CHILDREN'S QUESTIONS: THEIR PLACE IN PRIMARY SCIENCE EDUCATION

A thesis

submitted in fulfilment

of the requirements for the Degree

of

Doctor of Philosophy

at the

University of Waikato

by

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University of Waikato

1989

ABSTRACT

This study addressed four problems identified in primary science education in New Zealand.

(i) Most primary teachers lacked confidence in science and therefore avoided teaching the subject as much as possible.

(ii) Primary science teaching that took place tended to be superficial, and inconsistent with the processes of scientific endeavour.

(iii) Children seldom appreciated the purposes of the experiences and tasks in which teachers engaged them.

(iv) Children frequently constructed ideas that were unintended and unrecognised by their teachers.

The study consisted of a series of relatively small-scale, action-research investigations carried out in selected primary schools and classrooms in two regions of New Zealand. These explored the possibility of developing a viable alternative approach to primary science education that might overcome the difficulties identified. Recent advances in both the philosophy of science, and the psychology of learning (for example constructivist learning theory), suggested that children's own questions might provide a suitable basis for such an alternative. The study therefore built upon

(i) three former primary science programmes that had children's questions as a central focus, namely Nuffield Junior Science, Science 5/13 and Elementary School Science, and

(ii) the experimental study by Symington (1980) in Melbourne which tested several assumptions relating to the use of children's questions in primary science programmes.

There were four main phases to the study:

(i) determining whether questions could be elicited readily from New Zealand primary school children in science classrooms,

(ii) constructing a viable alternative teaching approach incorporating children's questions,

(iii) investigating the ability of a small but representative sample of teachers to adopt the alternative approach as intended by the developers, and

(iv) exploring the views of children and teachers who had experienced the alternative teaching approach.

Teaching and observations in classrooms, together with both formal and informal interviews of teachers and children, constituted the main methodology used.

The major outcomes of the study were:

(i) A sample of New Zealand primary school children were found to be able to generate a wealth of questions in school about natural and technological phenomena if given the opportunity and encouragement.

(ii) With judicious selection, their questions could be incorporated into a viable, structured, but flexible alternative teaching approach that largely overcame the problems identified. This approach was termed an 'interactive' teaching approach to emphasise the interactive and transactional nature of the learning and teaching that occurred in primary science classrooms when the approach was used.

(iii) Since the approach differed markedly in its perspective on science, learning, and teaching from that held by most teachers, few could adopt it as intended by the developers without the experience of a special inservice programme designed to be congruent with the principles of the interactive approach.

(iv) When children experienced the interactive approach they were found to have far greater ownership of the learning involved than previously, while their teachers experienced considerable relief in feeling they no longer had to be 'experts' in science themselves, together with a sense of fascination with the world of children's ideas and skills which was opened up to them.

ACKNOWLEDGEMENTS

To my supervisors, Associate Professor Malcolm Carr and Professor Ian McLaren, I express my deep gratitude for their guidance and encouragement in recent years.

I should also like to acknowledge my great debt to my first supervisors and colleagues, the late Dr Roger Osborne and the late Professor Peter Freyberg, who steered me so ably through the years of research.

I am also extremely grateful to Mark Cosgrove, Jane McChesney and John Faire, three Hamilton Teachers College colleagues who selflessly relieved me of three of my second semester teaching classes in 1988 to enable me to devote more time to writing up my study.

Other colleagues who have provided valuable support and encouragement from time to time include Ken Appleton, Dr Beverley Bell, Dr Ken Carr and Anne Carr, Eleanor Hawe, Dr Valda Kirkwood, Dr David Symington, and Ross Tasker.

I should also like to acknowledge the significant contribution of the Department of Education, Wellington, which made the research possible through funding the Learning in Science Project (Primary).

Finally, I wish to record my heartfelt appreciation of the on-going support provided by my wife Jeanne, and children Philipa and Chris. Philipa typed all the references, and Chris provided valuable advice and help with word processing.

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CHAPTER 1

INTRODUCTION

This introductory chapter is in five parts. First it contains a statement of the thesis which motivated the investigations reported. Secondly, an overview is provided of the contents of the chapters which follow. Thirdly, there is a section which indicates that the study comprised a series of mainly small-scale, action-research investigations rather than the more usual form of one major investigation. This third section also sets out the research questions which guided the various investigations. Fourthly, there is brief mention of the theoretical position which informed the studies. Finally, there is a substantial section which backgrounds the study; it summarises difficulties relating to primary science education in New Zealand, proposes a need for the development of an innovative teaching approach to overcome such difficulties, and raises the possibility of children's own questions being an integral part of such an approach.

STATEMENT OF THESIS

The thesis of the investigations reported here is that primary school children's own questions about natural and technological phenomena can have considerable significance for their learning in science.

OVERVIEW OF THE REMAINING CHAPTERS

Chapter 2 considers children's questions as a possible basis for devising primary science education curricula by reviewing literature reports of research into children's questions, as well as research into teaching strategies and programmes for using children's questions to promote their learning. The focus is on learning in primary science, but other relevant references are also explored, especially for possible implications for a teaching approach that might incorporate children's questions. This chapter contains the major literature review. References which have specific relevance for some of the issues and investigations reported in later chapters are examined in those chapters.

Chapter 3 contains a justification for the use of children's questions in primary science education. Fields such as philosophy of science and learning theory are examined to provide grounds for justification. Constructivist learning theory is argued to be the appropriate theoretical base for the classroom interaction explored in this thesis.

General issues of research methodology are discussed in Chapter 4. Since the focus of the investigations is on individual learners (both children and teachers) interacting in social contexts, special consideration is given to the value of qualitative techniques.

The next four chapters report classroom-based studies carried out by the researcher and a small sample of primary teachers. The first investigation, reported in Chapter 5, addressed the issues of whether questions about science topics can be elicited readily from children in New Zealand primary schools and, if so, then what are the characteristics of such questions and what factors seem to influence the number and kind of questions asked.

Chapter 6 reports several small studies which had as their goal the development of a viable teaching approach in primary science built around children's own questions.

Chapter 7 consists of several case studies designed to explore whether selected classroom teachers could adopt the developed science teaching innovation in a way consistent with the intentions of the developers. Implications are drawn both for modifying the teaching innovation (by now termed the 'interactive' teaching approach) and for the kind and level of support teachers are likely to need to enable them to adopt the interactive approach.

Chapter 8 records the results of a fourth distinctive investigation. It examines the reported effects on a sample of primary school teachers and their children of their experience of the interactive teaching approach in learning in science.

Chapter 9 concludes the study by reflecting on several issues. These include the potential of children's questions to enhance their learning, the value of a constructivist theory-based approach in helping children and teachers learn in science and science education respectively, the implications for curriculum change of the results of the various investigations reported in Chapters 5-8, and further research that seems to be needed.

THE RESEARCH APPROACH AND THE RESEARCH QUESTIONS

Several years before White and Tisher (1986) challenged science education researchers to shift their research endeavours closer to the complexities of the practical school classroom so that their results could inform teaching practice, the study reported here was initiated to try to help primary teachers overcome a number of difficulties that had been identified, through interviews and observations in classrooms, in science education in this country. In this respect it was in what Tamir (1984) regarded as the rare category of curriculum development studies. It consisted of a series of relatively small investigations rather than one major investigation. There were four investigations in all, these being the ones reported in Chapters 5-8. They were designed to obtain answers to a number of research questions focussing on the use of children's questions in primary science classes. The questions are set out below.

(i) Investigation 1: (Chapter 5)
Questions children ask about natural and technological phenomena.

RESEARCH QUESTION 1

Can questions about science topics be elicited readily from children in New Zealand primary schools?

RESEARCH QUESTION 2

What are the characteristics of questions asked?

RESEARCH QUESTION 3

What influences the number and type of questions asked?

(ii) Investigation 2: (Chapter 6)
Towards a teaching approach using children's questions.

RESEARCH QUESTION 4

Can a viable teaching approach be devised that incorporates children's own questions as a central feature?

(iii) Investigation 3: (Chapter 7)
An invitation to adopt an innovative teaching approach: the responses of several classroom teachers.

RESEARCH QUESTION 5

Can teachers adopt the science teaching innovation as intended by the developers?

(iv) Investigation 4: (Chapter 8)

Effect on children and their teachers of experiencing a teaching approach based on the children's own questions.

RESEARCH QUESTION 6

What is the effect on teachers of using a science teaching approach that has their children's own questions at its centre?

RESEARCH QUESTION 7

What is the effect on children of experiencing a science teaching approach that accords their own questions a central place?

SOME THEORETICAL ISSUES FOR THIS STUDY

> *What the scientist takes as fascinating and interesting, what strikes him as curious, is influenced at least in part by his theoretical orientation.*
> *(Martin, 1972, 111)*

Martin was describing a person working in the natural sciences but the same applies to a social science researcher, such as the author of this document. It is no longer acceptable to claim that research is a neutral activity, so one's biases should be acknowledged at the outset.

White (1983), who with Tisher carried out a major review of science education research within the previous ten years (for the third Handbook of Research on Teaching), noted that during that period there had been a marked change from behaviourist to constructivist theories of learning as a basis for research, while Driver and Erikson (1983) commented that "epistemological constructivism" was a theoretical perspective common to many current science education researchers.

