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ABSTRACT

The Learning in Science Project (Primary)--LISP(P)--was designed to examine problems and difficulties in primary science and to explore ways of overcoming these problems. Early research led to a proposal that children's questions and explanations could form the basis of an alternative teaching approach. However, several issues were raised which led to the need to reconsider the proposed teaching approach. Following a brief discussion of these issues this paper: (1) considers how any teaching approach is developed from a particular view of learning; (2) analyzes what a teaching model should include to be internally consistent; (3) discusses features of a generative model designed to help children develop ways of exploring and viewing the world around them (reconsidering the set of learning experiences; identifying the roles of learners, teachers, and students in the learning process; and examining the criteria to be used in the approach); (4) examines several constraints related to the proposed instructional approach; (5) outlines a framework for teaching sequences (consisting of exploration, investigation, and reflection phases); (6) discusses the content of science in the primary school; and (7) offers suggestions to encourage teachers to adopt new ways of teaching. (JN)

LEARNING IN SCIENCE PROJECT (PRIMARY)

TOWARD A TEACHING MODEL FOR PRIMARY SCIENCE

Science Education Research Unit
University of Waikato
Hamilton, N.Z.

Working Paper No. 114

TOWARD A TEACHING MODEL FOR PRIMARY SCIENCE

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A Working Paper of the Learning in Science Project (Primary)

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INTRODUCTION

The Learning in Science Project (Primary) was set up by the New Zealand Department of Education to consider the problems and difficulties of primary science and to explore ways of overcoming these problems. Inadequate teacher background in science and the diversity of viewpoints about the aims of primary science, both in theory and in practice, surfaced as real problems in the early work of the Project.

The work of Symington, Osborne, Freyberg & White, (1982) and Symington, Osborne, Biddulph & Freyberg, (1982) led to a perspective on primary science and to a research emphasis on children's questions and explanations. This focus of research led to a proposal that children's questions and explanations could be the basis of a teaching approach (Biddulph, Osborne & Freyberg, 1982). However recent research on children's questions and explanations, use of the teaching approach, and discussions with teachers and researchers about the approach have isolated some concerns and potential problems. These include:

(i) If children are invited to ask questions about objects and events before they have had considerable interaction with related materials, then some may ask questions to which they are not really interested in finding answers. They may, for example, simply wish to please the teacher or copy the format of other children's questions.

(ii) Some children may find it difficult to construct an explicit question from their interests or curiosity. Their actions and statements, however, may indicate things they are wondering about.

(iii) Unless there is modification to children's (and even teachers') expectations that there are easily obtainable 'right' answers to questions, some children may experience frustration when they find that many of their questions and explanations cannot be investigated scientifically.

(iv) Without some guidance teachers may have difficulty recognising which among the diverse questions and explanations generated by children on a topic are amenable to scientific investigation.

(v) Teachers may attempt to provide a wide range of classroom activities in response to the diversity of children's questions and explanations and end up with children going in too many directions at once, so feeling that they have lost control of the teaching situation.

(vi) The use of inadequate selection criteria may sometimes result in children being invited to generate questions and explanations on topics or situations which would be difficult to justify as important ones in terms of societal significance, further learning in science, and/or helping children make sense of familiar events and experiences.

These issues led to the need to reconsider the proposed teaching approach as previously described in Biddulph, Osborne and Freyberg, 1982.

In this present paper we start by considering how any teaching approach is developed from a particular view of learning, and then analyse what a teaching model should include in order to be internally consistent. We then take the view of learning being applied in LISP(P), together with what has been learnt from the research so far, as the basis for reviewing the proposed teaching approach. On this basis we reconsider the set of learning experiences, identify the roles of learners, teachers and students in the learning and consider the criteria to be used in evaluating the approach.

A FRAMEWORK FOR CONSTRUCTING PRIMARY SCIENCE TEACHING MODELS

There are many ways of teaching but a teacher usually keeps to a certain style, though she may teach different topics and children there are usually patterns in her actions and in her interactions with children which are consistent and constitute her teaching style (Galton, Simon and Croll, 1980). Though a teacher may not be aware of it her style relates to a certain view of education, of children's learning, and of the sorts of experiences schools should provide for pupils. In the same way any proposed model for primary science teaching must be based on a certain view of science education, of learning in science and of the experiences which should be provided for learners.

In proposing a new model for teaching, therefore, we should make explicit the view of learning on which it is based. The proposed children's activities, the class organisation and interactions, and the means of evaluating learning should be consistent with this view. If this is not the case then we run the risk of putting into practice a sequence of teaching procedures whose effects are different from those intended, or are inadequate for bringing about the intended (but unstated) learning, or cannot be interpreted in a meaningful way.

