to keep some record of the achievement of all the children and to do this in a way that the same kinds of information are recorded for each child.* The act of completing the records ensures that the teacher becomes aware of what (s)he knows or does not know about each child. It is very easy, especially in a large class, for the teacher to know a great deal about the noisy and disruptive children, those who claim attention for one reason or another, but much less about those who are quiet and do not stick out as high or low achievers.

Records can be less cumbersome when they refer to some document where the detail is spelled out. For example, in Resource 12, Teacher 3 referred to the lists of progressive development of skills and attitudes.

Using ongoing records for summative assessment

Much of the information gathered for formative purposes and recorded in teachers' ongoing records can be used for summative purposes, that is, for judging what children have achieved at a certain point, usually the end of the school year. Indeed the formative information should not be ignored, since it is the richest source of information about the children's achievement. But for reliable assessment, as required for summative purposes, there must be certain conditions as to the use of this information, specifically that:

- it is reviewed strictly against the criteria
- the criteria are applied in a 'best fit' approach
- there is some way of ensuring that the judgements of one teacher are comparable with those of other teachers.

The features of formative and summative assessment

In addition to their different purposes, formative and summative assessment differ in other features which are summarised in the following table.

Feature	Formative/ongoing	Summative
Purpose	Helping teaching; promoting learning; positive in intent	Reporting achievement at certain points in time, usually at 'natural breaks'
Timing	Takes place as an ongoing part of teaching	Takes place at specified times
Use	As basis for 'next steps' in learning	Report to parents, other teachers and pupil on point reached in learning
Type of information	About ideas ('small' ideas) and skills used in particular activities and how these were arrived at	About the grasp of 'bigger' ideas which are achieved as a a result of several activities and which relate to the requirements of the curriculum
Basis of judgements	Takes account of effort as well as quality of work	Takes account of the quality of the work only
Comparability of judgements	Judgement depends on the child as well as the criteria; so not comparable for different children	Products of assessment (grades, levels, marks, etc.) mean the same for all children
Role of children	Children have a central part in the assessment of their own work	Children have a part but there must be overall confidence that criteria are applied in the same way for all children

Type of information

Because formative assessment is carried out so that it can be used in helping teaching and learning, the type of information it requires is concerned with the learning in the activities as they take place. It will therefore concern the ideas and skills that can be developed in

particular activities. We can call these 'small' ideas because they are likely to be specific to the activity. Of course the teacher will have in mind 'bigger' ideas, of wider application, towards which (s)he intends the children to make progress. Several 'small' ideas will have to be linked together to form gradually bigger and bigger ideas.

For example, if children collect 'minibeasts' and attempt to keep them in their classroom , they are learning about the conditions needed for survival by the particular animals that they find. Their teacher would want them to link their ideas about these particular creatures to their experiences with other living things – keeping pets, learning about animals in the wild, etc – to form general ideas about the needs of living things and eventually to link the characteristics of animals to the features of the habitats in which they live. The characteristics of living things and adaptation to habitat are 'big' ideas (big because they relate to more than the particular animals studied) that will become bigger still as children's experience extends and supports a deeper understanding of these concepts.

Summative assessment is concerned with progress towards the big ideas rather than the learning in specific activities. For this the teacher will wish to judge the extent to which the children can apply ideas in contexts different from those in which they were learned.

Basis of judgments and comparability of outcomes

Formative and summative assessment also differ in the way information about aspects of children's behaviour is judged. As we noted in the background information for Module A, assessment always involves a judgement and the outcome is the product of the judgement. Three kinds of standard (criteria, norms and the child's previous performance) are in common use in assessment giving rise to criterion-referenced assessment, norm-referenced assessment and child-referenced (or ipsative) assessment.

In formative assessment teachers are interested in the progress made by individuals and how to help further achievement, which means that in deciding whether the smile or the frown is the appropriate response, the teacher will take into account the child's previous achievement, the effort put in and any particular difficulties the child is experiencing, as well as the quality of the work. This means that it is possible that a piece of work which might result in praise for one child would, if produced by another, be regarded as less than satisfactory for that other child. There is no harm in this *as long as comparisons between children are not made on the basis of these assessments*. What the teacher is doing is using a mixture of child-referenced and criterion-referenced assessment. This is good practice, since, if the teacher were to use strictly criterion-referenced assessment, the same for all the children, then for some this would mean constant discouragement.

For summative assessment, however, it is important *that comparable outcomes of assessment imply comparable quality of work*. So the grades, levels, marks, and so on that are assigned to children's work must mean the same thing for different children. Their meaning comes from the criteria being applied. For this purpose, then, no aspects should be considered other than what the work means in terms of ideas and skills achieved.

The role of the children

Encouraging children to take part in the assessment of their own work is a way in which teachers can communicate to children the objectives of their learning. (See Module B). The children's role in assessment is most readily encouraged in the context of assessing specific pieces of work. Creating portfolios, or collections of work in folders or boxes, is a popular and effective way of doing this. However, the extent to which primary children can genuinely take part in summative assessment is limited. It requires understanding of rather longer-term aims and the broader picture of the progression in learning, as well as the ability to stand aside from their work, that will develop at a later stage.

Using criteria

It is clear in the arguments about assessment, whether for formative or summative purposes, that it should be criterion-referenced, since only this form gives information about what children can and cannot do. But where do teachers find the criteria to use? Some developmental criteria are given in Resource 5, but this is only an example. They are unlikely to be used by all teachers, and so lack the necessary status for widespread use. Teachers have to use the same criteria as each other, reflecting the aims of the science curriculum applying in their district, region on country.

It is becoming more common for curriculum statements to be in the form of expected achievements or outcomes at different levels. These may be stated year by year, or in terms of developmental levels, for example:

Progressive stage	Criteria
PS1	Statements of what a child may be expected to have achieved at the end of stage PS1
PS2	Statements of what a child may be expected to have achieved at the end of stage PS2
PS3	Statements of what a child may be expected to have achieved at the end of stage PS3
etc	etc

These statements of achievement are the criteria against which the achievement of individual children are judged. The outcome may be, for example, to indicate that a child has achieved PS2 but not yet PS3, but this is a shorthand for the statements of what the child has and has not yet achieved which are spelled out in the list.

Using criteria holistically: the 'best fit approach'

Generally it is possible to pick out separate statements of achievement in the list defining a particular level. It would be possible to look for evidence in relation to each statement in the children's work during the period being summarised. But this is often problematic as well as arduous, since children's work over a period of time will show peaks and troughs. At times they may seem to be able to do something which at other times they seem unable to do. These ups and downs are useful for formative purposes because they indicate conditions which work in favour or against certain kinds of achievement. But for summative purposes they pose a difficulty for the decision as to whether or not a child has achieved a particular level in skills or understanding.

A preferred approach to using criteria is to review the work as a whole and to decide the 'best fit' with the criteria to be applied, accepting that not every piece of work will meet the criteria and not every criterion will be met.

Professional judgement is required and this can be enhanced by teachers having an opportunity to discuss actual collections of children's work and sharing their views on how they should be assessed.

Making teachers' judgements more reliable

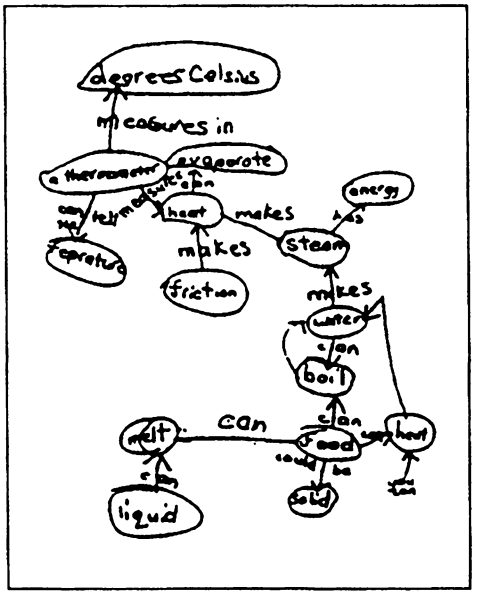
One way of ensuring that judgements made by different teachers for summative purposes are comparable is to provide opportunities of the kind just described, where teachers meet to compare their judgements. Another way is to build up a bank of examples that can be used as reference points in making judgement. A third way is to provide a means for teachers to check their own assessments by using an externally devised task or test that has been validated for the purpose of indicating certain levels of achievement. This brings us to the third matter discussed in this module, the use of special tasks to supplement other information for the purposes of summative assessment.

The role of special tasks in summarising progress

As noted earlier, part of the information needed for summative assessment concerns the development of 'bigger' ideas and the ability to apply ideas in contexts other than those in which they were learned. This means that summarising evidence from learning activities carried out may not provide all the information that is needed to report on progress. True, some information about ability to apply will be gained as an ongoing part of teaching and this will contribute to summative assessment. However, in addition to using information from regular learning activities, there may be the need to introduce tasks designed to assess understanding through the application of ideas, and the ability to use skills in a range of contexts.

These tasks need not be externally produced and indeed the main value of ones that are available from publications is to give ideas to teachers so that they can develop their own. Examples of useful approaches are:

- A set of questions written round one theme. Children can be asked to write their ideas for planning investigations, how to interpret given data, how to explain some findings that are described, etc all in relation to the same theme.
- Using concept maps to explore children's understanding of links between things. Concept maps are diagrammatic ways of representing relationships between words. For example the map in the figure (from Harlen, 1996) was drawn by 6-year-old Lennie, using words relating to his ideas about heat and its effects on various things. The words were supplied by the teacher and were ones that she knew that Lennie had encountered. Some teachers write the words on cards so that the children can move them around whilst they are thinking about how they are related to each other and then draw the arrows and the words that link them. Reading the maps produced in this way helps a teacher to know what ideas have been formed. For example, Lennie has some useful ideas about the effects of heat but has not distinguished heat from temperature.



- Developing a 'circus' of small practical tasks designed to address particular criteria. These tasks are sometimes designed so that children at various levels of development can tackle them and their level of achievement is determined from the response. Alternatively they can be more targeted so that children can answer them when they have reached a particular level.

Introduced as part of their work, children invariably enjoy the change and challenge that these activities provide. As well as providing the additional information that teachers need to report on progress, they also give a great deal of information that can be used in planning later topics and activities.

Formal Testing (double module)

WORKSHOP LEADER'S NOTES

Aims

This double module aims to develop an understanding of testing for the purpose of summative assessment. It is particularly concerned with the development of items which go beyond testing the recall of information. It considers the features of items which test process skills and the understanding of concepts.

Objectives

1. Ability to distinguish between questions which assess ability to recall facts and those which test understanding of ideas through application.
2. Identification of the characteristics of questions which assess process skills and understanding.
3. Knowledge of how to mark open questions.
4. Ability to devise questions to assess specified process skills and understanding.

Note

This module is described as 'double' since it requires at least twice the time of any other module. It could be extended further still if there is the opportunity to extend Task F5 sufficiently to produce items good enough to be tried out with children. Each item has to be thoroughly discussed and revised until it is unambiguous and appropriate to the children. (If it is possible to conduct a school trial, each group of participants might concentrate on refining its two best items for this purpose, giving a test of about 12 items long.)

Task F1

Organisation: Participants in groups of about four.

Materials needed: Task F1, Resource 12.

Time: Allow at least 10 minutes for the task and 20 minutes for plenary feedback.