The present researcher also worked from within this constructivist perspective, being particularly influenced by Wittrock's generative learning theory (Osborne and Wittrock, 1983; Wittrock, 1974). Constructivism, generative learning theory in particular, is therefore discussed in some detail in Chapter 3. The rationale for adopting this theoretical stance is that it allows attention to be given to children and teachers as individuals interacting in, and construing in their own ways, the complex social context and requirements of primary science classrooms. It was intended that the research with this theoretical stance would illuminate and inform teaching practice.

BACKGROUND TO THIS STUDY

The study reported here grew out of science education research conducted in New Zealand within the Learning in Science Projects at the University of Waikato in the late 1970's and early 1980's (Biddulph, 1982a, 1982b; Freyberg and Osborne, 1982). In the remaining pages of this introductory chapter, the findings of this research are summarised, and compared briefly with comments about the state of primary science education in several other western countries, to allow an appreciation of the background to the present study.

Science Education in New Zealand

By the late 1970's science teachers in New Zealand secondary schools were, in Freyberg and Osborne's (1982) view, generally aware that what they were teaching seemed to be quite difficult for many of their pupils. As one secondary science teacher said,

> *I have tried just about every approach I can think of and still there are so many in the class who I feel are not* ***successfully*** *working out what it is all about. They might try to think about it a bit - I don't know - but they miss the point.... You find that some of the most enthusiastic, eager and willing types still miss the point.*
> *(Freyberg and Osborne, 1982)*

And because so many pupils did seem to 'miss the point' it was not uncommon to hear teachers of higher classes complain that they had to spend a significant proportion of their time re-teaching what had been 'taught' already (Freyberg and Osborne, 1982).

In a review of research in science education in New Zealand during the 1970's, Osborne (1980) pointed out that there was a lack of investigation of typical teaching methods and learning procedures used in schools, and that the little research that had been done into other aspects of science education seemed to have had little effect on the teaching and learning of science. In particular he noted that psychometric studies had not had the hoped for impact on teaching. Reasons for this, he suggested, were that

> *It is difficult for the statistical models to represent the complexity of the teaching and learning situation, it is difficult to identify and measure all important variables, and the findings are not easily related to how teaching and learning should be modified.*
>
> *(Osborne, 1980, 323)*

Further, as Freyberg and Osborne (1982) pointed out, while syllabus revision procedures should in theory have resolved most of the difficulties associated with teaching and learning in science, in practice many difficulties remained unidentified and unresolved as late as 1979.

Difficulties at the Form 1-4 Level

Osborne's concern was shared by the New Zealand Department of Education which in 1979 awarded him and his colleague, Professor Peter Freyberg, contract funding to carry out a three-year research project at the University of Waikato into science teaching and learning at the Form 1-4 level. The project, known as the Learning in Science Project, set out specifically to identify some of the key difficulties in this subject area, and to find ways of helping teachers overcome such difficulties.

The principal research methods used were interviews (of various kinds), classroom observation techniques, and collaborative action-research with practising teachers. The classroom observation techniques used

> *offered the best chance of illuminating the nature of problems in learning and teaching and, as well, had the advantage of providing outcomes which were useful to both the Project team and to teachers.*
> *(Freyberg and Osborne, 1982)*

These research techniques were supplemented where appropriate with surveys to establish the prevalence of various ideas held by students as revealed in the interviews.

Important findings emerged from all three phases (exploratory; in-depth; action-research) of the Project. These may be summarised as follows:

(i) Children do have difficulty understanding scientific ideas and theories; many seem to reject the ideas, or distort them to fit their own views, or learn them superficially.

(ii) Despite the assumption by most teachers and programmes that children either have no concepts, or all have the same prerequisite concepts, of phenomena to be studied, children were found to have a range of strongly-held views about how and why things behave as they do. Furthermore these ideas, being based on and largely compatible with everday experience, appear to be particularly resistant to change by science teaching, or are likely to lead children to interpret in unanticipated ways things that they see, hear and read.

(iii) Frequently teacher and children were unknowingly talking past each other; teachers used various key words in their scientific sense without realising that the children who had only an everyday meaning for them, a meaning which differed in important ways from the scientific usage, were interpreting what was said in terms of the everyday meaning.

(iv) Although there was a syllabus emphasis on the development of intellectual process skills, much science teaching was primarily content-oriented.

(v) Many children seemed to have no understanding of the real purpose or nature of investigations that they were required to undertake and tended to see each lesson as an isolated event. They were likely to invent a purpose for a lesson which was subtly but significantly different from that of the teacher. They had also developed various strategies to get the 'right' answer they expected the teacher wanted.

(vi) Children frequently had difficulty relating what they were doing both to the real world in which they lived, and the way they thought about that world.

(vii) Children were often unaware of, or unconcerned about, particular design features of an investigation which the teachers considered critical.

(viii) Teachers were largely unaware of the ideas and meanings that children brought to and took from their science studies, and also of the mismatches between their intentions as teachers in providing various learning activities and the children's perceptions of those same activities.

This may seem a formidable catalogue of difficulties but an attempt was made to address at least some of them in the action-research phase. Teaching materials devised were designed to take sufficiently into account the children's ideas about the world and their meanings for words. The researchers concluded that the science curriculum itself needed to do likewise. They also believed that if the teaching of scientific concepts was viewed by teachers as a process of modifying children's ideas **toward** those of scientists, rather than as a process of instilling new concepts into the children's heads, then there was a greater likelihood that worthwhile learning would occur.

Freyberg and Osborne (1982) noted that a number of the views held strongly by children about a variety of topics in science developed at a relatively young age and prior to formal learning in science. Indeed some non-scientific ideas were found to become increasingly popular as children moved upwards through the school system. On the other hand they had little doubt that most children are inherently curious and that science teaching should try and build on this.

> *Young children are already budding scientists - active and interested in the world around them and trying to make sense of it. Our job as teachers is to ensure that they retain that curiosity and also come to appreciate and respect, in so far as they are able, the growing collective wisdom of the sciences.*
>
> *(Freyberg and Osborne, 1982)*

They quote a Form 4 girl who remembered quite clearly a particularly meaningful activity in biology that she had carried out. "That one I found really interesting 'cos I was finding out something for myself" (Freyberg and Osborne, 1982).

Difficulties at the Primary[1] Level

In 1978 the New Zealand Department of Education introduced into schools a new national Primary Science Syllabus for the Infants to S4 level (Department of Educaton, 1978). It was supported by a wealth of resources in the form of science resource booklets and kits of equipment. Most primary teachers had used trial versions of the units in the resource booklets for several years prior to 1978. Despite this, several of the findings of the Form 1-4 Project suggested that some of the difficulties revealed may have had their origin, and may be more effectively remedied, at a lower level of the school system. They particularly had in mind the evidence that children seem to develop their own ideas about a variety of phenomena at an early age and that these ideas are remarkably resistant to modification towards the scientific viewpoint at a later time. Again the New Zealand Department of Education agreed, and awarded the two original directors a further three-year research contract (1982-84) to investigate difficulties, and ways of overcoming them, in the learning and teaching of science at the primary school level. The writer, a former primary school teacher, was employed as Project Officer for this new Learning in Science Project (Primary).

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1. In New Zealand the terms "primary" school, "primary" school children and "primary" school teachers include Form 1 and 2 pupils and their teachers, although the distinction between primary and secondary is becoming blurred with a number of official syllabi covering the Form 1-4 area, and a substantial proportion of Form 1-2 pupils being located in intermediate schools, area schools (infants - F7) or secondary schools (F1-7). In this thesis the term "primary" will therefore include Form 1 and 2 children and their teachers but will refer mainly to the children and teachers at the junior (infant) and Standard 1-4 level of the school. As a guide to overseas readers, New Zealand new entrant/junior 1 (NE/J1) children are five-year-olds, junior 2 (J2) children are mostly six-year-olds, junior 3 or standard 1 (J3/S1) children are mostly seven-year-olds, standard 2 children (S2) children are mainly eight-year-olds, while standard 3 and 4 (S3/4) children are for the most part nine, ten and eleven-year-olds.

The Primary Project used a similar approach (exploratory, in-depth, action-research phases) to, and the same research techniques (interviews, surveys, classroom observations, collaborative classroom action-research) as, the Form 1-4 Project.

During the exploratory phase it became clear that a number of the difficulties identified at the Form 1-4 level also existed at the lower level. At both the F1-4 level and the primary level most teachers were observed trying to induct their pupils by one means or another into what the teachers considered to be the scientific view. This seemed to stem from a belief on the part of the teachers that the purpose of science teaching is to lead children to scientific 'truths'. This was illustrated by one primary school principal who commented forthrightly in the course of a staff meeting, "There still has to be that correct answer at the end. That's what we're saying, isn't it?" (Biddulph, 1982a, 13). And how do teachers endeavour to lead their children to the 'right' answers? One common method was described by a primary school inspector.