There are therefore, certain features which any model of teaching should have and certain criteria it should meet to be a useful framework for describing or guiding action. The features are suggested in Figure 1.

The two-headed arrows signify that there should be consistency between the linked features. The broken lines and single arrows suggest feedback to various parts of the model. Through this feedback a model can be dynamic, not static, adapting to information about effects so as to increase internal consistency.

In this 'model of models' the statement of intended learning is not in the form of a list of pupil knowledge, abilities and attitudes but in terms of the process through which learning takes place. For example, it could be 'rote learning' or 'discovery learning'. There may be several ways in which such learning might take place, thus several hypotheses about necessary learning experiences. They are stated in general terms and then, at the next stage in the model, translated into operational terms which indicate the roles and procedures involved in providing the learning experiences. Finally, there is a statement of the criteria to be used in evaluating the model in action. These criteria represent outward signs of the intended learning taking place and may be used to modify ideas about experiences or to adjust procedures; the feedback may result in the abandoning of one hypothesis about experiences in favour of another or may confirm that there are several means to the same end.

For the sake of illustrating a model fitting this framework, suppose the statement of intended learning _is_ rote learning. The model of learning might then be as in Figure 2. Here there is only one hypothesis about learning experiences consistent with the intended learning (rote learning is attractively uncomplicated) and the consistency between stages in the model is so clear as to lead to repetitiveness.