Instructions: Tell the participants to:

- First answer each of the items.
- Then consider what skill, idea or factual knowledge they were using in answering each one.
- Identify an appropriate age group for each item.

Task F1

Read the three test items in Resource 12 and answer them. Then decide, as a group:

(i) What skill, idea, or factual knowledge is being assessed by each item?
(ii) For what age levels are these items suitable? What are the reasons for your suggestions?

Plenary discussion

Ask one group to report on answers to both i) and ii). Then invite comments, not full reports, from other groups.

Points to emphasise

- The difference between recall (item 1) and application (item 2).
- Although item 3 also involves the idea of dissolving, this is used as a context for a question which requires an investigation to be planned. Answering depends on being able to plan a controlled investigation not on the understanding of dissolving.
- Comparing item 1 and items 2 and 3 should lead to a discussion of the pros and cons of multiple-choice formats (see background information).
- Age appropriateness is determined by the presentation and wording of the item as well as the ideas and skills involved.

Task F2

This takes the activity introduced in Task F1 much further. It is an important exercise in analysing test items as a basis for creating items to test process skills and the understanding of ideas.

Organisation: Participants work in pairs for 40 minutes to complete the activity for all the items in Resource 13. Then they move into groups of four to compare responses and identify points of disagreement for a further 15 minutes.

Materials needed: Task F2, Resource 13.

Time: Allow at least 40 minutes for the task in pairs and 15 minutes in groups in preparation for plenary feedback (which may take a further 45 minutes).

Instructions: As for Task F1. This task extends the range of items to be considered and opens up new points for discussion.
Tell the participants to:

- Try to pick out the main skills or ideas that are assessed, not all that are possible. This is particularly relevant in relation to 'observation' and 'communication' which can often be thought to be assessed in all items. These skills should only be listed when they are the main ones.
- Decide whether knowledge or application of the content is being assessed.This is a essential since all the items have to be about some content. Suggest that the participants ask themselves: '*Could this be answered without more knowledge of the content than is given?*' If so then it is not testing that knowledge.

Task F2

For each test item in Resource 13, decide what idea(s) and process skills(s) are being assessed and for what age level it is appropriate? Work in pairs and complete a table of the following kind:

Item	Idea(s) assessed	Process skill(s) assessed	Appropriate age
1			
2			
3			
4			
5			
6			
7			
8			

Plenary discussion

Ask the first group to finish. Write their table of answers on an OHP transparency, or a large sheet of paper, or a blackboard, according to what is available. Begin the plenary feedback by asking for additions or changes to these responses. Where something is challenged, ask for the reason and discuss it. Also invite criticisms of the items but at the same time ask for suggestions of how they might be improved.

Points to emphasise

- Some areas of disagreement about what is assessed can probably be sorted out by referring back to the advice given in the instructions, that is to identify the main skill and to consider whether the question requires the child to use conceptual knowledge gained previously in order to answer the question.
- Other disagreements may reveal different understandings of the meaning of certain process skills, since items show the skills in operation. There are genuine differences in views of, for example, the meaning of an 'hypothesis'. It is important to talk them through. Reference to background information for Module D may help.
- What is assessed depends as much on what is given credit in marking as on the question. Thus the marking scheme must reflect the intentions of the item. At the same time the 'wrong' answers have value for the teacher in giving clues to children's understanding and in teacher-marked tests, these should be noted.
- Marking can be seen as a problem where children give open answers . This is a link to Task F3.

Task F3

Organisation: Participants in groups of four to six.

Materials needed: Task F3, Resources 13 and 14.

Time: Allow at least 20 minutes for the two parts of the task and about 15 minutes for plenary feedback.

Instructions: Tell participants to:
- Refer back to item 2 in Resource 13.
- Read the answers which were written by some 10-year-old children.

Task F3

Work as a group. Read the answers (Resource 14) given by some 10-year-old children to item 2 in Resource 13.

(i) Can you mark each of these answers as 'correct' or 'incorrect'?
If not, which do you think deserves most marks? Which deserves least marks? Why?

(ii) Devise a mark scheme for this question.

Plenary discussion

Ask one group to give its answers to sub-task (i). Children's answers are rarely wholly correct or wholly incorrect. Discuss each answer in turn. Provided we can define categories which are sufficiently clear and distinct from each other, graded marks can be given.

Ask groups to give their answers to sub-task (ii) briefly. If no-one suggests a scale, propose and discuss the idea of giving:

2 marks to b);
1 mark to d) and to a);
0 marks to c) (since it does not answer the question).

Points to emphasise

- The mark scheme and the question should be designed together. If a fair scheme cannot be devised, then the question may need to be reworded to indicate more directly what kind of answer is intended. For instance it may well be argued that answer c) *does* answer the question in the eyes of a child. However we can't be certain that the child who gave it had noticed the pattern in the span and number of coins. Thus the link between the mark scheme and question is seen to be crucial and it is important for the two to be considered at the same time.
- It is not necessary to give numerical marks to the different kinds of answer. The answers could be assigned to qualitative categories, given labels A, B, C, etc or whatever. This enables differences between different kinds of answers to be noted without suggesting that some are 'better' than others. It is possible to count the number of answers of the children in each category and to use this information in relation to some overall criteria. When numbers are used and totalled it isn't possible to know whether a score of 10 was made up of three 3s, a 1 and a 0 or five 2s.

Task F4

Before introducing Task F4 it is useful to distribute Resource 15. This gives a brief overview of the way in which items for testing process skills and conceptual understanding are constructed. Allow time for reading and then review the items in Resource 14 to see to what extent they 'fit' the generic descriptions. Making this link will help participants use the descriptions in Resource 15 in this next task.

Organisation: Participants work in pairs.

Materials needed: Task F4, Resource 15.

Time: Allow at least 40 minutes for the task in pairs to produce first drafts of the items.

Instructions: Tell the participants they are to:

- Draft three items, with their mark schemes, according to the specifications.
- Be prepared to defend their approaches and, whilst it is recognised that polished products can't be produced in the time, the items should be ones they consider useful in practice.
- Choose the format (open or multiple-choice) for themselves.
- Write their items on large sheets of paper or on overhead projector transparencies.

Task F4

Devise a test item and mark scheme to assess each of the following specifications:

(i) An item using the context of the conditions needed by plants for life and growth and testing the process of controlling variables, suitable for 8/9 year-olds.

(ii) An item applying simple ideas about forces suitable for 7/8 year-olds.

(iii) An item using the context of shadows and testing the process skill of predicting, suitable for 9/10 year-olds.

Plenary discussion

Discuss each question and mark scheme and criticise constructively with a view to writing better second drafts. This may be done as part of the next task in this module.

Points to emphasise

- Avoid questions which depend both on process skills and the use of prior knowledge. It will not be possible to know if failure is due to lack of the skill or the idea or both. This may not matter if an overall score is computed, but it is more helpful to have sub-scores for skills and understanding of ideas.
- In general a single question is not enough to test a process skill, since its use is influenced by the content (even if knowledge of this content is not required). Ideally several questions, spread across different contexts should be used for each skill.
- Avoid gender bias in selecting the content and context (ie situations commonly associated mainly with the activities of either boys or girls but not both).
- Avoid questions that could be answered by recall without either applying concepts or using process skills.
- It is useful to use the same context or subject matter to ask several questions so that the children don't have to read too much for each question. For instance the example for testing the understanding of concepts in Resource 15 could be the basis for a process skill question such as:

> *"If the snails had not moved in straight lines, how would you have measured the distance they had moved?"*

This would be a useful question in a test where both skills and concepts were being tested because answering this does not depend on answering the other questions in the item correctly. It should be marked separately, however, and not as part of the concept-based question.

Task F5

Organisation: Participants in pairs.

Materials needed: Task F5, Resource 15, locally used curriculum or syllabus.

Time: This activity can take as long as is available. If time is limited allow about 60 minutes workshop time and ask for other items to be created outside the workshop.

Instructions: Tell participants to:

- Draft items and mark schemes which could be used in schools in their locality for pupils in the fifth or sixth years of primary school.

Task F5

Select a part of the current science curriculum for pupils in the fifth or sixth year of primary school and prepare items to assess understanding of the relevant ideas and the skills that are intended to be developed. Prepare mark schemes for these items in a suitable form.

Plenary discussion

This can take the same form as for Task F4. It may be useful to add to the earlier point about using the same context/subject matter for several questions. When a test is being created, it is often possible to use the same context (situation) and to ask separate questions requiring process skills to be used. (See the example at the end of background information) Although this reduces the amount of reading it increases any bias that may be associated with this context.

The development of questions is not complete until they have been tried out with children. If possible arrange for this as part of the workshop, using a nearby school. If not, ask participants to try them with children between sessions of the workshop and bring the responses to the next session.

Points to emphasise

- It is the mark scheme which will ultimately determine what is given credit. Thus it is very important to develop this at the same time as the item. In the case of open-ended questions it is helpful to do this in two phases. First produce a draft mark scheme, then try out the items with children and adjust the scheme as necessary. Often children produce types of answers which are not at first anticipated and may make a difference to what is considered worthy of marks.
- The question should give some indication to the children as to what is expected as an answer. For example if 'similarities and differences' are asked for, then specify the number expected and create the mark scheme to fit. Again, in a planning question, if the mark scheme gives credit for mentioning, say, equipment to be used and how the results will be calculated, then make this clear in the question: e.g. 'Make sure you say: what you will use, how you will use it, and how you will decide the result...'

Background information

There are two main ways of arriving at a summary assessment of children's achievement at a particular time. One is by forming a summary of the records of on-going assessment; the other is by 'checking up' through giving some special tasks, or test items, which are designed to find out the extent to which children have developed certain skills and ideas. Ideally both would be used, so that the special tasks become checks for the teachers' assessment based on records of formative assessment.

As discussed in Module E, summarising can preserve the detail of the on-going assessment and enable summary statements to be made about progress during the period in question over a wide range of ideas, skills and attitudes. At the same time two less favourable aspects need to be considered: first, that some of the information may be out of date if areas of work at the beginning of the year have not been revisited later; second, that it may be difficult to produce a descriptive summary which enables pupils' achievement to be compared, for their opportunities may have varied.

Checking up has the attraction of providing apparently equal opportunities for children to show what they can do at a particular time, although necessarily over a reduced range of experiences. However, it must be remembered that giving children the same tasks is not the same as giving them the same opportunities since learning opportunity implies a match between the task and the child's ability to engage with it. In other words, children who have developed the ability being tested may not be able to show this in the test situation.

Issues relating to tests

Here we consider the approach to summative assessment of giving special tasks or tests. In doing so their disadvantages should be kept in mind:

- They have low validity since the tasks are restricted to those which can be done in the test context.
- There is a restricted range of skills and ideas that can be included, partly because of the limitation on the length of a test and partly because some skills are only revealed in extended activities.
- They require considerable teacher time for organisation and marking.
- They take up learning time.
- They can induce anxiety in children.

To minimise the disadvantage in terms of validity the test items must cover the full range of skills and ideas that are the goals of science education, but in less detail than in the case of formative assessment. This means that it must go further than testing a knowledge of facts, which is always relatively easy. For example:

What is the boiling point of water?	
A	0°C
B	32°C
C	90°C
D	100°C

What is the name of the part in the centre of the eye through which light passes?