> *They [teachers] only ask questions when they know the answers exactly, and if they don't get the answers they will keep nodding and looking until they get the answer they want and the words they want.*
>
> *(Biddulph, 1982a, 16)*

Subsequent observations by the author confirmed the inspector's observation. Teachers were also seen to cue children in various ways toward the answers they sought to establish. For example, the following interaction was recorded on audio tape when a teacher of six-year-old children wanted the children to respond with the term 'ligaments' at the conclusion of a lesson on bones:

Teacher: *Stretchy things called... [waiting for response but none] Lig... [offering cue]*

Child: *Lig...*

Teacher: *Liga... [offering further cue]*

Several children at once: *Liga...*

One child: *Ligamin*

Teacher: *Ligament, that's right.*

(Biddulph, 1982b, 5)

What was observed was consistent with the finding of Ball (1980) that teachers give out cues to children by style of speech, accent and tone of voice, gestures, facial expression and so forth the moment they walk into a classroom. Other instances supported Donaldson's (1978) contention that contextual cues have significance for children in that children respond not so much to the words used by a teacher but to what they think the teacher intends.

Just as the teachers used various means to lead the children to predetermined views, so the children adopted a variety of strategies to play the teacher-defined 'right answer' game. In the example above the children were using a 'repetition' strategy. Children's ability to employ such techniques was recognised clearly by a primary school inspector who commented,

> *the children expect to receive the answers... so why bother doing a lot of thinking; if you stall and hold off the teacher in desperation at the end is going to give you the answer.*
>
> *(Biddulph, 1982a, 5)*

Other findings that paralleled those of the Form 1-4 Project included those which identified many children holding firmly to a range of non-scientific views, interpreting the purpose, practice and conclusion to be drawn from specific activities quite differently from those intended by the teacher, and experiencing science as a 'boring' subject, especially when teachers talked too much, when words or ideas were not understood and when too much writing was required.

Two other findings that also reflected difficulties revealed by the Form 1-4 Project were that teachers frequently failed to take their children's prior ideas into account in their teaching, and that at least some of the teaching was incompatible with scientific inquiry. With respect to this latter point, Biddulph (1982a) found that some teachers themselves recognised that the emphasis on transmitting scientific knowledge inhibited children's learning in science. For example, a teacher of eight to nine-year-old children mentioned how the children have

> *got a problem of maintaining that open-minded approach to things because in this day and age we seem to gear them up towards a right and wrong answer.*
> *(Biddulph, 1982a, 18)*

A primary school principal reflected,

> *I tend to think that there are a lot of teachers who would stifle [children's] questions, or direct questions in a way to suit themselves rather than children.*
> *(Biddulph, 1982a, 18)*

A finding exclusive to the Primary Project related to the aims of science teaching at the primary level. It was found that there was no real agreement among teachers and science educators about the aims of primary science education (Biddulph, Osborne and Freyberg, 1983). Some considered that the ultimate focus should be on science content (i.e. the products of science), others that it should be on the development of the processes of science (although a number of those teachers genuinely professing this view were observed to pursue the former in practice), yet others that the development of appropriate attitudes was of central importance, while a minority perceived science learning as predominantly a vehicle for language development.

Another difficulty identified by the Primary Project that did not seem to be mirrored to the same extent at the Form 1-4 level concerned teacher confidence in the teaching of science. Primary teachers on the whole reported that they did not understand the scientific views themselves, hence they lacked confidence in the subject, and consequently avoided teaching it if they could (Biddulph, Osborne and Freyberg, 1983). One primary school inspector, for example, observed that, "Science is disregarded by the vast majority of teachers" and another described his recent experiences thus:

> *When I first started as an inspector, in the first year I don't think I would have seen more than two or three science lessons and that's being in schools about, well 90% of the year. Now that they know I'm responsible for science they tend to show me a bit more [laughs] but in general, no, you don't see it. If there's something goes by the board it's either science or music.*
>
> *(Biddulph, 1982a, 15)*

Primary Science Difficulties in Other Countries

Problems with learning and teaching in science at the primary school level in New Zealand can be compared with those reported in countries such as Great Britain, the United States of America and Australia.

The relative neglect of primary school science has been commented on by Bainbridge (1980), Department of Education and Science (1978) and Plimmer (1981) in Great Britain, by De Rose, Lockard and Paldy (1979), Mechling and Oliver (1983), Neuman (1981), Perkes (1975) and Rudman (1978) in the United States, and by Alford and Kerrison (1974), Appleton (1977), Stamp (1982) and Symington (1974) in Australia. For example, in Britain Her Majesty's Inspectors noted that science work was developed seriously in only a little more than 10% of primary school classes (Department of Education and Science, 1978). In the United States, Perkes (1975) wrote of science occupying a **tenuous** position in the elementary classrom. Mechling and Oliver, after considering the results of a number of extensive surveys of primary school science, concluded that "In many of the 16000 school districts in the United States, elementary science programmes lie mortally wounded or dead (Mechling and Oliver, 1983, 15). Neuman, a Professor of Science Education at the University of Wisconsin, observed that

> *when one sees science being taught today in an elementary school it is the exception rather than the rule. It is difficult to get school administrators and teachers to admit that science is being systematically excluded from the school's curriculum.*
>
> *(Neuman, 1981, 4)*

After surveying 200 teachers in 40 primary schools in and around Hobart, Tasmania, Alford and Kerrison reflected on the results,

> *These findings gave some support to a growing feeling on our part that science for a significant number of primary children either does not exist or is merely a pseudonym for various second-hand experiences.*
>
> *(Alford and Kerrison, 1974, 11)*

In those classes where science was being taught, it was observed that it tended to be superficial; science experience and inquiry was undervalued by teachers and seldom found a place in their programmes. In Britain Harlen, Black and Johnson commented,

> *It is not surprising that the essential nature of primary science as a process of enquiry has not been carried forward to any degree in the work of the pupils.*
>
> *(Harlen et al, 1981, 178)*

In the United States Welch, Klopfer, Aikenhead and Robinson noted,

> *In spite of new curricula, better trained teachers, and improved facilities and equipment, the optimistic expectations for students becoming inquirers have seldom been met.*
>
> *(Welch et al, 1981, 33)*

In Australia White (1977) observed that, at the secondary level at least, stimulating students to ask questions is largely a neglected area in science education programmes.

It has been suggested that a major factor involved in the relative neglect or superficial nature of primary science teaching is that because many primary teachers believe their own understanding of science is inadequate they lack the confidence needed to teach it (Alford and Kerrison, 1974; Department of Education and Science, 1978; Mechling and Oliver, 1983; Perkes, 1975; Plimmer, 1981; Symington, 1974). For instance, Perkes' view was that

> *Multi-pronged efforts to improve science instruction in the elementary classroom have been undertaken with increasing vigor and ingenuity during the last two decades. Since the teacher stands as the pivotal person around which a science program survives, grows or vanishes, efforts have been directed at every stage of his role development - from preservice education in the sciences and teaching methodologies through inservice support, remediation, curriculum development, and innovation. Yet, in spite of all these efforts, evidence and opinion prevail that teachers remain "frightened" of science and report a great sense of inadequacy in understanding the science they teach. This prolonged malaise needs both a concerted effort to diagnose and to remediate.*
>
> *(Perkes, 1975, 85)*

Similarly, Alford and Kerrison concluded that

> *...the problems facing a primary school teacher in teaching science stem largely from a lack of self-confidence; a feeling of total inadequacy has caused science to be a non-subject in many Tasmanian primary schools. Attempts to remedy this lack of confidence have for the most part resulted in failure.*
>
> *(Alford and Kerrison, 1974, 12)*

The main problems in the area of primary science education identified by overseas' researchers may be summarised as

(i) relative neglect of science teaching at this level;

(ii) teaching that is largely incompatible with scientific inquiry;
(iii) lack of confidence on the part of teachers to engage in science education, stemming from their own perceived inadequacy of scientific knowledge.

Thus, a number of the major difficulties identified in primary science education in New Zealand seemed to be shared by several other western countries.

An Alternative Perspective on Primary Science

One of the first tasks that members of the Learning in Science Project (Primary) tackled as a means of overcoming the major problems identified was clarification of the purpose of primary science education. The perspective which emerged, after considerable deliberation, was that primary science education should help children make better sense of their natural and technological world by working in ways consistent with those of scientists (Symington, Osborne, Freyberg and White, 1982). This perspective was discussed with a wide range of science educators and generally found favour (Biddulph, Osborne and Freyberg, 1983).

Difficulties for Teachers of this Alternative Perspective

Although the perspective outlined above appealed to a number of teachers as well, members of the Learning in Science Project (Primary) team were aware that the perspective would require insights into the nature of scientific endeavour which most primary teachers lacked, and teaching roles which were contrary to the way in which most primary teachers conceived of their work. For example, implicit in the perspective is the notion of challenging children to extend their understanding, or construct more useful ideas, about their world in ways consistent with the evidence available to them and in terms that make personal sense, whereas teacher practice has tended to be that of conducting pupils to the 'right scientific answers' (as perceived by the teachers). Also implicit in the perspective is constant questioning by children of their present views about their world although, as already noted, current practices of many teachers tend to inhibit such questioning.

The dilemma, therefore, was how to help teachers gain the necessary insights and confidence to change from a predominantly 'transmission' mode of teaching in primary science to one consistent with the perspective decribed, at the same time as children were being given experiences to enable them to make better sense of their world.