Figure 1: Features of a Model

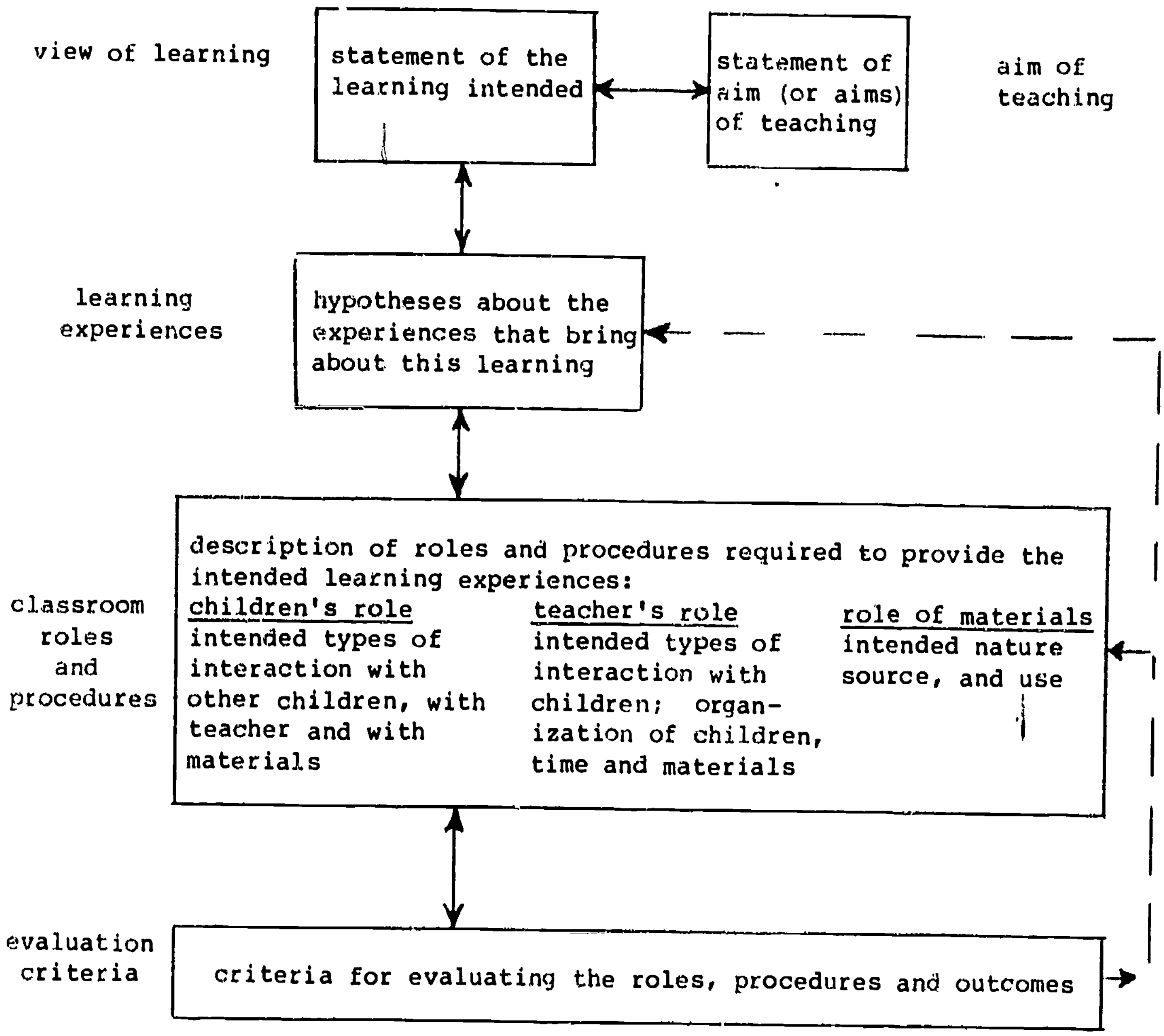
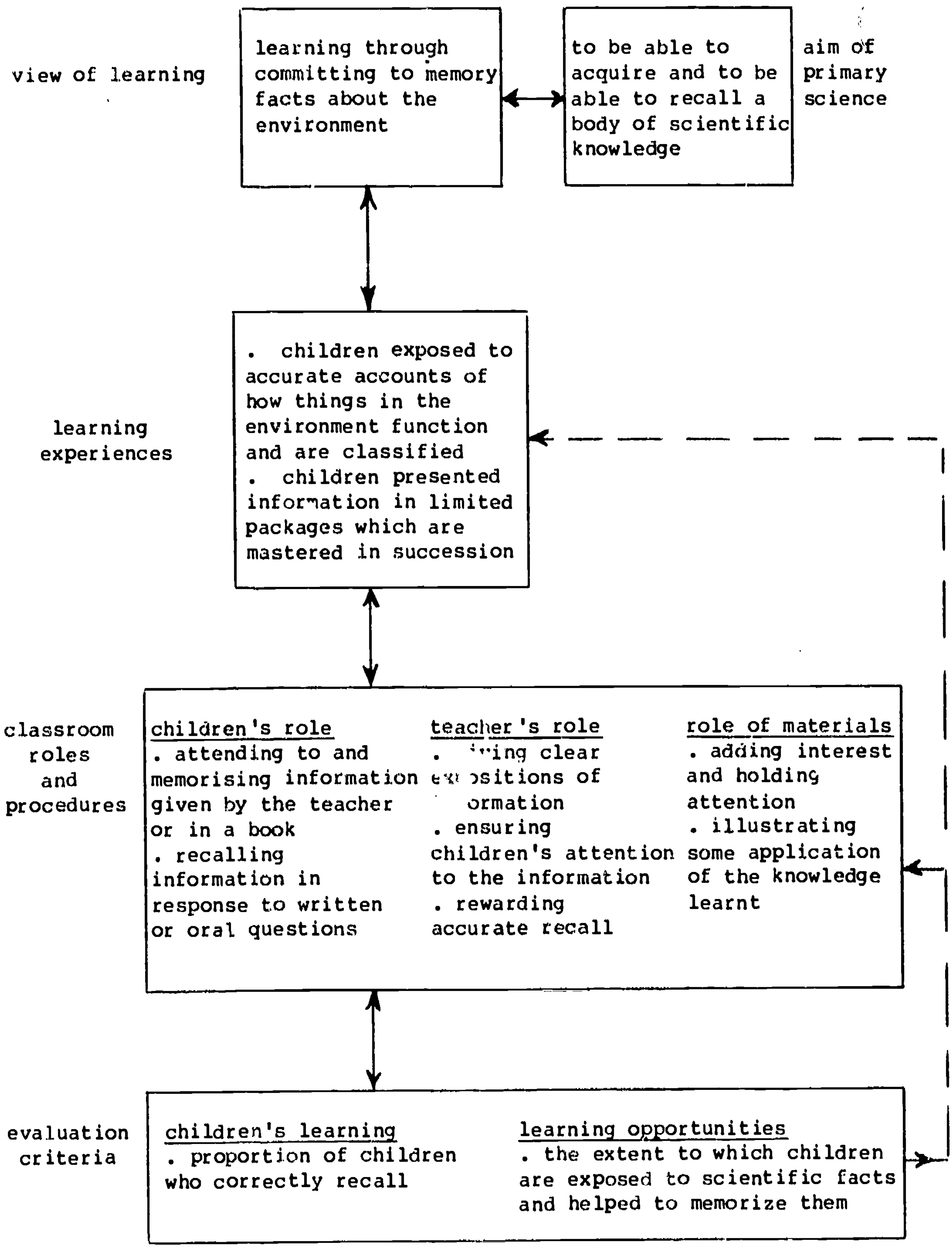


Figure 2: A Model for Rote Learning in Science



A MODEL FOR LISP(P)

When we come to propose a model for teaching primary science which serves the purposes of LISP(P) the view of learning as generative learning is accepted as an appropriate basis (Symington, Osborne, Freyberg and White, 1982). When applied to primary science this view of learning is consistent with the goal of children developing for themselves, albeit with the help of others, ways of exploring and viewing the world around them. Figure 3 summarises the features of a proposed model of teaching which is designed to achieve this goal of primary science education.