Would these items really tell us anything about children's scientific development? The knowledge of facts is a means of building broader generalisations, the ideas or concepts which constitute the more important knowledge that children need to make sense of their environment. Testing knowledge of facts must not replace testing the understanding of

ideas; this shows in the ability to apply the ideas in situations other than those in which they were learned.

For checking on children's developing ideas the important aim is to ensure that children are applying their ideas, working out their answer from their own thinking rather than simply recalling it. The decision as to what children are likely to be able to recall and what they will have to work out depends on the experiences of the children. For some, an answer to the question: *How would you try to stop an ice cube from melting for as long as possible without using a 'fridge?* may require application of ideas about the need for heat to bring about melting and transfer of heat through different materials. For others, however, who may have undertaken such an activity, it may be a matter of recalling what was done and the reasons put forward for it at that time. However there are many variations in ways of ensuring that the application of ideas is required and it should be possible to avoid questions which ask for straight recall of facts or for applications which can be recalled.

Forms of presentation of test items

Test questions are most commonly presented on paper, perhaps using pictures or symbols, and pupils answer by writing or drawing. This is more suitable for assessing ideas or concepts than for process skills. To assess practical enquiry skills it is necessary for pupils to be given tasks to be carried out using real objects and equipment. This is particularly so for assessing the performance of whole investigations.

However, the process of practical enquiry can be divided into component skills, such as planning procedures, identifying variables, making observations, recording findings and drawing conclusions from them. Some of these components lend themselves to assessment on paper and the difficulty of providing practical test situations means that this is an attractive option. Two points must be kept in mind when assessing process skills on paper:

- for a skill to be assessed the pupils must be required to use the skill, not just to show knowledge of how to use it
- being able to perform separate components of investigations in isolation from the whole is not the same as performing a whole investigation from start to finish.

Forms of answering test items

In all assessment the influence on performance of abilities which are not under test should be minimised. So, particularly for young children, it is important that the demand of a question in terms of reading and writing should not prevent them showing what they understand or showing the scientific skills they have. For young children it is helpful for them to be able to respond by drawing, constructing something or carrying out an investigation.

In written questions, one of the popular ways of reducing the burden of writing – and at the same time making marking easy is to provide alternative answers from which the pupil chooses an answer. These multiple-choice tests have many disadvantages, however, in relation to assessing learning in science.

A multiple-choice question takes the form of a 'stem' which is a statement or question and several alternative answers. For example :

Tigers are striped so that they can:
A keep clean
B run faster
C hide easily from other animals
D be seen easily by other animals

Some of the points in favour of such questions are:
- they do not require pupils to write answers and so do not limit pupils' performance on account of writing ability
- they can be marked easily, by hand or by machine
- they can be answered quickly so that several such questions can be asked and a range of different topics covered.

Points against questions in this form include:
- they can often be answered by intelligent guessing or elimination of obviously wrong alternatives (distracters)
- they do not assess what pupils can produce as answers, only their recognition of right answers (plus the ability to eliminate wrong distracters and to 'spot' the signs of correct answers)
- they give no guarantee that the ideas behind the questions have been understood; the right choice might be made for the wrong reason
- they often require more reading than open-ended questions, which is time-consuming and causes difficulty for some pupils
- they are difficult to produce and need careful trials to eliminate ambiguous wording and supposedly wrong answers which turn out to be correct, or vice versa
- young children find this form of question difficult to handle; they often tick more than one answer, however careful the instructions
- they do not test the ability of learners to express themselves, which is an important aspect of science education.

Marking

One of the chief reasons for the introduction of multiple-choice questions was to avoid difficulties in marking. However, all that this did was to shift the balance of difficulty to the writing of the questions. Open questions are much easier to write but more difficult to mark. For example the question above could be expressed in a more straightforward way:

What advantages do tigers get from being striped?

.....

.....

But this would be more difficult to mark. Inevitably pupils will express their ideas in different ways and most answers will be neither wholly correct nor wholly incorrect. There are well established ways of dealing with such answers, which involve establishing qualitative categories of answers. For example, such categories for the open question about the tiger's stripes might be:

i An answer which gives correct reasons making reference to
   - stripes not easily seen in tigers' habitat
   - therefore they can hunt without being seen or attacked

   or • other ways of expressing the idea of camouflage

ii An answer which is correct as far as it goes, but is limited eg the single word 'camouflage'

iii Incorrect answer, eg reference to stripes frightening other animals

iv Not answering the question.

The boundaries of the categories would be derived either from the criteria to be used, if these exist, or from the kinds of answers which can be expected of the children of the age being tested. When the general compass of the categories has been decided it is useful to

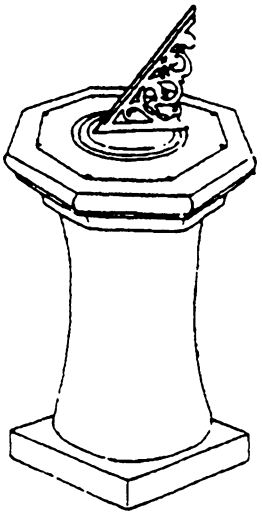
provide examples of answers which would fall into them. So, for instance, a decision would have to be made as to where an answer such as *'it helps them catch their food'* would fall. If illustrative responses as well as descriptions for each category are provided then it is entirely feasible for marking schemes of this type to be used reliably.

For some purposes, it is most useful to report in terms of the qualitative categories. This gives information about the extent to which pupils have achieved certain ideas. For other purposes, marks could be assigned to the categories (eg a = 2, b = 1, c and d = 0).

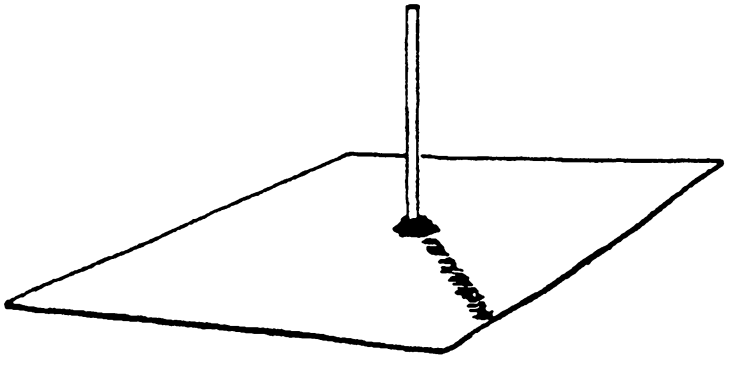
Example of a set of questions on the same theme

(Taken from Hargreaves, et al 1990)

After looking at a sun-dial in an ornamental garden, children made their own:

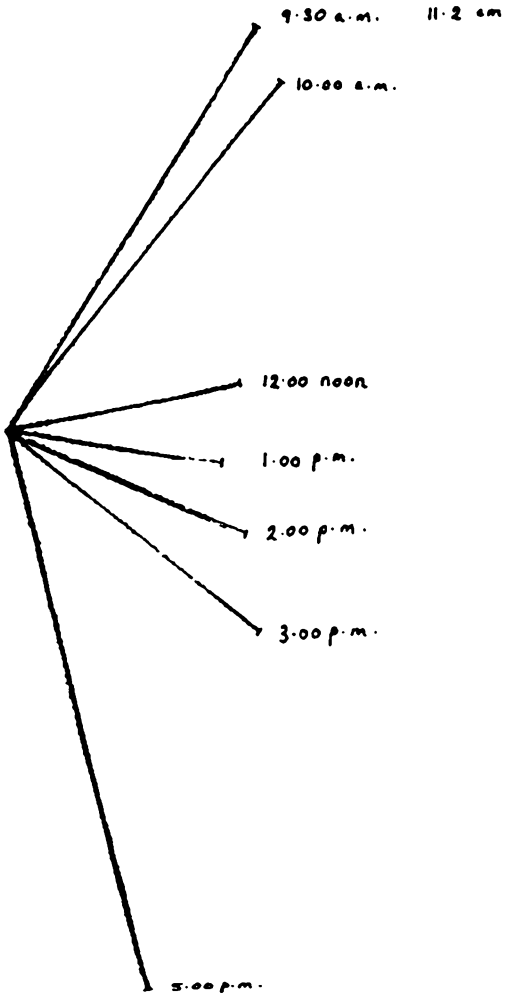


The sun-dial in the garden



The children's sun-dial

The shadows on this page were marked by children during one day in August. They used the sun-dial they had made.



1. Measure the shadow length at each time shown. Write the time and length in the table below.

   The first one has been done for you.

Time of day	Length of shadow in cm
9.30 a.m.	11.2

2. At 4.00 p.m. it was cloudy, so there was no shadow.

   Draw in the shadow for 4.00 p.m. as you think it might have looked.

3. How did you decide where and how to draw the shadow?

Task A1

You need Resource 1

Read the account in Resource 1 of how an investigation about heartbeat rates was planned and undertaken by pupils in the fifth year of primary school. Then, working as a group:

i List all the kinds of information relevant to the children's scientific development that the teacher gained in the events described. (It may help to focus on one child, the one called J.)
ii Indicate how you think these kinds of information were gathered by the teacher.
iii What aspects of development were assessed in these activities?
iv What else would the teacher need to do to assess the children's achievements?

In each case note points about which there is disagreement as well as agreement within the groups. Prepare to report on your answers and discussion to other groups.

Task A2

You need Resource 2

Resource 2 is an account of an activity deliberately devised to provide opportunities for assessing pupils' work in science. Put yourself in the position of the teacher and, with your group, answer these questions:

i What kinds of information would the teacher be able to collect about the pupils?
ii What basis for assessing their performance would be the most appropriate? Consider each of these:
Pupil-referenced – comparing the information with what that particular pupil could do at an earlier time
Criterion-referenced – comparing the information with a specified standard of performance
Norm-referenced – comparing with what is the norm (or average) for pupils of the same age or stage.

Task A3

You need Resource 3

Read the three tasks, A, B, and C in Resource 3 which assess in different ways children's ability to investigate. Then answer these questions and give a reason for your answer in each case. Do this individually and then share your views with the group.

i Which task (A, B or C) do you think is the closest to assessing how well the children can investigate something?

ii Which one gives a result that would be most likely to be judged in the same way by different teachers?

iii Which is the most interesting from the point of view of the children?

iv Which is the most convenient for the teacher?

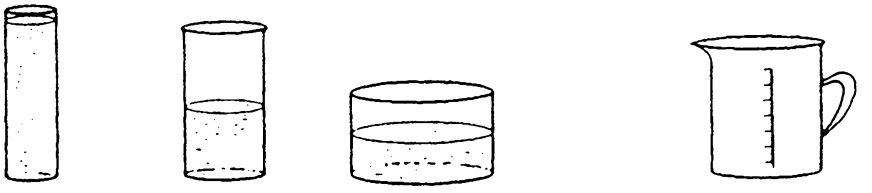
v Which task would be best for finding out what the children would do to investigate, even if the teacher can't let them do it?

Don't forget to give the reason for your choice!

Task B1

First read this episode

An 8-year-old child was given three containers, A, B, and C, as shown and a measuring jug. The child was asked to label them 1, 2 and 3 according to the amount of water in them, giving 1 to the one containing the most and 3 to that containing the least.



A B C Measuring jug

The child's answer was: A = 1, B = 2, C = 3.
The teacher marked A = 1 as correct but the other answers as wrong.

The teacher was puzzled that only the first answer was correct.