An Investigative Approach to Primary Science

Dr David Symington, a Melbourne colleague who acted as a consultant to the Learning in Science Project (Primary), suggested it might be possible to resolve the dilemma by developing a teaching approach that promoted children's own questions about natural and technological phenomena as the basis for investigations devised and undertaken by the children. He had found (Symington, 1977, 1980) that a sample of primary school children in Melbourne were quite capable of generating questions in primary science if given the opportunity and encouragement.

In an exploratory study, members of the Learning in Science Project (Primary) confirmed Symington's finding with a small sample of Waikato primary school children. In addition they observed that in those classes where the researchers had elicited children's questions the teachers responded positively to both the insights these provided into the children's thinking and to the possibility of using the children's questions as a basis for studies in science (Biddulph, Osborne and Freyberg, 1983).

As a result, **children's questions** came to assume considerable significance in the quest to find ways of overcoming the major difficulties identified in the learning and teaching of science at the primary school level in New Zealand.

It was also considered that a teaching approach that enabled the teacher to work alongside the children as a senior co-investigator might help the teacher concurrently to gain insights into the process of science and and also to acquire confidence teaching children this subject. Such a role meant that the teacher no longer had to be an 'expert' in scientific knowledge but could rely on adult commonsense to assist children with their investigations.

CONTEXT OF THE PRESENT STUDY

The investigations reported in Chapters 5-8 were undertaken within the framework of the Learning in Science Project (Primary).

While these investigations focus on children's questions and their use in an alternative primary science teaching approach, it should be noted that the development of several teaching units incorporating the 'interactive' approach also involved interviewing children on the topics concerned to identify the ideas that they already held. The notion of helping children make better sense of their world implied that children be challenged to consider more useful alternatives if their present views were inappropriate in some way, or to extend views that were narrowly based. It was therefore necessary to gain some indication of the children's current thinking about the phenomena chosen for study, and interviews (especially of the interview-about-instances and interview-about-events variety as used in the Form 1-4 Project) carried out for this purpose formed an important preliminary phase in the development of the interactive teaching units described in later chapters. Data from these interviews will not, however, be examined in any detail in this study.

Instead, in this study it is argued that children's own questions about physical and technological phenomena provide a viable means of helping them make better sense of their world. Some attempts, but not many, have already been made to incorporate children's questions into teaching approaches in science education. These are reviewed in the next chapter.

CHAPTER 2

CHILDREN'S QUESTIONS AS A POSSIBLE BASIS FOR PRIMARY SCIENCE EDUCATION

This chapter considers briefly views about the role of children's questions in their learning in science, and then explores the use made of them in science education programmes. The chapter concludes with an examination of Symington's (1980) experimental research study designed to investigate several fundamental assumptions inherent in three primary science education programmes that have children's questions at their centre, namely the Nuffield Junior Science programme, Science 5/13, and Victorian Primary Science programme.

Grounds upon which the use of children's own questions might be justified in a primary science programme are considered in the next chapter. That chapter also contains a caution that not all children's questions reflect curiosity about their world.

ROLE OF CHILDREN'S QUESTIONS IN THEIR LEARNING

In the view of Armstrong (in Van Praagh, 1973), Blough and Schartz (1969), Carin and Sund (1970), Isaacs (1930) and Piaget (1959), children's questions are an important strategy which they learn to use naturally and spontaneously to investigate, and make personal sense of, phenomena around them. But the issue needs to be addressed as to whether children do, or can, ask questions, as distinct from the **assertion** that it is a naturally occurring process.

The experience of many adults in middle-class, western societies suggests that children, young children in particular, do constantly ask questions about things in their lives - at least in their lives outside school. There is some research data that confirm this impression. In a British study of 30 four-year-old girls, Tizard, Hughes, Carmichael and Pinkerton (1983) found that the girls asked on average 24 questions per hour at home, although they asked only 1.4 questions per hour in preschool. Isaacs (1930) recorded many questions which were asked by preschool children at the Malting House School, Cambridge, and Piaget (1959) recorded 397 questions asked by two six-year-old boys alone. At a slightly older age level, some 9000 questions were elicited from 1400 elementary school children in the United States by Baker (1969); Lawrence, Isaacs and Rawson (1960) illustrated the number, range and variety of questions springing from the active interests of eight to ten-year-old children in Britain; Rallison (1939), also in Britain, elicited 44684 questions from 3514 children aged 11-13 years over a one week period.

It seems reasonable to conclude from data of this kind that many children are indeed capable of generating questions if permitted or encouraged to do so.

PROPOSALS TO USE CHILDREN'S QUESTIONS IN SCIENCE EDUCATION PROGRAMMES

From time to time it has been proposed that children's questions be used to provide meaningful investigations in science education, or that science programmes should foster children's curiosity, question-asking and inquiry. For example, at the preschool level Crabtree (1982) urged teachers to help children to ask questions and find answers to them. Pemberton (1969) did the same at the infant school level. At the primary level, Alfke (1974), Blough (1975), Goldberg (1979) and I. Hawkins (1974) have all proposed that science classes should be occasions for questioning by children, while Harlen (1979) and Harlen, Darwin and Murphy (1977) reported that teachers see the stimulation of curiosity and questioning among children as important science education goals.

The latest New Zealand primary science syllabus (Department of Education, 1978) likewise promotes the development of inquiring minds as an important goal. Developing children's curiosity is considered a means of achieving this and under the objective 'Curiosity' there is the following highlighted paragraph which presumably intends to convey what curiosity means in practice:

> *Children ask questions, seek answers through initiating and carrying out investigations and use reference material.*

Proposing that a science education programme promote children's question-asking is not the same thing as a programme that includes children's questions as an important feature. The next section, therefore, summarises those science education programmes which have been located that seem to incorporate children's questions as part of the teaching approach.

SCIENCE EDUCATION PROGRAMMES THAT MAKE USE OF CHILDREN'S QUESTIONS

Only a few programmes could be found that made specific use of children's own questions. On a small scale, the Malting House Preschool in Cambridge conducted by Susan Isaacs certainly made use of the young children's questions to help them investigate various phenomena that mattered to them (Isaacs, 1930). Lewis and Potter (1961) describe a programme used by a teacher of Grade 3 children in which the children posed a variety of questions about plants and animals that they then investigated, and which led them to ask further questions.

Alfke (1974) also devised a primary science teaching approach incorporating children's questions but it seems to have been more structured than the other approaches mentioned above. Alfke was concerned to narrow the questions to be investigated to what she called 'operational' questions, that is, ones that could be investigated using hands-on type materials. This meant downplaying 'why' questions with the hope that they would disappear from the children's lists after a while.

At the junior high school level, Vogt and Haney (1974) reported an earth science course that used the students' questions in order to ensure that the subject matter was relevant to the students' needs or concerns. The students submitted an average of 17 questions apiece that they wanted to find answers to during the course. The authors noted several changes in the students' responses; they were more highly motivated than under a previous traditional approach, they assumed more active roles in class, they asked questions requiring more sophisticated thinking, and they were enthusiastic about their involvement in the planning of the course.

On a slightly wider scale, the Illinois Studies in Inquiry Training (Suchman, 1977) sought to aid children in their quests for explanations by providing them with almost unlimited opportunities to ask questions. Although the approach seemed to lack the richness and naturalness of, say, the learning environment of the Malting House Preschool - it required teachers to give restricted answers to pupils so that they would be encouraged to ask further questions but of a more specific kind - nevertheless Suchman concluded that it was successful, in a number of respects.

it was indeed possible to create a learning situation in which children were not only free to ask questions as a basis for acquiring knowledge, but were strongly tempted to do so by their own desire to find the solution to a problem.

the children almost always expressed great satisfaction in this learning model because they could learn on their own terms; they were in the driver's seat, so to speak, and could match the learning process to their own needs and styles.

we had tapped a learning mode that was familiar and comfortable to almost all children with whom we worked.

(Suchman, 1977, 265)

On a broader scale still, that is, at the level of the major primary science curriculum projects, only three such projects incorporated children's questions into their teaching format, and two of the three were in Britain.

Of the reasonably well-known United States programmes - Science, a Process Approach (SAPA); Science Curriculum Improvement Study (SCIS); Experiences in Science (EIS); Conceptually Oriented Programme in Elementary Science (COPES Project); Minnesota Mathematics and Science Teaching Project (Minnemast); Elementary Science Study (ESS) - only the last under the onetime directorship of David Hawkins promoted the use of children's questions. (It is interesting to note in passing that in the SAPA programme, questioning is not even included as one of the science processes.)

The developers of the Elementary Science Study programme, according to Waters (1973, 109),

proceeded with the belief that children are scientists by disposition. Children ask questions and use their senses and reasoning powers to make sense of the world... ESS strives to cultivate this natural curiosity and direct it to new channels of thinking and learning.

In the view of Kuslan and Stone (1972), the ESS sought to foster in children an inquiring spirit, an attitude of curiosity, interest and willingness to find out for themselves. The units included materials designed to make the children curious about aspects of their physical and biological environment so that they would be encouraged to learn more about them. The children could explore the materials either individually or in small groups. David Hawkins himself, in his 1965 article, "Messing About in Science", cites pendula as an example of such materials and comments on how all the questions that a teacher might hope would arise were indeed asked by the children, together with other thoughtful questions which were quite unanticipated (D.Hawkins, 1974). Kuslan and Stone (1972) noted that the ESS developers assumed that the methodology they recommended would bring together the two aspects of science, namely its logical, highly structured aspect and its intuitive, imaginative and humanistic aspect.