The following comments expand on each feature of the model.

1. The View of Learning

The generative view of learning is that meaning or understanding is created by the learner through mental processing which involves relating new input to existing ways of viewing the world (Osborne & Wittrock, 1983). The way in which ideas, or conceptual structures, are developed according to this view is through creating tentative meanings from sensory input, and memory. Tentative constructions are mentally tested against structures created from previous experience which have been committed to long-term memory. Thus existing ideas play a central part in the matter of understanding new information. The ways in which this mental testing is carried out are important features of a learners' processing strategies. These concern the way in which links are made between existing ideas, new experiences, and tentative explanations. The generation of meaning which fits experience therefore must depend on the development of sound processing strategies as well as on ideas formed previously.

2. Learning Experiences

It follows from the generative view of learning that certain experiences are required for children to produce their understandings of the world around. The generative view denies that learning can take place by simply being told the results of how others have made sense of the world. Knowledge cannot be transferred from teacher to children at the conceptual level but has to be created within each child. Thus

Figure 3: A Generative Model for Learning Primary Science

view of learning

learning through children
. generating new views of the world which enable children to make better sense of their world
. developing the processing strategies which enable children to more effectively and efficiently interact with things about them and the ideas of others

↔

to help children construct effective, and useful ways to view their world and to develop effective ways of learning

aim of primary science

↕

learning experiences

. children actively seeking evidence through their own senses and thinking about the evidence in terms of prior experiences and memory
. children listening to, reading, and thinking about the ideas of others in relation to both their own ideas and the evidence available
. children interacting with things to try out ideas and reconsidering them in the light of evidence
. children seeking more effective ways of organising information and testing ideas

↕

classroom roles and procedures

children's role
. to become involved in developing their own ideas and ways of processing information and to realise that this is something they must do for themselves

teachers's role
. to find out the children's ways of viewing the world and provide experiences which help children build more effective ones
. to help children ask, and attempt to answer, their own questions
. to help children reflect on their thinking and on their ways of thinking
. to help children test out their ideas and the ideas of others in a fair manner
. to promote interactions of children with materials and with the ideas of others

materials role
. to provide opportunities for for children to investigate and manipulate things in their environment
. to arouse curiosity and interest in the ways things behave

↕

evaluation criteria

children's learning
the extent to which possible indicators like those described on page 9 can be identified

learning opportunities
the extent to which the learning environment provides the opportunities discussed on page 10

learning experiences must be such that put the children are put into direct contact with the world around, and the verbalizations and writings of others about that world, so that children can construct ideas. Many such experiences could be provided, not all of which would enable children to generate meaning. For young children, particularly, the experience of interacting with objects and events is essential. Their previous experience is more limited than that of adults and their processing strategies have not built up to the extent of being able to carry out actions in thought to test their ideas. Thus interaction with the situations they are trying to understand is important. This interaction will be more effective in learning if at the same time the children are trying various ways of gathering information and testing out ideas so that they gradually develop more versatile and useful processing strategies.

3. Classroom Roles and Procedures

The consideration of roles and procedures requires that we identify in more precise terms ways of providing the intended learning experiences. Materials, books and other people are required if children are to be able to seek and consider information through interaction. Thus the role of these things is to engage children's interest and to enable children to find answers to their questions. The role of the children is to use their senses, take part in interaction and strive to make some meaning of the things and events around them. Without spelling out all the possible mental and physical activity this might involve, what it means is that children are taking responsibility for their own learning.

The teacher's role is a crucial one in providing the materials, the physical and social classroom organisation, and the encouragement and opportunities for children to learn. For generative learning to occur it is important to gain access to children's existing ideas by encouraging them to ask questions, by encouraging them to explain their reasoning and by helping them to reflect upon their ideas in relation to evidence and the ideas of others. The teacher's role must also include helping children to find more effective ways of testing their ideas so that they become able to generate meanings which have wider application. Later in this paper we will elaborate on this and discuss the support teachers will require.

4. Evaluating the Model

When we attempt to put into practice any model of teaching (that is, any set of procedures related consistently to a certain view of learning) we should constantly be asking questions such as "are the children really having the opportunities that were intended?", "are they learning in a way consistent with the model?", "are we giving the children the type of support and guidance envisaged?". To answer such questions means gathering relevant information about the events in the classroom and comparing them with the criteria or expectations provided by the model. This is the process of evaluation.