She asked the child: "Why do you think all your answers are correct?"
The child replied: "Because I did the same for all of them, I looked at the height of the water level in each one and numbered them."

i Suppose the teacher had not questioned the child to find out why only one answer was correct, what could have been the consequences for the child's immediate learning?

ii If you were the teacher in this situation how would you react to the child? Work with a partner and take turns to role-play the child and the teacher. Write down what you think is the best way of reacting to the child.

Task B2

You need Resource 4 (later Resource 5 will be distributed)

i For each episode in Resource 4, write down what the teacher would be able to assess using the information (s)he could collect in these situations. Brainstorm the ideas in your group onto a chart like this:

Situation	Information obtainable
A	
B	
C	
D	

ii Now consider the examples of criteria for assessing skills, attitudes and concepts of primary children in Resource 5. List the criteria that might be used for assessing in these situations. Complete a chart of this kind:

	Process skills	Ideas	Attitudes
A			
B			
C			
D			

Task B3

First read this episode

One week before a test, 7-year-old children are asked to observe a living spider closely and told that the test will be such that they can answer it well if they have observed the spider well. The children will answer orally or on paper (as a picture or using words).

Working as a group:

i Write five questions to assess how well the children have observed the spider.

ii Imagine you are the teacher. How will you arrange for the assessment to take place? How will you plan the session when the children are giving their answers so that each one can be assessed?

iii Suppose the teacher wants to assess children whilst they are investigating some materials. How could (s)he do this with at least eight groups of children?

Task B4

i In the episode in B3, in what ways might the children take part in assessing their own work and/or each other's work? How might your answer differ if the children were 10 years old instead of 7?

ii How would practice have to be modified in very large classes?

iii What advantages and disadvantages do you see in children taking part in assessment?

iv What examples of children taking a role in their assessment can you give?

Task C1

You need Resources 5 and 6

Working as a group, answer questions (i), (ii) and (iii) and be prepared to share your answers with other groups.

i Read the account in Resource 6. Imagine you are the teacher. By observing the children, what would you be able to find out in relation to the sections in Resource 5 on *observing* and *investigating*

ii To what extent do you think the lists of criteria would help you, as the teacher, in assessing the children's process skills by observation?

iii What are the advantages and disadvantages of assessing children by observing them?

Task C2

You will need a sealed matchbox and Resource 7

i Divide into pairs. Each pair has a sealed matchbox. Neither of you knows what is inside the matchbox. Handle it and form your own ideas of what is inside *without saying anything*. The idea is to find out by questioning what the other person *thinks* is inside. Each person should devise three questions and then take turns to ask each other their questions. Then decide which question(s) were most productive in finding out the other's idea.

ii Work as a group with Resource 7. Read the examples of questions asked of pupils by teachers. Divide them into groups of different *kinds* of questions (ignoring the subject matter). Do this in any way you think makes distinctions between questions that are helpful for the purposes of ongoing assessment and those not so helpful. Be prepared to say what it is that makes some questions more useful for this purpose. Record your result using the numbers of the questions and write these on a large piece of paper.

Task C3

You need a clockwork toy or home-made cotton reel 'tank'. (Later Resource 8 will be distributed)

i Wind up the toy or 'tank', set it moving and watch it for a short while. Then, working alone, make a drawing to show what is happening to make it move in the way it does. Don't label the drawing. Now exchange your drawing with that of your partner. Ask your partner questions to help you understand his/her drawing of how the toy is moving. Then let your partner question you about your drawing. Then add labels and annotation to your drawings that answer the questions you have been asked.

ii As a pair, exchange your annotated drawings with another pair and see how well you can understand their drawings from the start after they have been annotated. Look at the examples of children's drawings in Resource 8. What can you tell about the children's ideas from these drawings? Discuss how you would set up the tasks for these children so that they annotated their drawings to show their ideas.

Task C4

i Working alone, for no more than 5 minutes, write down your ideas about the answer to this question:
Why do you think our hearts beat more quickly during and just after exercise?

ii Exchange your writing with that of your partner. Consider whether this helps your own understanding and answers any of your questions.

iii Discuss as a group the implications of this for asking children to write in science and the use made of their writing in class activities.

vi Reflect on the experience of working in a group in the tasks in this module:
- How well did the group work together?
- What were the reasons for this (working well or not)?
- How did you feel when working alone at the beginning of this task compared with sharing ideas?
- What was achieved by working with others that could not have been achieved by working alone?

v Discuss the implications of the group interactions for the performance and learning of individuals. Is there a case for assessing a group of children as a whole in a particular activity?

Task D1

You need Resource 9

The lesson on fabrics in Resource 9 is described as having three phases:
exploratory phase
investigation phase
reporting and reflecting

i Identify the information relating to assessing skills, attitudes and understanding that the teacher could gather about the pupils in each of these phases.
ii Identify where the teacher used information from assessment immediately in the progress of the activity and in his planning.
iii What other information might the teacher have gathered and used during this lesson?

Task D2

You need Resources 1 and 5

i Read Resource 1 (or look at it again if you have already done so) and decide what you can tell about child C's achievement in the skills and attitudes in Resource 5.

If you don't think there is any evidence, leave a blank. Complete the first column of a table such as that below.

ii Suggest what the teacher should do to help C development of the skills and attitudes for which there is information about achievement. Give as much detail as you can.

	Achievement shown	Action by the teacher
Observing		
Explaining (hypothesising)		
Predicting		
Raising questions		
Planning and conducting investigations		
Interpreting (drawing conclusions)		
Communicating		
Respect for evidence		
Flexibility		
Critical reflection		

Task D3

You need Resource 10

Look at the examples of children's writing and drawings in Resource 10.

For each one consider:
- the evidence in relation to whether the child has understood the idea that is stated as the aim
- what action the teacher should take to help further development.

Complete the following table:

Example	Evidence related to aim	Action by the teacher
A		
B		
C		

Task E1

You need Resources 5 and 11

Look at the methods of recording of Teachers 1, 2, 3, and 4, in Resource 11.

Working in groups of four:

i Three of the main purposes of record keeping are:
a keeping track of the achievements of the children
b helping the teacher's planning to match the children's achievements.
c keeping track of the activities completed by the children.
Consider the advantages and disadvantages of the methods used by Teachers 1, 2, 3, and 4 for each of these purposes.

ii What advantages and disadvantages are there of involving children in keeping records? What part could the children have in keeping these records?

iii How might these records be modified to make recording practicable with very large classes?

iv Would these kinds of records be useful for other subjects in the primary school? What would be the advantages and disadvantages of incorporating science with other subjects in a single record?

v What other forms of record are used by members of the group? What are their advantages and disadvantages for purposes **a**, **b** and **c**?

Task E2

You need Resources 5 and 11

Consider again the records in Resource 11 but this time to decide how the information for each child could be summarised to provide an assessment of achievement at the end of term or of the school year. This is the summative assessment that would be the basis of an end-of-year report to parents and would be passed to the child's next teacher.

i For each of the records answer these questions:
a How might the teacher go about producing a summative assessment from the ongoing record?
b What form could the summative assessment take?
c How reliable do you think the assessment would be?

	How to produce the summative assessment	Form of the summative assessment	How reliable?
Teacher 1			
Teacher 2			
Teacher 3			
Teacher 4			

ii Consider how the process of producing end of term/year reports could be streamlined to help teachers of very large classes.

Task E3

The Head Teachers of the schools where Teachers 5, 6 and 7 teach were not confident that a fair summative assessment could be derived from the records of ongoing assessment. They therefore obtained a collection of test items and practical tasks which could be used at the end of each year to provide the summative assessment. The test items and tasks had been tried out and analysed so that they could be labelled according to the skills and understanding of ideas they assessed.

In the school of Teacher 5, selections of the items and tasks were put together to make tests suitable for each age level. The tests were rather similar to the children's normal work and so there was no feeling of being tested. The children took the tests at the end of the year, the teachers marked them, using the mark schemes provided and the total score for each child obtained in this way formed the summative assessment.

In the school of Teacher 6, the Head Teacher told the teachers to use their judgement and their ongoing records to decide whether certain criteria had been met. They were then to select appropriate tasks and test items and use these as part of the children's activities, to check their own judgements. Where there was disagreement, teachers looked again at the evidence from both sources and refined their view of how to judge certain kinds of achievement.

In the school of Teacher 7, there was a combination of externally produced tests, marked by the teacher, and assessments based on the teacher's ongoing records. The tests were given 30% of the marks and the teacher's assessment 70% per cent.

In pairs:

i List the strengths and weaknesses of the approaches used in the schools of Teachers 5, 6 and 7.

ii Identify the conditions in which you would use each of these approaches. Give your reasons.

Join with another pair and identify any points of disagreement. Be prepared to report these.

Task F1

You need Resource 12

Read the three test items in Resource 12 and answer them. Then decide, as a group:

i What skill, idea, or factual knowledge is being assessed by each item?

ii For what age levels are these items suitable? What are the reasons for your suggestions?

Task F2

You need Resource 13

For each test item in Resource 14, decide what idea(s) and process skills(s) are being assessed and for what age level it is appropriate? Work in pairs and complete a table of the following kind:

Item	Idea(s) assessed	Process skill(s) assessed	Appropriate age
1			
2			
3			
4			
5			
6			
7			
8			

Task F3

You need Resource 14

Work as a group. Read the answers (Resource 14) given by some 10-year-old children to item 2 in Resource 13.

i Can you mark each of these answers as 'correct' or 'incorrect'?
If not, which do you think deserves most marks? Which deserves least marks? Why?

ii Devise a mark scheme for this question.

Task F4

You need Resource 15

Devise a test item and mark scheme to assess each of the following specifications:

i An item using the context of the conditions needed by plants for life and growth and testing the process of controlling variables, suitable for 8/9 year-olds.

ii An item applying simple ideas about forces suitable for 7/8 year-olds.

iii An item using the context of shadows and testing the process skill of predicting, suitable for 9/10 year-olds.

Task F5

You need your local curriculum planning document for science

Select a part of the current science curriculum for pupils in the fifth or sixth year of primary school and prepare items to assess understanding of the relevant ideas and the skills that are intended to be developed. Prepare mark schemes for these items in a suitable form.

Resource 1

As part of the topic "Ourselves" a class was studying the circulation of the blood. The teacher asked:

"What do you think your blood does?"
"How do you think it moves around your body?"

In the discussion of ideas that followed the children began to press their hands on their chests and to feel their hearts beating.

The teacher asked if they knew of any other way of finding out about their heartbeat. J suggested feeling the pulse at the wrist and the teacher showed them how to feel the pulse in the neck. They began to count the beats, but before they timed them, the teacher asked them:

"How many times do you think your heart will beat in a minute?"

Their predictions ranged from 50 to 80 beats a minute. J suggested 60 per minute. Then they began to count the beats, timing with a watch that had a minute hand. They put their results into a table (see J's results).

From the table they noticed that S had the slowest heartbeat. S was the smallest in the group. They thought that the heart beat was related to size, increasing with a person's size. They decided to take the teacher's heartbeat to see if this was right. Their prediction was that the teacher's heartbeat would be higher than any of the children's. C wrote his prediction and the reason for it:

"I think Sir's heart beats 89 times because the blood takes longer to travel round the body."

The children discussed whether an adult's heartbeat would be different for other reasons, such as age.