The two primary science curriculum projects in Britain which made use of children's questions were the Nuffield Junior Science Project begun in 1964, and the Science 5/13 Project which evolved from it (Henry, 1976), beginning in 1967.

The intention of the Nuffield Junior Science Project was to encourage children to pose their own questions since it was considered that this would be more likely than a traditional approach to stimulate them into becoming engrossed in investigating and learning (Henry, 1976). In the first chapter (Children Learning) of the Teachers' Guide 1 to Nuffield Junior Science, a section devoted to children's questions records some of the Project members' experiences with, and ponderings about, children questioning in science. It is worth quoting a number of these comments for the insights that they provide into children's questioning as a learning strategy. All are taken from Wastnedge (1967, 27-28).

> *Their [the children's] own questions seem to be the most significant and to result most often in careful investigations.*
>
> *If the next most relevant piece of understanding is the bit which dovetails into the pattern already existing in the child's mind, it is almost impossible for a teacher to predict what it will be. It will certainly be different for every child in the group, and only the individual child is able to ask the question which will be most significant for himself. That is why we state firmly our belief that once children have become involved, they should be encouraged to follow the lines of enquiry arising out of their own questions.*
>
> *It is certainly true that children will ask many questions, especially if the teacher encourages them, or does not discourage them, but they do not follow them all up equally keenly, and in fact, drop many of them altogether. It appears that many are of fleeting interest and require only a brief, almost casual answer. But there are times when a situation captivates a child. He (sic) will look, listen, and if possible manipulate quietly and intently, and in many cases will ask a question not always posed in the interrogative, but often expressed as a statement of belief.*
>
> *As they grow older, the children... seem more prepared to take up other people's questions - but especially other children's. It would be useful to know more about this tendency. Why is it that children who may show little interest in questions asked by adults - verbally or in books - will often join a group and work hard at answering other children's? Is there some subtle quality about children's questions which eludes the adult? What can it be? Are some kinds of questions more significant than others? If so, what gives them their significance?*
>
> *It is possible to interest young children in many things, and they will often adopt as their own the questions the teacher asks, but they leave no doubt when they have run out of interest or patience.*

Principles similar to those of the Nuffield Junior Science Project were the basis of the Science 5/13 Project. One of the aims, as expressed in the book "With Objectives in Mind", was to develop a willingness in children to ask questions and find answers through investigations (Science 5/13, 1972a). In a companion publication, "Early Experiences", another role for investigations was mentioned, as was the possibility of occasional use of teacher-generated questions:

> *Investigations invite questions, those asked by the children are usually the best ones to pursue, but this does not preclude those from the teacher.*
> *(Science 5/13, 1972b, 2)*

It was considered that children work best trying to find answers to problems (from their own environment) they themselves have chosen to investigate in a practical way. The role of the teacher was seen as that of a guide; the teacher would guide children to ask questions, to find answers through devising investigations, and through discussion to organize experiences into personal patterns (Henry, 1976).

If anything, the emphasis in the three Projects above which made use of children's own questions seems to have been on practical or 'hands-on' investigations to find answers. It would also be fair to say that the programmes were relatively loosely structured from a teaching point of view.

According to Lucas (1974) a significant feature of science syllabus revision in Australia since 1960 has been the recognition that the child's interests, questions, answers and suggested methods of investigation, rather than the subject, are important. This certainly seems to have been exemplified in the Victorian primary science programme which Symington (1980) considered similar in many respects to the Nuffield Junior Science and Science 5/13 programmes. The Victorian programme proposed as an objective, for example, that pupils "will develop the habit and ability to ask questions (Education Department of Victoria, 1968, 4).

THE FATE OF PROPOSALS TO USE CHILDREN'S QUESTIONS IN PRIMARY SCIENCE PROGRAMMES

Teachers may have been counselled to make children's own questions a cornerstone of their science programmes but the evidence suggests that the response of teachers to this proposal has not been particularly positive (Martin, 1983). In the United States, Shymansky, Kyle and Alport (1982, 14) asked,

> *Whatever happened to ESS [Elementary Science Study]...? Why, in less than 10 years, have hands-on, activity-based programs faded almost entirely from the elementary school curriculum after so much time, effort, and money were invested in developing and introducing them?*

Lucas (1974) noted that with respect to the Nuffield Junior Science programme teachers were either enthusiastically in favour of it, or were unable to cope with the apparent lack of structure. Science 5/13 did not live up to the expectations of the developers either, and a follow-up project was mounted to give teachers guidance in fitting learning experiences in science to the development of five to thirteen-year-olds. It seems significant that in a handbook published by this latter project, namely "Match and Mismatch - Raising Questions: Leader's Guide" (Harlen, Darwin and Murphy, 1977) there is almost no mention of **children's** questions, and certainly no advice about how teachers might stimulate them or incorporate them into their science activities. In Australia, Symington (1980) noted that a large number of Victorian primary school teachers did not agree that a classroom science programme could be built around questions that pupils ask.

While it may appear eminently reasonable to construct a primary science education programme around children's significant questions, obviously there are hidden difficulties that need to be identified if such a programme is to enjoy any measure of success. In the next and final section of this chapter several difficulties identified by Symington (1980) will be examined.

SOME IMPLICIT ASSUMPTIONS IN MAJOR PROGRAMMES THAT HAVE SOUGHT TO MAKE USE OF CHILDREN'S QUESTIONS

Concerned at the lack of enthusiasm for primary science education shown by many teachers in his home state of Victoria, Symington (1980) decided to test experimentally some of the major assumptions upon which the Victorian primary science programme, Nuffield Junior Science and Science 5/13 were based.

The first assumption he probed was one common to all three programmes, that children could ask investigable questions about everyday phenomena. In keeping with the approach of the three programmes, he defined 'investigable' questions as those to which pupils could arrive at meaningful answers through practical investigations using commonly available materials and with the aid of their teacher. Various constraints meant that his investigation was limited to a sample of Grade 6 children (that is, approximately 11-year-olds). The results showed that less than half the questions asked were investigable in the sense just outlined.

A second assumption was that all children would participate equally in the question-asking process, but Symington found that there was significant variation among the children in the number of investigable questions asked, with over half of the children asking three or fewer investigable questions. This finding endorses the observation of one teacher involved in the evaluation of Nuffield Junior Science:

Those interested in their work asked questions related to it - the dull accept their environment.
Crossland, 1972, 633)

A third assumption was that questions would be generated about almost any topic within the compass of children but Symington's data showed clearly that some phenomena stimulated a greater number of investigable questions than others.

A fourth assumption in the programmes mentioned was that primary teachers with no special knowledge of science could teach the courses in the spirit intended by the developers. Symington's data revealed that teachers who lacked a science background were far more **directive** in their relationships with children than their colleagues who had such a background. Lack of confidence seemed to accompany lack of background in science and this resulted in a directive style of teaching which was contrary to that required by the three programmes.

In the course of his investigations Symington also found that pupils asked more investigable questions when they had an opportunity to engage in a period of 'free play' with materials provided, followed by class discussion of the experiences, prior to the posing of questions. He noted further that the materials provided could influence the children to focus on a certain aspect of a topic.

Symington concluded that a number of issues remained to be addressed, three of which seem particularly pertinent to the present study. He was not satisfied with the notion that primary science should be restricted to practical inquiry in the 'hands-on' sense; it seemed to him that it did not do justice to either science or the curiosity of children. The second issue concerned the dissemination process; he wondered what might be the best means for curriculum developers to communicate to teachers the classroom procedures needed for pupil inquiry in science, especially what guidance teachers might need to help children explore questions that are not amenable to practical investigation. Finally he considered that research was needed to identify topics best suited to pupil inquiry with materials, rather than assuming that any topic would lend itself to such inquiry.

SUMMARY AND IMPLICATIONS OF MATTERS RAISED

The data included in this chapter indicate that if given encouragement and opportunity children can and do ask a host of questions about their world in their efforts to make sense of it. Further, in those few instances where children's questions have been given prominence in science education courses the children have been generally enthusiastic about learning in science. Despite this, the notion of children's own questions having a fundamental place in their learning has had negligible long-term impact on primary science teaching. Reasons for this seem to include unwarranted assumptions about children's questioning ability contained in the few programmes that have given children's questions a central place, a probable lack of sufficient structure in the programmes to enable teachers (especially teachers who lack a background in science) to facilitate children's question-asking and subsequent investigation, and a conception of 'investigation' that is too narrow, namely one restricted to 'hands-on' type investigation.

THE PRESENT INVESTIGATION

The present study, comprising a series of investigations, reports on the development of a viable primary science teaching approach incorporating children's own questions that sought to avoid weaknesses identified in previous such approaches, to build on the insights provided by Symington (1980), and to take advantage of recent developments in the psychology of learning and philosophy of education. These psychological and philosophical developments are explored in the next chapter.