In teaching it is always necessary to adjust what is being done by regularly comparing it with what was intended, for we can never practice exactly as we would wish, we never get it quite 'right'. Evaluation is particularly important when new approaches are being tried. What is required is a means of identifying where changes might be made and of monitoring progress towards the intended teaching and learning.

It is necessary to focus onto the critical aspects of the model rather than to try to evaluate all that is going on in the teaching and learning. To identify these critical aspects there is no better starting place than the learning which the LISP(P) model is designed to promote. What we would really wish to know about, in order to evaluate the model, is what is going on inside the children's heads. This not being possible it is necessary to use what are considered to be the outward indications of the intended learning taking place.

The following might be indicators of children generating new conceptual structures and processing strategies:

- children familiarizing themselves with new situations (direct or, where necessary, vicarious), framing questions (explicity or implicitly), and generating explanations and ideas,
- children seeking out, listening to or reading about the ideas of others,
- children relating new ideas (their own and others) to earlier experiences and ideas recalled from memory,

- children questioning new ideas (their own and others) and testing them against the memory of previous experience and against additional new experiences,
- children basing their statements on evidence, seeking evidence to support statements and confirming their findings carefully before accepting them as evidence,
- children being prepared to change their own ideas in the light of such accepted evidence,
- children reflecting upon how they have tested ideas and how their testing can be improved.

To improve classroom practice, however, we need to be able to link the children's learning (or lack of it) to the factors in the classroom which influence that learning. It is necessary, therefore, to find out what opportunities there are for children to learn in the ways indicated by the above list. Such learning opportunity depends not only on the materials and activities provided but also on the encouragement, or discouragement, to interact in the intended ways that the children perceive in the behaviour of their teacher and their peers. The process of evaluating learning opportunities involves firstly finding out about what children actually do, how they do it, how they interact with each other, with materials and with other children. From this information it is possible to find out to what extent there is opportunity to:

- work on questions or problems which they have generated or have accepted as their own,
- define clearly to themselves what they are attempting to find out, to investigate, to observe,
- discuss their observations and ideas with other children (explaining their own views and listening to others),
- try out their ideas by seeing 'what happens if ...',
- devise and apply fair tests of their own and others ideas,
- base conclusions on the evidence and appreciate the tentative nature of conclusions,
- decide the best way of making a record of their activities,
- relate their findings to previous ideas and experience,
- reflect upon how their procedures for testing ideas might be improved.

POSSIBLE WAYS OF TEACHING

1. Practical constraints

There are several constraints to be borne in mind in proposing possible ways of teaching. The main ones come under the headings of teachers, pupils and school resources. Further guidelines as to what is feasible are, and will need to be, suggested by research and experience (LISP(P) working papers).

Generally primary teachers are not knowledgeable in the subject matters and methods of science. Therefore it is unrealistic to propose a teacher-role which requires them to identify on the spot the experiences which will help children reconsider their existing ideas and move towards more widely useful ones. Neither can many teachers be expected to help children use more scientific approaches to solving problems when they may be uncertain themselves of how a particular investigation might be undertaken in a 'fair' manner. Whereas a teacher who does have an understanding of scientific ideas and ways of problem solving has a basis for deciding which of many possible directions are likely to be fruitful for learning, a teacher without such an 'internal map' is wandering in, what is to him or her, uncharted territory. It seems more reasonable, therefore, to suggest that teachers and children work in areas which have been mapped through research and where there is some guidance as to how progress can be made.

Consideration of the children's limited experience and investigatory skills suggests too, that it may be wise for a class of children to work on a restricted range of investigations, within the children's capabilities, at any one time. To launch out in all directions in which children's interests might take them and hope to find answers to all the questions that children might raise, could easily lead to disappointment and dissatisfaction for all concerned. At the same time it is important that the children are engaged in investigations that are important to them, that are helping them answer their questions. This creates a dilemma: on the one hand children have questions which interest them but on the other hand not all their questions lead to scientific investigations. Conversely, there are many questions which can be investigated scientifically but children may not be interested in or able to learn from them. It will be necessary for teachers to tell pupils that many of the questions they raise are not suitable for them (or in some cases anybody) to investigate, as they would not be able to obtain answers, or check out possible answers to them. It needs to be pointed out to pupils that scientists choose to find answers only to those questions which they think they might be able to obtain answers to through investigations or through studying the findings of other investigators. Also scientists choose to study only those tentative explanations that they think they can evaluate in terms of things they can find out. The recognition by teachers of this feature of scientific endeavour, and their making it public knowledge to pupils provides an intellectually honest way of choosing some questions and ignoring others. It may also help pupils develop the ability to focus on answerable questions and testable explanations (the essence of scientific endeavour).