The teacher asked them if they could find out if size affects the heartbeat. The children decided that they needed to measure height and weight. They chose to measure height with a metre measuring stick and to use bathroom scales (marked in stones). For each measurement the teacher asked the children to make a prediction before using the stick or scales. See J's report of his investigation, results and conclusion.

After the investigation the teacher explored the children's ideas about the circulation of the blood and their ability to investigate by asking them to write the answers to these open questions:

1. During and after exercise your heartbeat goes up more quickly than when you are not moving. Why do you think this is? Write down as many reasons as you can.

2. How much does your heartbeat change when you have been running hard compared with sitting still? How would you find out? Make a list of all the things you would do, in the order you would do them, to answer this question.

J's report of his investigation of heartbeat rates

We are going find out if older peoples heart beats are faster or slower

I think Sirs heart will beat 78 times a minute

We found that Sirs heart beats 71 times a minute

We are going to weigh and measure each other and see if height make a difference

J	63 beats
S	50 beats
M	65 beats
C	65 beats
Sir	71 beats

Name	Estimate	Answer
J	154	147
S	120	129
M	140	134
C	150	147
Sir	195	171

Name	Estimate	Answer
J	6stone	7stone
S	4stone	4stone
M	5stone	5½stone
Sir	9stone	11½stone
C	6½stone	7stone

I think that height and weight have nothing to do with it because C and M have the same heart beat but they're not the same height or weight.

Resource 2

As part of a study of camouflage in animals the teacher asked pupils to design and carry out an investigation of whether the pattern of the coat made animals less easy to see against a certain background.

The children worked in groups. They cut out the shapes of animals and painted them to represent a tiger, a leopard, a zebra and a lion. They used books to find out about the habitats of these animals and then painted different background pictures to represent them. They had to decide for themselves how to carry out the investigation.

When all the groups had finished, each group presented their findings to the others. The teacher encouraged them to question each group about the methods and materials they used and how they reached their conclusions.

The teacher assessed the children during their group work and the presentations, noting what questions they asked as well as how they answered each other's questions.

Resource 3

These are three tasks for assessing pupils' ability to investigate.

Task A

Suppose you want to find out which of two strips of wood will bend more easily. Which of these things would be best to do? Tick one.

1. Try bending them with your hands and feel which easier to bend. ☐
2. Find out what kinds of wood they are and then use a book to tell you the answer. ☐
3. Support the ends, put a load in the middle and see how much each one bends under the same load. ☐
4. See which one is easiest to hammer a nail into. ☐
5. Clamp each one to a table so that the same length overhangs. Then hang weights on the end to bend them. ☐

Task B

Describe what you would do to find out which of two pieces of wood was more bendy.

Say what equipment you would use (you can choose anything you like), what you would do and how you would find the result.

.....

.....

.....

.....

Task C

You have two pieces of wood and some equipment in front of you. Use these things to find out which of the pieces is the more bendy.

Resource 4

Episode A

As part of the study of creatures in their environment the teacher planned this activity in order to assess various aspects of the children's development in science.

Each child was given a creature to study and the task of finding out as much as possible about it over a certain period of time. The children could use books, observe the creature, ask adults, look at pictures, etc. The children also made a mask to represent their creature.

The whole class then came together and the children in turn put on their masks and told the other children all about 'themselves' as their creature. When each 'impersonator' had finished describing herself/himself, other children asked questions of the child about the creature being represented. The idea was not to guess what the creature was but to share information about it.

Meanwhile the teacher observed and assessed both the pupil answering and those asking questions.

Episode B

A teacher set up a display of materials and instruments that could be used to make pitched sounds. The 8-year-old children were given opportunities to observe and experiment with the materials and encouraged to find how to make sounds of different pitch from one object (such as a bottle with some water in it, or a rubber band stretched across a wooden box). The children were told to draw and write about what they found and the teacher assessed how they worked, as well as their written work.

Episode C

There are some sayings about the weather, that:

If the sky is red at sunset the weather next day will be dry.
If the sky is red at sunrise there will be rain later that day.

The problem given to a class of third-year children was to plan what they would do to test the truth of these sayings.

Episode D

Children in a fourth-year class in a rural school were asked to try out at home various ways of accelerating the decay of leaves to make compost. They were expected to keep records of what they did. At the end of the period of time allowed they were asked to present their findings to the class in any way they liked and they were assessed on the presentations.

Resource 5

Examples of criteria for assessing process skills

Observing

Do the children:

O1 succeed in identifying obvious differences and similarities between objects and materials?

O2 make use of several senses in exploring objects or materials?

O3 identify differences of detail between objects or materials?

O4 identify points of similarity between objects where differences are more obvious than similarities?

O5 use their senses appropriately and extend the range of sight using a hand lens or microscope as necessary?

O6 notice patterns, relationships of sequences that are to be found in a series of observations?

O7 distinguish from many observations those which are relevant to the problem in hand?

Explaining (hypothesising)

Do the children:

H1 attempt to give an explanation which is consistent with evidence, even if only in terms of the presence of certain features or circumstances?

H2 attempt to explain things in terms of a relevant idea from previous experience even if they go no further than naming it?

H3 suggest not only *what* but *how* something is brought about, even if the 'how' would be difficult to check?

H4 show awareness that there may be more than one explanation which fits the evidence?

H5 give explanations which suggest how an observed effect or situation is brought about and which could be checked?

H6 show awareness that all explanations are tentative and never proved beyond doubt?

Predicting

Do the children:

P1 attempt to make a prediction relating to a problem even if it is not derived from the evidence?

P2 make some use of evidence in making a prediction, rather than basing it on pre-conceived ideas?

P3 make reasonable predictions which fit the evidence without necessarily being able to make the justification explicit?

P4 explain how evidence has been used in making predictions?

P5 perceive and use patterns in information or observations to make justified interpolations or extrapolations?

P6 show caution in making assumptions about the generalisation of patterns beyond the evidence available?

Raising questions

Do the children:

Q1 readily ask a variety of questions which include investigable and non-investigable ones?

Q2 recognise the difference between an investigable question and one which cannot be answered by investigation?

Q3 realise when an investigable question is in a testable form?

Q4 generally, in science, ask questions which are potentially investigable?

Q5 quite often express their own questions in testable form?

Q6 ask questions which arise from making a prediction or giving an explanation that can be tested?

Investigating

Do the children:

I1 start with a useful general approach even if details are lacking or need further thought?

I2 have some ideas of the variable that has to be changed or what different things are to be compared?

I3 keep the same the things which should not change for a fair test?

I4 have some ideas beforehand of what to look for to obtain a result?

I5 choose a realistic way of measuring or comparing things to obtain the results?

I6 take steps to ensure that the results obtained are as accurate as they can reasonably be?

Interpreting (concluding)

Do the children:

Int 1 discuss what they find in relation to their initial questions?

Int 2 compare their findings with their earlier predictions?

Int 3 notice associations between changes in one variable and another?

Int 4 identify patterns or trends in their results?

Int 5 check any patterns or trends against all the evidence?

Int 6 draw conclusions which summarise and are consistent with the evidence?

Int 7 recognise that any conclusions may have to be changed in the light of new evidence?

Communicating

Do the children:

C1 talk freely about their activities and the ideas they have, with or without making a written record?

C2 listen to others' ideas and look at their results?

C3 report events in drawings, writing, models, paintings?

C4 use tables, graphs and charts to record and report results when these are suggested?

C5 regularly and spontaneously use information books to check or supplement their investigations?

C6 choose a form for recording or presenting results which is both considered and justified?

Willingness to collect and use evidence (respect for evidence)

Do the children:

RE1 report results which are supported by evidence even if the interpretation is influenced by preconceived ideas?

RE2 realise when the evidence doesn't fit a conclusion based on expectations, although they may challenge the evidence rather than the conclusion?

RE3 check parts of the evidence which don't fit an overall pattern or conclusions?

RE4 accept only interpretations or conclusions for which there is supporting evidence?

RE5 show a desire to collect further evidence to check conclusions before accepting them?

RE6 recognise that no conclusion is so firm that it can't be challenged by further evidence?

Willingness to change ideas in the light of evidence (flexibility)

Do the children:

FL1 readily change what they say they think, though this may be due to a desire to please rather than the force of argument or evidence?

FL2 change ideas when there is considerable evidence against the existing ones and little in their favour?

FL3 show willingness to consider alternative ideas which may fit the evidence, even if they prefer their own in the end?

FL4 relinquish or change ideas after considering evidence?

FL5 spontaneously seek other ideas which may fit the evidence rather than accepting the first which seems to fit?

FL6 recognise that ideas can be changed by thinking and reflecting about different ways of making sense of the same evidence?

Willingness to review procedures critically (critical reflection)

Do the children:

CR1 review what they have done after an investigation even though they may only justify rather than criticise it?

CR2 consider some alternative procedures which could have been used without necessarily realising their advantages and disadvantages?

CR3 discuss ways in which what they have done could have been improved even if only in detail?

CR4 consider, when encouraged, the pros and cons of alternative ways of approaching a problem to the one they have used?

CR5 initiate a review of a completed investigation to identify how procedures could have been improved?

CR6 spontaneously review and improve procedures at the planning stage and in the course of an investigation as well as after completion?

Resource 6

The teacher of a class of 8 –10 year old children began work on dissolving by asking who in the class put sugar in their tea. She took some water, put a small amount of white sugar into it and stirred. She did not use the word 'dissolve' herself but asked the children to say what had happened to the sugar. Some said it had 'disappeared', but on questioning they admitted that the sugar was still there. Others used the word 'dissolve' and she asked them to give examples of other things which they thought dissolved.