CHAPTER 3

JUSTIFICATION FOR USING CHILDREN'S QUESTIONS IN PRIMARY SCIENCE EDUCATION

In this chapter, four grounds for using children's questions in primary science education are advanced based on curricular, pedagogical, philosophical and psychological considerations. The first two, although important, can be dealt with relatively quickly. The last two constitute much weightier grounds and require more extended treatment. The categories outlined above are not to be seen as mutually exclusive; there is overlap and interaction, particularly between the last two. Even so there is value in exploring each category separately.

The chapter ends with a consideration of some problems associated with children's questions.

JUSTIFICATION ON CURRICULUM GROUNDS

After reviewing a number of Australian research studies, Tisher (1977, 100) reported that, "Low levels of questioning and explaining on the part of the pupils were ... negatively correlated to pupils' achievement." One of his conclusions was that, "Strategies used in the classroom and in curriculum must be such as to require more questioning and explaining on the part of the pupils" (Tisher, 1977, 100).

In the context of the primary science curriculum, Baker (1969) has suggested that the many questions which children ask about natural phenomena provide a guide to what children want to know and when they want to know it. These questions can indicate to teachers topics that are likely to be suitable for meaningful study by the children. "As teachers we get clues to science content when we listen intently to children's questions" (N.S.S.E., 1975, 148).

Smith and Hall (Hall, 1921) went further and asserted that their research showed that the active minds of children can pose enough questions that are, at least partially, within their comprehension and wholly within their interests to furnish the basis of a liberal school curriculum without the addition of insoluble puzzles. Other research on the curriculum reinforces this view. "Questions children in primary grades ask indicate that they are reaching out for understanding and are sensitive to the unknown" (Selberg, Neal and Vessel, 1970, 318).

Ignoring children's questions may have serious curriculum consequences.

> *Whenever inquiry is not directly related to the satisfaction of their [children's] need to 'find out why', they show little interest in the strategies and tactics being discussed.*
>
> *(Suchman, 1969, 79)*

The suggestion in this section is that the children's own questions about natural and technological phenomena provide a simple and practical means for identifying the children's intellectual needs in the area of science, an aim of the New Zealand primary school curriculum.

JUSTIFICATION ON PEDAGOGICAL GROUNDS

Children's questions can also provide teachers with insights into the current thinking of their children (Blank and Solomon, 1976; Krantz and Bacon, 1977; Mason and Clegg, cited by Henderson and Garcia, 1973; Selberg et al, 1970). Donaldson (1978) comments in another context that

It is highly informative to listen to the comments children make and the questions children ask when they listen to stories. In this situation a rich harvest of reasoning may be reaped.

(Donaldson, 1978, 55)

An espoused principle of primary teaching in New Zealand is to 'take children on from where they are at', a notion consistent with Dewey's (1963) principle of continuity of experience (formulated in the 1930's), and with Ausubel's (1968) advice that teachers should ascertain what learners already know and teach them accordingly. Other science education researchers to reiterate this advice include Chalmers (1976), Finley (1983), Gilbert, Osborne and Fensham (1982), and Pope and Gilbert (1983). Stewart, Finley and Yarroch (1982) maintain that science education researchers should have children's prior and subsequent ideas as a primary focus because

it is imperative that science education researchers establish priorities that focus on the conceptual knowledge held by students both before and after instruction and how that knowledge is utilized in a problem solving context.

(Stewart, Finley and Yarroch, 1982, 427)

The interest shown by a few New Zealand teachers who observed their children asking questions (reported in Chapter 1) suggested that children's question-asking in primary science might be acceptable to them on pedagogical grounds.

The last section of this chapter contains a caution that question-asking by children will not necessarily reveal their understanding since a process other than information-seeking may be involved.

JUSTIFICATION ON PHILOSOPHICAL GROUNDS

At the end of the previous chapter, restriction of children's questions and investigations to those amenable to 'hands-on' activities was described as not doing justice to science itself. The current view of the nature of science, including the advancement of knowledge in this area, will now be considered as justification for the use of children's questions in primary science education.

Science and epistemology

As indicated in Chapter 1, most New Zealand primary teachers view science as a body of knowledge that has been 'discovered' by scientists. Macklin (1973) and Malitza (1982) have pointed out that the traditional empiricist-inductivist perspective influences to the greatest extent the way science is presented and explained. This positivist view relies on the idea of the existence of objective reality as something apart from human beings and views humans as the receivers of facts rather than their creators. This view of the epistemology of science has been superseded in recent years by a new perspective emanating from the theories of such philosophers of science as Brown, Feyerabend, Hanson, Kuhn, Popper and Toulmin (Butler, 1978; Stewart, Findley and Yarroch, 1982).

The new perspective views science as a disciplined **human construction**, inevitably influenced by the preconceptions and theories of those engaged in its construction, whose meanings come to be socially shared (Butler, 1978; Chalmers, 1976; Driver and Erikson, 1983; Finley, 1983; Macklin, 1973; Martin, 1972; Munby, 1982; Stewart, Finley and Yarroch, 1982; Young, 1974). Even in its most highly developed form, the constructions of science are now seen to be subject to human reconstruction

(Pope and Gilbert, 1983). Some quotations convey this perspective. In answering the question, "What is scientific thinking?" Munby (1982) proposed,

> *It is a human invention which involves using language to paint the perceptual world in a very particular and disciplined way. (p.21)*
> *From a logical point of view... the discipline of science strives for something importantly different from absolute truth; it strives for increasingly useful constructions of nature upon which predictions and generalizations can be based. (p.26)*

He added that,

> *In any discipline reality is constructed out of a network of concepts, principles, explanations and theories, which are all human inventions. (p.22)*

Findley (1983, 51) commented, "Scientific hypotheses and theories are not derived from observed facts, but are invented in order to account for them."

Driver and Erikson (1983) quote Einstein and Infeld's 1938 view of science that "Science is not just a collection of laws, a catalogue of facts, it is a creation of the human mind with its freely invented ideas and concepts."

Young (1974) argues that since all people are constantly trying to make sense of their natural world, they are all scientists in a sense. This constructivist view of scientific endeavour raises questions about the nature of 'science' in non-western societies.

Harris (1978), when investigating difficulties experienced in science education by Aboriginal children in Northern Australia, suggested that their world view and attitudes reflected a cultural knowledge different in many ways from that held by children brought up in a western society. Harris believed that this particular cultural knowledge was vital to the survival of the culture, and that how a culture classified its material and social universe could be described as that culture's science.

Harris's view exemplifies a new perspective of science as one of varied human construction, one which respects and values the cultural science that pupils bring to school. In the New Zealand context this would mean that Maori children and Pacific Island children (who constitute a sizeable minority of the primary school population, especially in the greater Auckland and Wellington areas) need to have **their** questions considered in the classroom if they are to investigate culturally significant aspects of their natural world. Such an approach would implicitly accord value to the oral tradition which is a feature of the cultures of these children.

Munby (1982) concurs. He argued that if teaching is to show how science knowledge is appropriately held and handled, then it must (among other things) respect students' questions and suggestions.

A further link between the new epistemology of science and the value of children's questions in primary science education comes from consideration of the relationship between the process by which scientists construct scientific knowledge and the manner in which children naturally make sense of their world.

The Scientific Process

Contrary to the traditional view held by many teachers that there is a single scientific method (based in the positivist position), scientific researchers and those who have examined the actual practice of scientific researchers, recognise that scientists have no single and set method (Kessen, 1964; Lee, 1967).

Rather they attack problems openly and adopt freely any method that promises a solution. Nobel prize winner, Percy W Bridgman, is quoted in Kuslan and Stone (1972) as saying, "The scientific method, as far as it is a method, is nothing more than doing one's damndest with one's mind, no holds barred."

The spur to scientific endeavour is described as curiosity (Elkind, 1975) or a powerful desire to find answers to perplexing questions (Blough and Schwartz, 1969). Kessen (1964) viewed science as a disciplined form of human curiosity which addresses the issue of whether there is a meaningful question to be asked, while both the Educational Policies Commission (1975) and Martin (1972) considered that a fundamental value underlying science is a questioning of all things.[2] Lee (1967, 21) described science as "a structured and directed way of asking and answering questions". Lee's description accords closely with an earlier one.

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2. The view of knowledge, and the place of questioning in the development of knowledge, outlined in this section on The Scientific Process is not exclusive to the field of science. In Westbury's (1973) view, the awareness that people are active agents of their own knowing and learning

> *represents one of the crucial understandings of twentieth-century philosophy. For us there is no content that is not inextricably entangled in the act of questioning... We believe that our discourses are discourses about a world, but this world is a world that is created by the questions we ask, not a world that is given... most of our current constructions of knowledge, most of the ways in which we conceptualize what knowledge is, give a higher priority to the question and the act of asking questions than they give to the bodies of answers that we have to past questions. This is the import of say, Collingwood in history, Polanyi in epistemology, Kuhn in science, Piaget in psychology, and Dewey.*
>
> *(Westbury, 1973, 117-118)*

The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle, requires creative imagination and marks real advance in science.
(Einstein and Infeld, 1938, 91)

It has been suggested that question-asking at the adult level has been the key to the most significant advances in knowledge (Eisner, 1965; Krantz and Bacon, 1977; Wertheimer, 1959). For example, Wertheimer wrote:

Often in great discoveries the most important thing is that a certain question is found. Envisaging, putting the productive question, is often more important, often a greater achievement than solution of a set question.
(Wertheimer, 1959, 141)

Raising questions is considered to be important to the development of research methodology itself. Rist (1982, 448), for example, says of the qualitative approach, "The trend is to raise new arguments and new complications, not new resolutions and conclusions. We are finding questions behind questions."