In addition, as has been implied, teachers can be helped to guide children toward fruitful investigations if the LISP(P) team and other researchers provide them with both research-based information about the kinds of questions children ask and suggestions for profitable investigations related to them. Also needed is information on ways of recognizing non-investigable questions and interesting children in investigable questions.

The LISP(P) research already indicates that when children pool their questions and ideas they become interested in each other's questions. Thus it is feasible to limit the number of different lines of investigation which are pursued to what can reasonably be handled by the teacher and at the same time preserve the children's interest and motivation which comes from working on problems they feel to be their own. Furthermore there are considerable similarities in the questions and ideas of different children and therefore it is possible to anticipate these and prepare activities likely to engage children and provide them with genuine learning opportunities.

One of the conclusions to be drawn from these considerations is that the children in a class would be best working on a single common topic. Such an arrangement would also provide a common focus for study interest and communication (e.g. sharing or challenging each other's strategies and ideas). From a common starting point, however, the investigations which groups of children may later devise will naturally vary, being based on their own ideas and ways of testing them. To ensure that the diversity of activities remains manageable it may be best for a teacher to limit the number of different questions or problems being investigated to not more than two or three. This does not mean that the groups working on the same questions will be doing the same things, for they themselves will need to decide what to do. What it does mean is that for each group the same sorts of problems in planning and carrying out the investigation will arise and the teacher can be prepared for these and give better guidance to each group.

The topic for a series of activities (a unit of work) would contain one of the broad ideas identified in the next section. For example, a topic within which could be developed the idea "seeing depends on light reaching our eyes from objects which either give out or reflect light" might be shadows. Topics which could serve to develop the idea "the special features that certain living things have which enable them to live in particular environments" might be trees, fish or even dinosaurs.

2. A framework for teaching sequences

Having considered a teaching approach proposed earlier (Biddulph, Osborne & Freyberg, 1982), a teaching approach proposed for more advanced science teaching (Cosgrove, Osborne & Tasker, 1983), and the ideas discussed in this paper we now propose a framework based on three phases (see Figure 4). Some suggested key steps within each phase are outlined, at this stage tentatively, since it will be one of the purposes of the LISP(P) action research to clarify and elaborate a useful framework for teaching (see Table I).

Figure 4: Framework for teaching sequences

Exploration

In which children interact with, raise questions about, collect, observe, discuss, try to explain, or classify objects or situations and discuss their questions and findings, and those of others, with a view to the class and teacher together identifying questions for investigations.

Investigation

In which children, plan and carry out an investigation and prepare to report their findings to others.

Reflection

In which children report their investigations to others, discuss new ideas they may have found, and possibly identify further investigations they wish to carry out.

TABLE I: Phases, Activities, Teacher's Role and Research Input (Tentative)

EXPLORATION PHASE

	Activity	Teacher's Role	Research Input
1.	Children in groups interacting with interesting materials, objects or situations; make observations and raise questions.	Foster interactions with materials and each other's ideas; ensure groups function (socially) to share observations and ideas.	Fruitful situations. Examples of focussing questions.
2.	Children in groups suggest ways of ordering their observations, refining their questions, or explaining them (depending on the topic.	Teacher interacts with children during group work, finds out about their questions and ideas, and relates them to ones identified by researchers.	Information about children's ideas from I.A.E., P.O.E. and research on children's questions.
3.	Groups report their observations, questions and suggested explanations/ relationships (patterns) to each other in whole class discussion.	Teacher collects reports from groups. Helps children to sift and clarify ideas.	Possible ideas to introduce if appropriate.
4.	Class and teacher choose those questions and/or alternative explanations which are researchable and will lead to worthwhile learning. Investigations relating to testing the most likely explanations of events or predictions based on patterns in observations are identified. Groups decide their investigation.	Teacher leads children into suggesting researchable questions, and asks for predictions based on patterns or explanations. Responds to non-investigable questions and ideas.	Suggested investigations which are fruitful for developing ideas and ways of testing ideas.