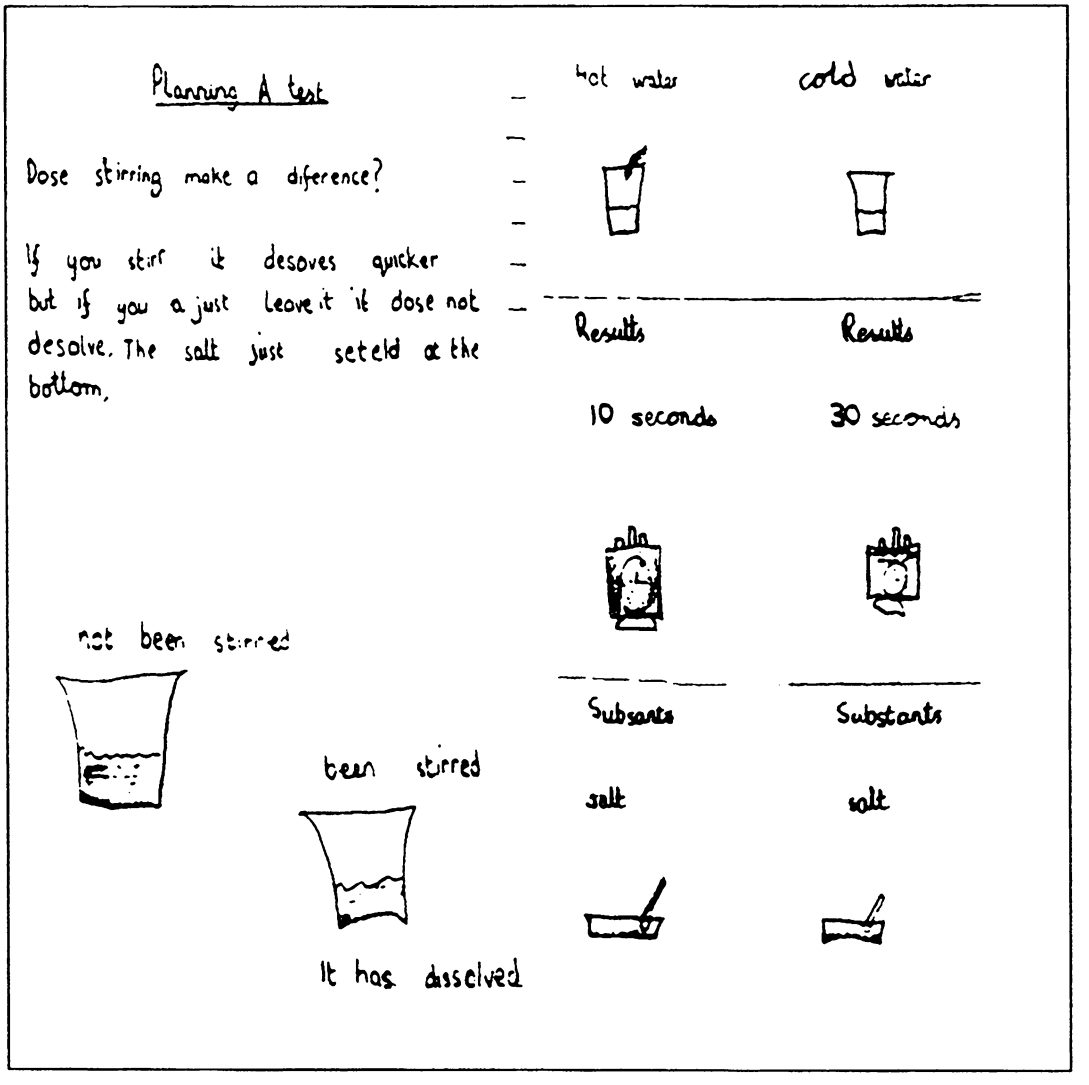
Then the teacher gave instructions for the children to begin group work. They were each given four substances (not the same for all groups) and were asked to find out if each dissolved, did not dissolve, or whether they could not tell. A's group produced this record:

Name of Substance	Dissolves	Does not dissolve	Not sure if it dissolves	Colours the water
brown sugar	yes			water change
OXO cube	almost			water change to light brown
salt	yes			✓
flour		yes		

The class was brought together to report their results. Differences between one group and another were explored. Some thought that they could tell if a substance partly dissolved and were challenged to say how they judged this.

Then the teacher asked them for ideas about how to make things dissolve more quickly. She accepted all their ideas and told them to try them out, using just one of their substances. The children were told to draw up a plan for their investigation, then do it and to keep records so that they could report to the whole class later. See the plan and record of A's group on the next page.

Plan and record of the investigation by A's group



Resource 7

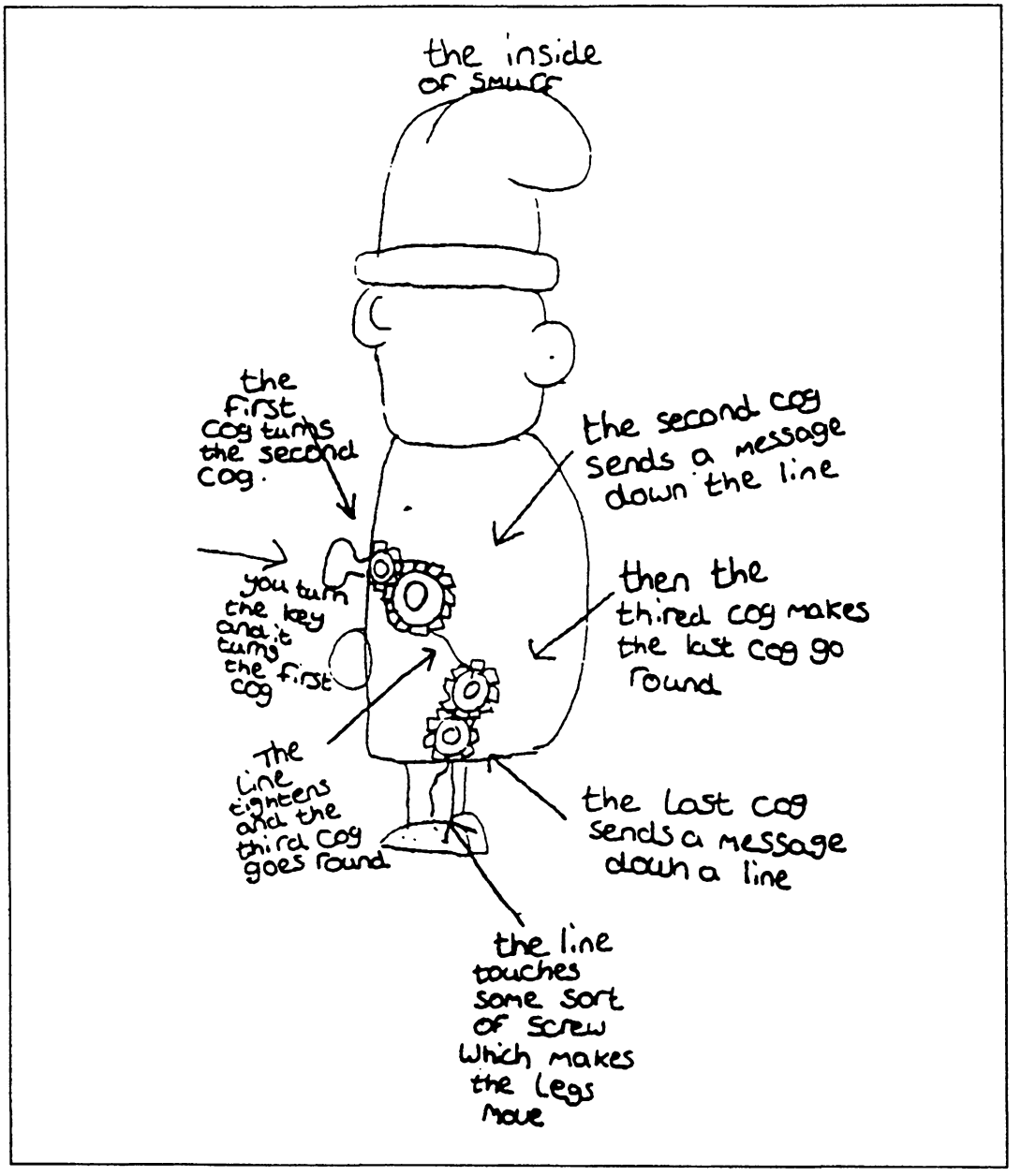
Some questions asked by teachers:

1. What are the differences between fruits and seeds?
2. Why do you think these (sycamore fruits) have these 'wings'?
3. What would you like to find out about these animals?
4. Why do heavy lorries take longer to stop than lighter lorries?
5. What happens when you put the stones in water?
6. What kind of metal are magnets made out of?
7. What do you think makes the flash of lightening appear before you hear the sound?
8. Why do you hear an echo under a bridge but not outside?
9. What do you think a seed needs to help it to grow?
10. How long does the Moon take to go round the Earth?
11. Do you think the rabbit likes the potato best or the carrot?
12. What makes the colour of the stones seem brighter when they are wet?
13. What is the part of a plant that is below ground?
14. How does soil help a plant to grow?
15. What do you think makes toffee sticky?

Resource 8

Children's drawings

Drawing 1

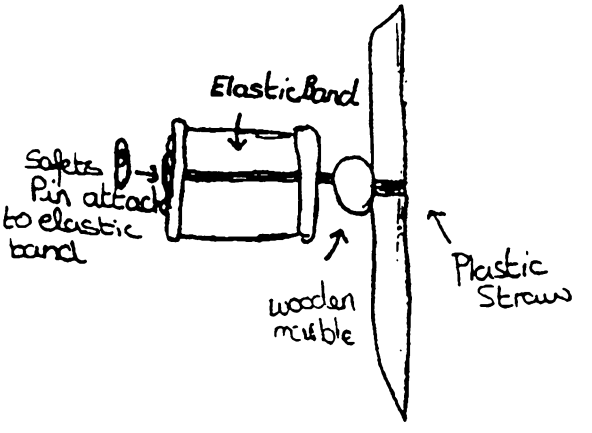


Drawing 2

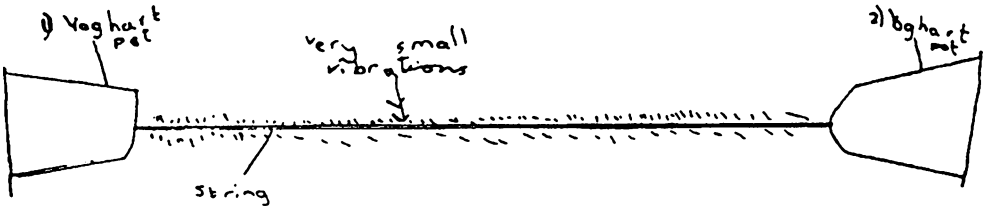
The cotton reel thing

It works by when you twist the plastic straw which is attached to the ~~plastic~~ elastic band, so when you twist the elastic band and put it on ground or water it moves I think it would work better in water because when you put on the ground its got the ground to hit it but when you put it in water it hasen't.

It stops because when you have twisted it the elastic band has just stopped twisting it has run out of that ergey



Drawing 3



The voice went to the string and were then transfered into vibrations which went down the string and when it got to the other yoghart pot (2) and were then transfered back to a voice.

Resource 9

The activities in this example took place with a class of third year primary children within an overall topic about clothing. The teacher planned that the children should discuss and investigate the selection of different fabrics for different purposes. He had in mind that the children should undertake some investigations of different fabrics, so he provided a collection of suitable pieces of fabric, etc, to which the children contributed. He wanted the investigations to advance the children's ideas and therefore to be based on their ideas and questions. It would have been easy to ask, for instance: *Which is the most waterproof material? Which is the most wind-proof?*, etc. and to start the children's investigations from these questions. These are perfectly good questions for children to investigate and likely to be among those the children ended up investigating, but he wanted to hold back his questions to find out what the children would ask and what ideas they had.