Because question-asking clearly plays a fundamental role in science it would seem that if children are to appreciate what it means to think scientifically then they should be provided with opportunities at school to engage in the ways of scientists, including questioning (Bruner, 1960; Martin, 1972).

A number of science educators make the link between children's everyday efforts to make sense of their natural world and the scientific process (Abruscato, 1982; Bruner, 1960; Carin and Sund, 1966; I Hawkins, 1974; Isaacs, 1974; Lawrence et al, 1960; Lawson, 1979; Lee, 1967; Selberg et al, 1970; Victor, 1975; Wastnedge, 1967). In Abruscato's (1982, 7) view, "All children seem to be scientists at heart" since they have not lost their natural curiosity to understand the world. On the basis of his detailed studies of children, Isaacs (1974, 118) decided that,

> *The basic essentials of the methods that build up science... are not a late and sophisticated discovery of the human mind, but a crucial part of its initial equipment. They are put to vital use during the earliest years of every infant. They actually build up in his mind, tier upon tier, a first fundamental scheme of knowledge all new to him but* ***mainly dependable****, precisely in the sense that it can be acted upon and further built upon.*

Isaacs (1974, 120) is convinced that one of the most powerful intellectual tools in the service of a child's finding-out, linking-up and organising activities is the "great open-sesame instrument of **question-asking**".

Krantz and Bacon (1977) have observed that since children have not been fully socialised into the perspective of their adult community, they can at times unwittingly ask quite profound questions which transcend the established tradition of the adult world surrounding them. Lawrence et al (1960) and Pope and Gilbert (1983) support the unorthodox thinkers.

> *The development of science depends on people having the courage to go beyond currently accepted notions. Teachers must support courageous exploration of ideas and help students to develop a sense of agency with respect to the construction of knowledge.*
>
> *(Pope and Gilbert, 1983, 201)*

JUSTIFICATION ON PSYCHOLOGICAL GROUNDS

This section describes the views of a considerable number of science educators and researchers who have outlined the benefits which they consider question-asking by children can have. These benefits include promoting the children's creative, moral and intellectual development, enabling them to make better sense of their world, providing a real purpose to their learning in school, and allowing them to learn at a pace appropriate to them.

The section concludes with consideration of the way that constructivist learning theory seems to provide substantial support for the utilization of children's questions in primary science.

Development of intellectual abilities, moral autonomy and creativity

A number of educators and researchers (Cazden, 1970; Eisner, 1965; Goldberg, 1982; Isaacs, 1930; Kamii and DeVries, 1978) believe that question-asking is important to intellectual development. For example, Isaacs (1930) wrote that success in searching for reorientation, readjustment and reorganisation (notions akin to Piaget's concepts of assimilation and integration) lead to the growth of adaptive intelligent behaviour. Goldberg includes 'independence' as a component of such behaviour. "Children," Goldberg (1982, 10) says, "grow in independence and knowledge by asking questions and making observations about puzzling things."

Critical thinking is also regarded as an important aspect of intellectual functioning, and Eisner (1965) considered that question-asking develops, and is a central component of, such thinking.

Kamii and DeVries (1978) claim that children's moral development as autonomous individuals also depends on question-asking. Chaudhari (1975) noted Suchman's 1967 claim that inquiry and discovery not only build the self-esteem of the discoverer but also develop in the person a sense of autonomy and intellectual potency.

Like critical thinking, 'creativity' also tends to be regarded as an element of intelligent behaviour. In the experience of Torrance (1970b, 16), "One of the most impelling of a child's creative needs is his curiosity" while Selberg et al (1970, 318) claimed that, "Children's questions set the stage for creative thinking." White (1977, 125) also considered that question-asking is an important characteristic of a creative person but, "The most difficult part in being creative is thinking of new questions." In summary, question-asking is considered to enhance children's intellectual[3], moral and creative development.

Helping children to make sense of their world

Many researchers link question-asking to children making sense of their world. A survey of these views follows. Question-asking is seen to be strong in normal children (Chaudhari, 1975; Hall, 1921; Isaacs, 1974; Lawrence et al, 1960; Tizzard et al, 1983; Zahorik, 1971) and a major process by which they come to know their world (Abruscato, 1982; Arnstine, 1967; Berlyne and Frommer, 1966; Carin and Sund, 1966; Day and Berlyne, 1971; I Hawkins, 1974; Holt, 1970; Lawson, 1979; Lee, 1967; Piaget, 1959; Robinson, 1983; Ross and Balzer, 1975; Torrance, 1970a; Tough, 1973; Victor, 1975; Zubrowski, 1982). Questioning, especially of elements of uncertainty, complexity, novelty, ambiguity and incongruity in their environment, is considered to be an important intellectual strategy by which children construct working models of their world (Day and Berlyne, 1971; Holt, 1969, 1970; Howe, 1972; Isaacs, 1930, 1974; Krantz and Bacon, 1977; Robinson, 1983; Tough, 1973).

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3. Tizzard et al (1983, 269) warn that,
The issue of whether children's questions and the quality of the answers they receive contribute to their intellectual development and educational attainment could only be satisfactorily tackled on an experimental basis.

In Holt's view,

> *curiosity is hardly ever idle. What we want to know, we want to know for a reason. The reason is that there is a hole, a gap, an empty space in our understanding of things, our mental model of the world. We feel that gap like a hole in a tooth and want to fill it up. It makes us ask How? When? Why?*
>
> *(Holt, 1970, 171)*

Holt (1970) also observed that until children have a great deal of data, they have no idea what questions to ask, or what questions there are to be asked.

To some science educators, children's pursuit of curiosity[4], question-asking and exploratory strategies represent the beginning of scientific inquiry (Arnstine, 1967; Isaacs, 1930; Kessen, 1964; Wastnedge, 1967). Selberg et al (1970) clearly linked children's questioning with science. They considered that at the primary school level, "Science is what children find out through investigation of their questions about themselves and their surrounding world" (Selberg, Neal and Vessel, 1970, 29).

To other educators, children's curiosity and questions also enable them to engage in meaningful learning in the school setting (Armstrong, 1980; Barnes, 1976; Beauchamp, Mayfield and Hurd, 1965; Blough, 1975; Blough and Schwartz, 1969; Francis, 1977; Kuslan and Stone, 1972; Maw, 1971; Postman and Weingartner, 1971; Suchman, 1969). In particular, it has been contended that children's questioning can allow them to learn at a pace that is appropriate to them (Kuslan and Stone, 1972).

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4. 'Curiosity' is a term that is used freely by educators but Day and Berlyne (1971) offer a reminder that it is an invented concept, and is an attribute that can be inferred only from the way a person behaves.

Making sense of one's world through question-asking and investigation is not necessarily as simple as Holt would suggest. David Hawkins' experience of working with children in the course of the Elementary Science Study led him to believe that,

> *When the mind is evolving the abstractions which will lead to physical comprehension, all of us must cross the line between ignorance and insight many times before we truly understand.*
>
> *(D Hawkins, 1974, 68)*

Children's questioning and constructivist learning theory

In contrast to behaviourist theory which views learning as largely a gradual accretion of extant ideas, beginning with those at the simple end of an elaborated hierarchy, constructivist theory views meaningful learning as involving an extension or restructuring of an individual's existing ideas.

Many researchers (e.g. Barnes, 1976; Craig, 1957, Doyle, 1980; Driver, 1982; Francis, 1977; Gilbert, Osborne and Fensham, 1982; D Hawkins, 1974; Kamii and DeVries, 1978; Kuslan and Stone, 1972; Lovell, 1980; Sutton, 1980; West, 1982) suggest that constructivist theory provides the most useful current explanation of how children learn most things about their world. As Stewart et al (1982) have said about information processing psychology, within which constructivism is located,

> *The importance to science education research of information processing psychology in general and the concept of schemata in particular is similar to that of the philosophy of science: that is, both stress the role that existing knowledge plays in shaping our perceptions of the world.*
>
> *(Stewart et al, 1982, 428)*

Kelly's personal construct theory (as summarised by Pope and Gilbert, 1982, 1983), and Taba's (1969) view of learning as a transactional process, are also consistent with this constructivist perspective on learning.

The particular form of constructivism underpinning the present study is the **generative learning theory** of Wittrock (Osborne and Wittrock, 1983; Wittrock, 1974, 1979, 1980). The fundamental premise of this theory is that human learning with understanding involves a process of generating and transferring meaning for incoming stimuli and events from one's own background, attitudes, abilities (including verbal) and experiences. Learners' active constructions of meaning are constantly influenced by their prior conceptions and dispositions. The theory allows for different learners responding differently to the same stimulus.

Question-asking fits comfortably with generative learning theory since it is a major intellectual process, albeit a largely internalised one, whereby children generate further meanings from their prior ideas. Expectations play a major role in this process, which explains why the question-raising circumstances of anomaly, novelty, complexity, incongruity, discrepancy, uncertainty, and surprisingness (Arnstine, 1967; Berlyne and Frommer, 1966; Claxton, 1984) are perceived as such; they are contrary to children's expectations of how the world is.