INVESTIGATION PHASE

	Activity	Teacher's Role	Research Input
1.	Children in groups plan their investigation, identifying (perhaps on paper) what is to be tested in operational terms, what things need to be changed, controlled and the effects to be observed (or the evidence to collect in a non-experimental investigation).	Helps children realise what has to go into a plan. Suggests 'thought experiments' to encourage children to anticipate possible effects of their actions.	Information about children's planning skills, and examples of adequate and inadequate planning.
2.	Plans discussed with teacher and modified if necessary. Requisite materials identified and place, time, etc. agreed.		Particular features of plans on this topic that teachers might look out for & discuss with children.
3.	Groups of children carry out their investigations. Collect data and attempt to interpret it. Methods of reporting discussed.	Teacher observes, finds out the ideas children have about what they find, and whether earlier ideas are being changed.	Notes on significant events in the investigations that relate to children using evidence scientifically.
4.	Interpretation & presentation data or observations discussed with teacher in groups.	Explores with children the evidence on which they are basing ideas.	

REFLECTION PHASE

	Activity	Teacher's Role	Research Input
1.	Groups present investigation reports to each other in whole class discussion.	Teacher organises reporting and display of results/observactions if appropriate.	
2.	Each group attempts to answer questions and comments from other children and teacher.	May ask children to comment on their findings in relation to their previous view. Challenges children to apply ideas to other problems or situations. May lead to further investigation.	Suggested problems that teachers can pose to help children try out new ideas in other situations.
3.	If topic still 'alive' then new investigations suggested.		

Recycle from Step 4 of

The time spent in different steps and the nature of the activity in each phase may depend upon the topic. There may be quite large differences in the size of each step depending upon the topic (for example, see Figure 5).

Figure 5: Varying the emphasis on various phases of the framework (depending on topics and pupils)

TOPIC 1 (Trees?)

Exploration
1. Interaction and observation
2. Ordering observations
3. Reporting
4. Proposing investigations

↓

Investigation
1. Planning
2. Discussing
3. Performing
4. Interpreting

↓

Reflection
1. Presenting
2. Discussing

TOPIC 2 (Shadows?)

Exploration
1. Interaction and observation
2. Initial explanation
3. Reporting
4. Proposing investigations

↓

Investigation
1. Planning
2. Discussion
3. Performing
4. Interacting

↓

Reflection
1. Presenting
2. Discussing
3. Further investigations proposed

↓

Investigation
1. Planning
2. Discussing
3. Performing
4. Interpreting

THE CONTENT OF SCIENCE IN THE PRIMARY SCHOOL

We would want children to generate conceptual structures and also develop their processing strategies through their involvement in science activities. Opportunities for this learning will depend upon the content and the way in which the children interact with this content. Children will not be able to generate ideas about electric current, for example, if they only ever encounter a 'nature study' content and they will not generate ways of devising investigations if their encounter with objects and situations consists only of making and recording superficial observations. But since conceptual structures and processing strategies are not independent of each other both must be considered in selecting content.

All activities have some content; they are about some specific objects or events - balls bouncing on different surfaces, candles casting shadows, fish gaping as they pass water over their gills. There are two components of the content which are worth considering separately, namely the concepts and their interrelationships (ideas) which are used to explain or describe what is occurring, and the particular context in which these ideas are made evident. So, for instance, there are activities other than those relating to the candle and shadows which could convey the same idea about light being given out by a source and travelling in straight lines, and many observations of things other than fish which relate to the respiration of living things. The particular context used is likely to depend upon the availability and the familiarity of different things in the school environment; the ideas developed, however, may be similar from area to area.

What then are the ideas which children should have opportunities to generate in their primary science activities? The criteria to be applied in answering this question reflect our recognition of the inter-relatedness of conceptual structures and processing strategies.

The ideas are ones which

- have significance for making sense of everyday events,
- can be generated by many primary children at their level,
- can be related by children to their own prior knowledge and experiences,
- can be placed in a socially meaningful context,
- will help rather than hinder further learning in science, and
- can be tested by children through simple investigations (including referring to books and experts about the findings of others).

To be acceptable it is not necessary for an idea to meet all of these criteria equally. It would be worrying, however, if some were not met at all. For example, an idea such as 'the gravitational force on a body gets less the further away it is from the earth', would get few votes from this list and is easily ruled out from primary science education. On the other hand, the idea that 'air exerts pressure in all directions' would be a stronger competitor, but not as strong in terms of everyday and socially-relevant understanding as, for example, ideas relating to food and health.

The ideas listed in Table II are some of those which we consider meet the criteria and which it is felt LISP(P) could usefully investigate. While it may be considered premature and even presumptuous for us to attempt such a list, without it LISP(P) cannot proceed. We hope it can be refined through debate and discussion. The ideas are deliberately cast in broad terms and each subsumes a number of associated ideas. Just what these subsumed ideas are, how they relate to children's own ideas and how they are combined by children in generating the broader idea is not well established. There are things that the project and associated research could endeavour to discover. In establishing the list some emphasis has been given to children learning about their senses and what their senses are telling them. Without such an understanding the interpretation of sensory input is likely to lead to ideas which will not help future learning.