So the first part of the work was an *exploratory phase* of looking at the range of fabrics. In groups, the children were given samples of the fabrics, some hand-lenses and some very open instructions: to put the pieces of material into groups according to what they could be used for and then to explain what is the same about the items in each group and how the groups differ from each other. This task required children to use the ideas the teacher wanted to develop in making their observations; it encouraged them to look closely at the materials and to think about the differences they found. It was not a long activity but gave the teacher time to visit each group to listen in to what the children were saying about the materials. Many of their statements at this stage contained hypotheses and predictions. For example:

> *This would be all right for a coat to keep you warm – it feels warm. Look, these go together because they're thick and you wouldn't use them for clothes – something where it has to be very strong, like for covering a chair. You wouldn't use this for covering a chair, much too thin and easy to tear. This would be OK for a raincoat – it wouldn't let any water through.*

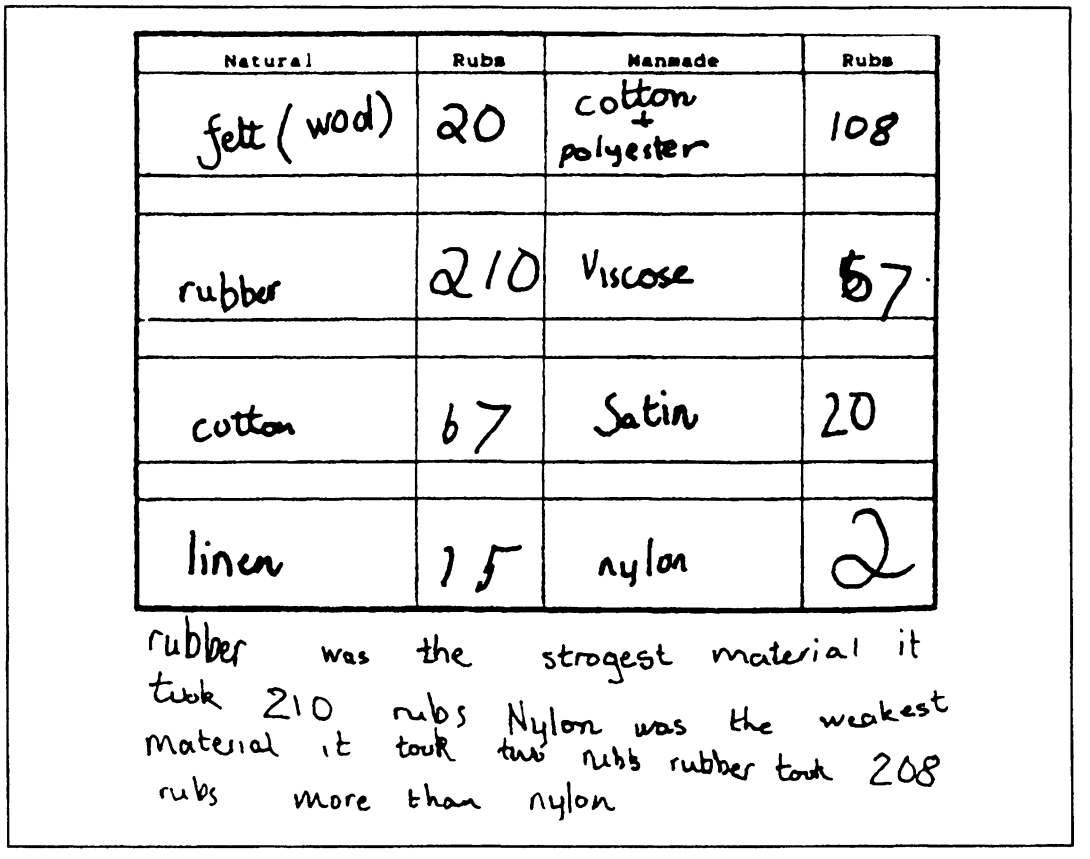
There was then a whole class discussion, pooling ideas from different groups. Two groups were interested in investigating one of the ideas emerging from the initial exploration, that natural materials are harder wearing than manufactured ones. Others followed up ideas about warmth and thickness and others did indeed investigate about what makes some materials more waterproof than others. Although the investigations were concerned with different properties, they were all relevant to developing the idea that the uses of materials are related to their properties.

In the *investigation phase* of the lesson the teacher used information about the children's ideas to set them going on investigations which used these ideas. The investigations provided opportunities to help the children develop their process skills, in order to carry out systematic and 'fair' tests which would arrive at findings useful in developing their ideas. So during the investigation the teacher needed to gather information about the children's process skills and to use this to give them any help they may have needed in thinking through how to collect evidence and make a record of it.

One group of girls took eight pieces of different kinds of material and compared them by rubbing them against the ground. The teacher observed that they chose the same piece of ground to test all the materials and they counted the number of rubs it took to make a hole. They kept to the same procedures and the same person rubbing. This method took a considerable time, however, and M suggested it would be quicker if they put a stone inside the material. So they wrapped each sample round a stone and started again. Their results were entered in a table drawn up for them by the teacher.

At the stage where results had been obtained, the teacher gathered information about how the children were interpreting what they had found out and whether their initial ideas had been changed. More information about this and about the children's communication skills was available in the *reporting phase* when the children made a report of the work, which they shared with the rest of the class. This also gave the teacher the opportunity to ask questions which challenged children to apply their ideas to closely related phenomena to find out the extent to which the children's ideas were becoming more widely applicable.

These were the results recorded by M's group.



Natural	Rubs	Manmade	Rubs
felt (wod)	20	cotton + polyester	108
rubber	210	Viscose	57
cotton	67	Satin	20
linen	15	nylon	2

rubber was the strogest material it took 210 rubs Nylon was the weakest material it took two rubs rubber took 208 rubs more than nylon

From their results, M's group first concluded that natural material is better than man-made but later, after discussing their results with their teacher, they wrote:

> *We don't know what's the best material because when we done our second test natural got the most points and man-made got the least point. But man-made material got the most points with our first test so we think man-made and natural have strong points.*

The written work alone gives no information about the extent to which they attempted to control variables or how they came to their first conclusion. The discussion with the teacher caused them to have second thoughts about this. Through the discussion the teacher was able to judge their use of evidence in arriving at conclusions and collected a good deal of information by observation which enabled him to see where these girls needed more experience.

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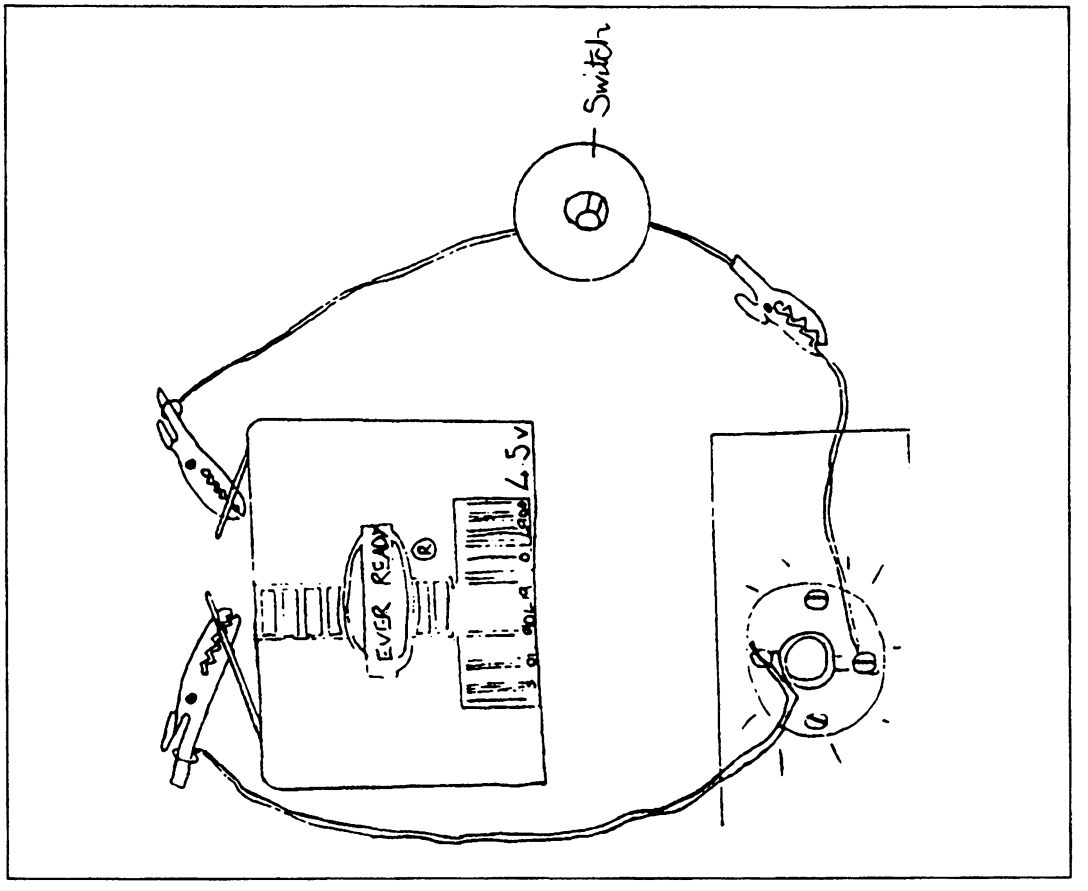
Example C

(Aim: Understanding of that the action of a switch is to close or break the path of conducting material in a simple circuit.)

Another pair produced this drawing of their circuit with a switch in it:



Resource 11

Four teachers each used a different way of recording their children's work:

Teacher 1

Teacher 1 kept weekly scores out of ten for each child. Marks were awarded either for tests administered by the teacher or for the children's work, in the following way:

Weeks	1	2	3	4	5	6	7	8	9	10	etc
Names	Marks out of 10										
Sam	6	5	8	6	7	3	4	9	7	8	
Sarah	7	8	6	7	5	6	–	9	6	7	
Brenda	3	4	5	3	6	7	5	–	6	4	
etc											

Teacher 2

Teacher 2 recorded comments on the children when they had completed particular activities. The record looked like this:

Activity Name	Dissolving	Separating soluble and insoluble	Evaporating a solution	Growing crystals	etc
Sam	*Messy unsystematic practical*	*Right idea but spoiled by carelessness*	*Made a good plan which worked*	*No success – he didn't follow instructions*	
Sarah	*Made a neat record; no conclusion*	*Tried without water before following what others did*	*Obtained a result but had difficulty explaining it*	*Watched others; had no idea why it grew*	
Brenda	*Careful practical work but poor record*	*Followed what the group did; no ideas of her own*	*Seemed to understand what to do but couldn't write it down*	*Absent*	
etc					

Teacher 3

Teacher 3 kept a record using a separate sheet for each child. Entries for the skills and attitudes referred to the developmental lists in Resource 5 and indicated the highest item observed in each case. Sam's record might have been like this:

Name: *Sam*
Record from _____ to _____

Activity	Dissolving and separating	Changing materials; heating and mixing	etc
Understanding ideas	Knew dissolved substance still there in the solution; applied idea in plan to separate sand and salt	Thinks that after a change the original can always be reclaimed somehow	
Observation	O4	O4	
Hypothesising	H2	H2	
Predicting	P3	P4	
Raising questions	Q4	Q4	
Planning and doing investigations	–	I3	
Drawing conclusions	Int 2	Int 2	
Communicating	C1	C2	
Respect for evidence	RE2	RE2	
Flexibility	F12	F13	
Critical reflection	–	Cr3	

NB No entry meant that there was no opportunity to observe this behaviour in these activities.

Teacher 4

Teacher 4 had a folder (portfolio) for each child in which the child's work was kept. This was mostly writing or drawing but sometimes actual samples of materials used or made (eg a crystal that had been grown):

Resource 12

Test item 1

Which of these things dissolves when you put it in water and stir?