TABLE II Helping Children to generate ideas and possible contexts for the ideas

Helping children to generate ideas about,	Possible contexts (some illustrations)
- the requirement for plants to live and grow, the special features which enable plants to live where they do, the ways in which plants reproduce (through case studies)	seeds native plants trees
- the requirements for animals to live and grow, the special features certain animals have which enable them to live in particular environments (through case studies)	hatching chickens aquarium
- the need of all living things for food and the range of ways of obtaining food (including some understanding of the sense of taste)	fruit earthworms tasting things
- the existence of air, the movement of air (winds), the existence of water in the air and the conditions under which water goes into and comes out of the air (including how air takes up space and how other things also exist in the air some of which can be detected by our sense of smell)	winds water in kitchen smelling things
- the importance of water on earth, how water finds its own level, the circumstances which determine whether an object floats or sinks, the substances that dissolve in water (and other liquids) and those that do not (including distinctions between melting and dissolving)	water waves measuring levels floating and sinking dissolving and melting
- hot and cold, how things that are hotter than their surroundings cool down and those that are colder warm up (including how these changes can be prevented and how hot and cold can be detected to a limited extent by the sense of touch and more accurately by a thermometer)	keeping things cold keeping food warm keeping humans warm making a thermometer
- how light travels from sources and can be reflected and absorbed (including how seeing depends on light reaching our eyes from objects that are either giving out or reflecting light)	shadows mirrors
- how sound is created by vibrating objects and travels through the air and other materials (including how hearing involves our eardrums being forced to vibrate by the sound waves)	musical instruments noise
- the way in which things can have their motion changed by pushes or pulls (how falling things speed up, how gravity speeds things up in the same way but the air can affect the motion, collisions)	falling things
- the daily and yearly pattern of changes in the apparent position of the sun, the reasons for this and effects on daylight, weather and the seasons (including the lack of effect of the moon, stars, and planets)	seasons
- the way in which materials are used for different purposes and why (including materials for protection, structures, electricity carriers, magnetic materials, transparent materials, rocks)	

ENCOURAGING TEACHERS TO ADOPT NEW WAYS OF TEACHING

In this paper we have suggested that primary science teaching should help children develop effective and useful ways of exploring and viewing their world. We have considered both a possible teaching sequence to achieve this goal and the research required to support the implementation of the sequence.

Even if the teaching sequence, supported by appropriate research findings, is found to be useable by teachers in the action-research phase of the project there will remain the problem of encouraging teachers to adopt a new way of teaching. Many teachers presently see their role as one of helping children to acquire scientific information and ideas rather than one of encouraging children to generate and test ideas. Because of this view of science teaching they feel inadequate since they consider that they do not have the knowledge to transmit to children. Other teachers, less concerned with transmitting knowledge and more with guiding children's enquiry, still feel that they do not have the scientific training to understand the scientific methods of enquiry and would consider that without this training they would not be able to teach science adequately whatever the method proposed.

Our proposal would be that teachers without a scientific background can develop their abilities to teach science if they change their view of the goals of primary science teaching and become familiar with some proposed ways of pursuing these goals in a few specific topics. We would argue that the most important knowledge required by primary teachers to teach any topic would be a knowledge of children's ideas and thinking with respect to that topic. Rather than being completely knowledgeable about the accepted scientific view of the topic it is more important for the teacher to know why certain of the children's ideas and ways of thinking are better than others in a scientific sense. In our view this information about children's ideas and thinking and the direction of the road toward a better scientific perspective should be able to be provided in a way that a teacher with no formal background in science can appreciate and understand.

How do we re-orientate teachers' views? Possible ways include;

(i) involving teachers in in-service courses where they themselves experience learning in science in the manner proposed here for children,

(ii) making available firstly, information and evidence about children's existing ideas about specific topics and secondly, guidance in identifying those ideas which have particular value for scientific understanding,

(iii) enabling teachers to observe teaching based on the generative view of learning and the proposed ways of teaching.

Through these approaches we would hope to encourage teachers to experiment with new ways of teaching, evaluate their progress in providing the proposed learning experiences for their children and, through such experimentation, re-appraise their view of learning and their goals for primary science.

If a teacher can adopt the role, in her classroom, of a keen and interested learner wanting to find out more about the world through the help of the pupils as research assistants, if she can listen to, value and devise ways to check out her own ideas and her pupils' ideas, and can encourage her pupils to do the same, if she can become a 'researcher' both in terms of finding out about things in the natural and technological world and in terms of finding ways to improve classroom practice, then science in the primary school must surely prosper. Our job is to find ways to support such endeavour.

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