Soil ☐

Sand ☐

Grit ☐

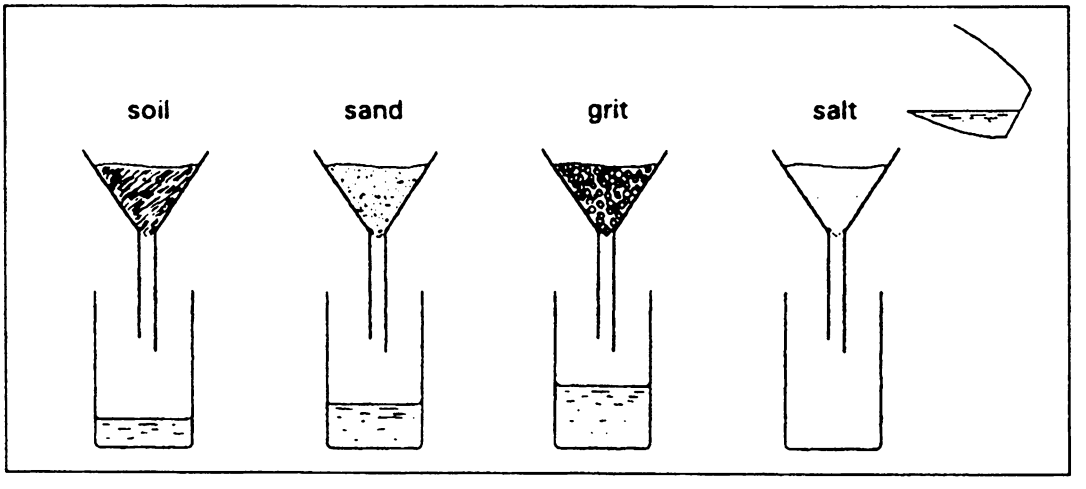
Salt ☐

Test item 2

A group of children put equal amounts of dry sand, soil, grit and salt into four funnels.

To find out how much each one would soak up, they poured equal amounts of water into each one. They looked to see how much water dripped through.

This worked all right until they came to the salt. When they poured the water in the salt disappeared.



Why do you think the salt disappeared but the other solids did not?

.....

.....

.....

.....

Test item 3

A.
Rock salt

B.
Table salt

Imagine you have some rock salt (A) and some table salt (B).

You have to find out which dissolves most quickly in water, or whether they are the same.

- What would you do?
- How would you decide the answer from what happens?

Write or draw your answer here.

.....

.....

.....

.....

.....

Resource 13

Item 1

Look at the two seeds in front of you. Write down differences you can find between them and three ways in which they are the same.

Different	Same
1.	1. .....
2.	2. .....
3.	3. .....

Item 2

This is a model bridge made out of a piece of card and two blocks of wood. When the middle of the bridge is loaded with coins it collapses. The number of coins that it holds before collapsing for different spans was found to be:

Span in cm	Number of coins
10	5
18	1
12	4
16	2
14	3

What do you notice about the number of coins and the span of the bridge?

.....

.....

Item 3

When you take a cold can out of the fridge and put it in a warm room, the outside of the can become wet, even though it was dry when it was inside the 'fridge.

Why do you think the can becomes wet? .....

Where does the moisture come from? .....

Item 4

You are given three different types of cloth, scissors, water and a dropper. Write down what you would do to find out which of the materials would be best for mopping up spilled water.

.....

.....

.....

.....

Item 5

A girl measured how far a clockwork toy would go for different numbers of turns of the key. This is what she found:

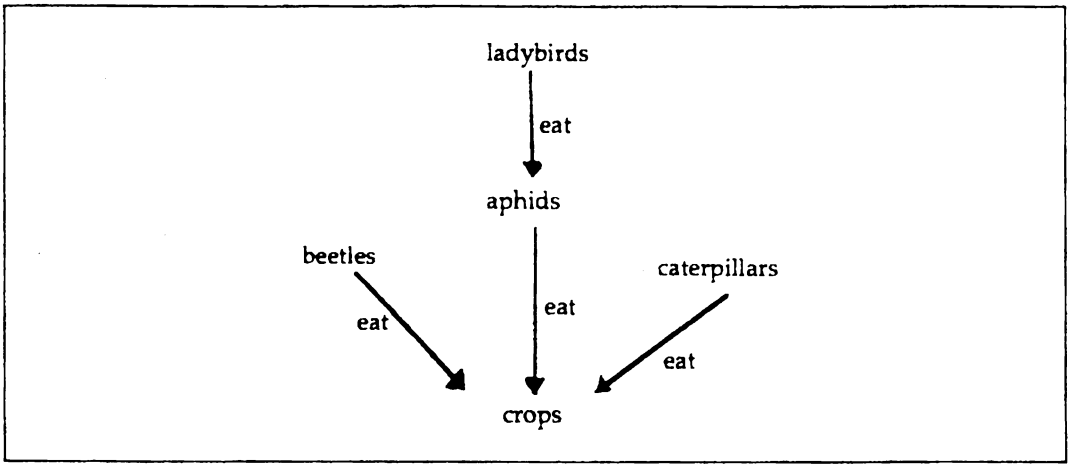
one turn:	7 cm
two turns:	18 cm
three turns:	28cm

a Make a graph of these results which would help you to say how far the car might go for four turns of the key.

b What do you think is the reason why the car goes further for more turns of the key?

Item 6

This diagram is part of a food web:



The farmer wants to protect his crops. Which of the creatures would it not be useful to kill?

- Aphids ☐
- Caterpillars ☐
- Ladybirds ☐
- Beetles ☐

Item 7

Michael made some lemonade using this recipe:

4 litres of water
2 lemons
500g of sugar
5g of dried yeast

Then someone told him that the fizziness depends upon the amount of sugar you put in. When Michael next made some lemonade he wanted to test whether this was true.

a. What should he change in the recipe?

.....

b. What should he not change?

.....

Item 8

To raise butterflies, you need their eggs and their food, and a cage to keep them in. (The food must be fresh.)

Here is some information about different kinds of butterflies:

Butterfly	Food plant	Egg colour	How many days for eggs to hatch?	Colour of caterpillar	Colour of pupa
Small tortoiseshell	nettle	green then black	5	black with white flecks	black, brown or green
Common blue	bird's foot trefoil	pearl white	10-15	green with brown line	green
Swallow-tail	fennel	yellow, then brown	6	black with white marks	green, then brown
Painted lady	spear thistle	pale green	7	grey-black	grey or green
Camberwell beauty	willow, sallow	red-brown	7	black with red blotches	brown

Use the table to help you answer these questions:

a. What is the food plant of the swallow-tail butterfly? .....

b. Which butterfly's eggs take the longest to hatch? .....

c. One butterfly lays red-brown eggs. The colour of its pupa is .....

Resource 14

These were some children's answers to Item 2 of Resource 13.

a. The number of coins goes with the span.

b. The wider the span the smaller the number of coins.

c. The wider the span the weaker the bridge.

d. The smallest one held the most.

Resource 15

Guidelines for writing test items

A. PROCESS SKILLS

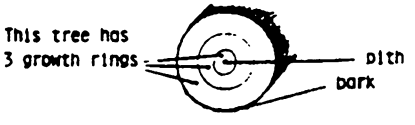
Selection of content

Items which assess process skills must have some content; a skill cannot be used in a vacuum. When the emphasis is on the process skill the content must not be a hurdle to using the skill (i.e. so unfamiliar that the question cannot be understood) nor so familiar that the answer can be given by recall.

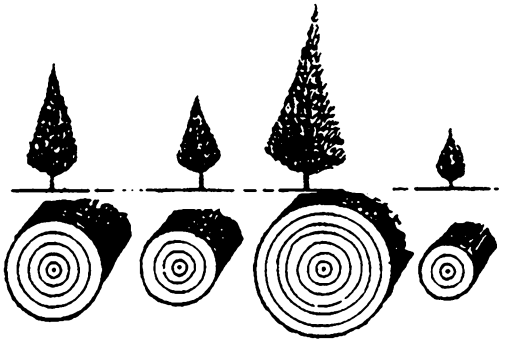
What is unfamiliar and familiar depends, of course, on the age and environment of the child. Thus a process-based question for a younger child may be straight recall for an older one. Hence it is important to consider the age of the children for whom questions are intended.

Any information that is required to be used in answering a skill-based question should be given within the question, so that success does not depend on being able to recall it. For example in the question below children are asked to find and use patterns in the heights of trees which have different numbers of rings in the trunk, given information about what is meant by rings in the trunk.

When we cut across the truck of a tree we see growth rings.



The trees below were planted at different times in the same wood. The drawings show the trees before they were cut down and, underneath, the growth rings seen after they were cut down.



What do you notice about the heights of the trees and the rings in the trunks?

.....

Process-based questions have two parts:

- **A given situation,** with necessary information
- **A request** to do something in relation to the given situation which requires the use of the intended process skill.

Here are some examples of what can be **given** and **requested** in questions assessing process skills.

Observation

Given: Something to observe (difficult in a purely written test, but could be careful drawings or photographs, or readily available simple materials).

Request: Describe similarities and difference between two objects.
Match objects to description that requires observation of fine details.
Group (drawings of) objects together according to observable features.

Hypothesising

Given: A situation or event which has no obvious single explanation.

Request: Give two possible explanations.

Predicting

Given: Observations or data in which a trend or pattern can be detected and then used to make a prediction in the form of an extrapolation or interpolation.

Request: To say what will happen if some specified change is made in one of the variables.

Planning investigations

Given: A question or problem which can be investigated by changing one variable and controlling others. (Note that only the planning of the investigation and not the control of variables in practice can be assessed in a written test.)

Request: Outline the investigation to be carried out, either as a whole or one specified part of it (eg which variables to be held constant, which changed, what to be measured or observed).

Interpreting/drawing conclusions

Given: Some data which contains a pattern or relationship between two variables

Request: Find the pattern or relationship which encompasses all the available data.
Decide whether there is evidence in the data that supports a given conclusion.

Communicating

Given: Data in numerical, tabular, graphical or diagrammatic form.

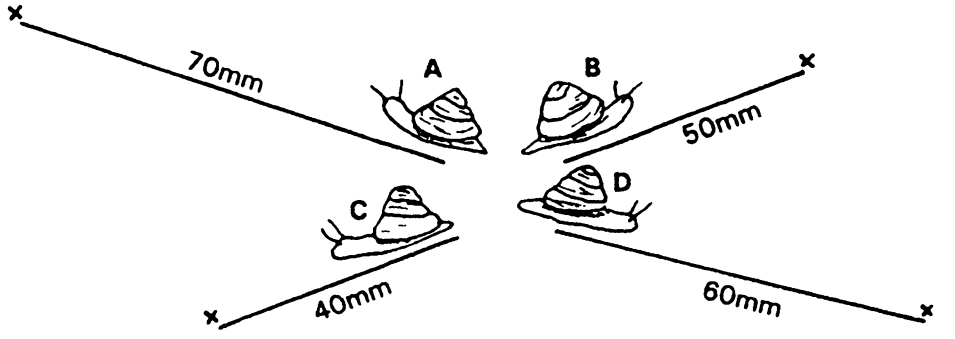
Request: Read off data or add more data or change data from one form to another.

B. UNDERSTANDING OF CONCEPTS

Understanding an idea or concept means being able to use it in situations other than that in which it was learned, that is, to apply it to new situations and in some case to transform it. In this example, it is necessary to know that speed is distance travelled in a certain time. Without this information the question cannot be answered. Although part b) asks for a prediction, being able to predict would not help if a person does not have an understanding of speed. Thus the question assesses the concept and not the ability to use given information to make a prediction.

How fast do snails go?

To find out John and Pamela put four snails down next to each other and marked their trails. They put a cross(x) where each snail had reached after 30 seconds.



a. Which snail went fastest?

.....

b. If snail C went on at the same speed for another 15 seconds, how far would it go beyond x?

.....

Given: A situation in which there is something to be explained by the application (not straight recall) of a scientific concept.

Request: Give an explanation.
Make a prediction and explain the reason for it

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