The element of self-responsibility for meaningful learning implicit in generative learning theory is also consistent with the contention of D Hawkins (1974) and humanistic psychologists such as Rogers (1969) that meaningful learning is self-directed, and marked by qualities of personal involvement and self-evaluation.

Although the major focus of generative learning theory is individual conceptual development, Osborne and Wittrock (1983), in discussing motivation, acknowledge that there are affective components to learning that also require consideration in future research. Educational psychologists such as Rogers (1969) and Claxton (1984) have described a number of affective factors (e.g. feelings of threat, willingness to take risks, sense of significance) that influence learning. Hence the affective domain is brought alongside generative learning theory to inform the present study.

A further reason for using the generative and humanistic psychology learning theories to underpin the present research is that the action-research reported in later chapters is concerned with teacher learning as much as it is with child learning in science education. These learning theories were considered (Osborne and Wittrock, 1983) to provide a promising means of facilitating such teacher learning.

The implications for primary science education of the generative and humanistic psychology learning theories would seem to include the need to respect children's prior ideas about the natural and technological world, and to challenge them to extend or, where necessary, restructure these in their own terms and in ways that enable them to make better sense of these phenomena.

Providing challenging contexts and materials that confound their expectations in some way, encouraging them to make their questions about these explicit, and providing a supportive climate to enable them to construct and test tentative links with their existing understandings, are likely to aid them in their meaningful learning endeavours in primary science. Lawrence et al (1960) suggested with respect to younger children,

> *If a child leaves the Junior School always prepared to question when in doubt, unwilling to take new facts for granted, and with some initial training in sifting evidence, a base has been laid for learning science and for living in a scientific age.*
>
> *(Lawrence, Isaacs and Rawson, 1960, 126)*

SOME CAUTIONARY COMMENTS ABOUT CHILDREN'S QUESTION-ASKING

At least four cautions are to be noted when investigating children's questioning.

(i) Not all questioning by a child is made explicit. Day and Berlyne (1971) point out that much exploration by a curious child may be internalised.

(ii) Although questions are part of the fabric of our language, those asked by children are not all in the usual question form. Some can take the form of statements in which the intonation alone indicates that a question is being asked. Cazden (1970) has examined closely the forms that developing children's questions take, but for the purposes of this study it is sufficient to be aware that they may be couched in other than standard form, particularly in the case of younger children and in the case of children whose mother tongue is not standard English.

(iii) Not all questions asked by children stem from their curiosity. Questions can indicate an anxious child, or one who has been reinforced to question-asking previously (Day and Berlyne, 1970). When children are asked to generate questions some may mimic the teacher-type interrogatory questions. Questions may be a means of seeking social intercourse (Arnstine, 1967; Eisner, 1965), that is, a device to capture attention or to keep the conversation going (Tizard et al, 1983), or a verbal game (Cazden, 1970). Some questions are simply exclamations of protest or anger (Isaacs, 1930) or represent challenges to control (Tizard et al, 1983)[5].

(iv) Question-asking by children almost always involves an affective as well as an intellectual dimension. This is obvious with 'challenge'-type questions but in the view of Arnstine (1967) and Krantz and Bacon (1977) there can also be feelings of joy and wonder associated with question-asking. Further, question-asking by children usually involves placing an element of trust in the person (often an adult) being asked.

The implications of these cautionary comments are that teachers should not pressure children to externalise their questions. They need to be sensitive to non-standard forms of questioning and to accept that what might appear to be non-genuine questions may still have the potential to engage children in useful studies. They, and other children, will need to respect the inner lives exposed by children's questions.

SUMMARY

This chapter argues for the use of children's questions in primary science education on pedagogic, curriculum, philosophic and psychological grounds. The views assembled suggest that serious consideration be given to promoting and valuing children's questions in primary science education. This is

5. Tizard and Hughes (1984) found that it was almost impossible to allocate a question to a clear-cut functional category since many served, or had the potential to serve, several functions at once. For example, 'challenge' questions might also contain an element of genuine curiosity.

supported by considerations of the nature of science and constructivist and humanistic learning theory. A radically different teaching mode (where the children's own questions play an important role in their learning) is proposed in place of the 'directed' mode which exists in most primary science classrooms.

CHAPTER 4

SOME CENTRAL ISSUES OF METHODOLOGY

This Chapter examines central issues relating to the overall methodology of this thesis. The issues are congruity, procedure, reliability and validity. As indicated in Chapter 1, Chapters 5-8 will begin with particulars of the methods used in the investigations reported in each chapter.

CONGRUITY

Congruity refers to the consistency or 'goodness of fit' of the research methodology to

(i) the purpose of the research - **external congruity** and

(ii) the theoretical perspective underlying the research - **internal congruity.**

External Congruity

The first three chapters make it clear that the intention of the present study is to inform primary science education practice. In this sense it is 'problem-driven research' (Driver and Erikson, 1983) of the kind that Cohen and Manion (1980) have termed 'intervention action research', and Bogdan and Biklen (1982) have characterised as 'applied pedagogical research'. The main purpose is to improve science education at the primary level through exploring the possibility of incorporating children's questions into a viable teaching approach. There is also a determination to maximise the probability that the research outcome will have some long-term impact rather than being rejected by teachers (Bolster, 1983; Spector, 1984) as has happened in the past.

> *These new practices typically enjoy a brief vogue in the schools and then are gradually overpowered by the more persistent techniques of traditional pedagogy.*
> *(Bolster, 1983, 295)*

Research evidence shows that current primary science teaching practices are influenced by strongly-held teacher beliefs about aspects of teaching (Bolster, 1983; Eisner, 1984). Easley's (1982) concern that insensitivity by researchers and curriculum developers to the social mechanisms operating in classrooms and schools can create new problems also needs to be considered.

These factors require use of an ecologically valid (Rist, 1982) form of research methodology, namely **naturalistic** research (also variously termed qualitative, ethnographic, or case study research), to address and illuminate significant processes, or inner dynamics (Bogdan and Biklen, 1982), involved in teaching and learning in the natural setting of the classroom (Rist, 1982). Following Smith (1982), the term 'naturalistic' is preferred over the alternatives since it is a more neutral term which avoids both the connotation that the research is solely anthropological in nature, and the unnecessary dialectic between qualitative and quantitative approaches. Some of the following chapters use simple quantitative strategies since, like Roberts (1982), qualitative and quantitative approaches were viewed as complementary.

Internal Congruity

Two sociological-type, theoretical positions have been identified as underpinning naturalistic research methods. These are **phenomenology** and **symbolic interactionism** (Bogden and Biklen, 1982; Bolster,` 1983; Spector, 1984; Wilson, 1977). The premises of both these theoretical perspectives are highly compatible with the new perspective on science and with generative and humanistic psychology learning theory; all stress that knowing is a process of social construction or reconstruction. In addition, both symbolic interactionism and humanistic psychology learning theory recognise the influence of affective factors on individual interpretation of events and episodes of social intercourse. In this respect the use of naturalistic research methodology provides a valuable complementary role to generative learning theory and enables a focus in this study to be maintained on the effect of context on learning, an aspect that generative learning theory does not encompass so readily.

In Young's (1974) terms, the theory and methodology of the research reported here are 'organically' linked or related.

PROCEDURE

Naturalistic methodology requires decisions about (i) suitable field sites, and the gaining of access to them; (ii) the role of researcher(s) and teachers; (iii) means of data collection. The first of these can be discussed on its own, but the latter two cannot be so readily separated and will therefore be examined as a single procedural category.

Selection of, and access to, field sites

In Easley's (1982) view, random sampling is not necessarily a useful way of selecting field sites in naturalistic research since in some school settings the teachers would not be particularly co-operative. Easley recommends selection of schools to which access is assured, the approach adopted for this study. The field sites were recommended to the researcher by Kelvin

Smythe (an Inspector of Primary Schools in Hamilton), or were known to the researcher, as likely to be welcoming. These included a mix of rural and urban schools in the Waikato and Canterbury districts, in order to extend the type of location to which the findings might be applicable.

Easley (1982) observed that the manner in which the researcher gains access to the field site influences the value of the data collected (Easley, 1982; Rist, 1982; Smith, 1982; Wilson, 1977). Easley (1982) also commented that an approach which involves an offer of help to teachers can be a good way to gain access. In the present case, the researcher presented himself to teachers as a primary teaching colleague[6] with no expertise in science, who was exploring ways to help teachers feel more confident about teaching primary science. As a result, the participating teachers did not feel threatened.

Eisner (1984) stresses the importance for naturalistic researchers of an intimate acquaintance with the distinctive processes of life in classrooms, so that the results will be useful for the people who work there. The researcher and his colleagues had such acquaintance and felt for the teachers in some of the difficulties they experienced in the course of the study.

Researcher/teacher roles, and data collection

The presence of a researcher in classrooms affects teachers' normal routine, something Easley (1982) sees as unavoidable. Easley (1982) also considers that more can often be learned about

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6. This was a more accurate description than a university researcher since the field work was carried out when the researcher had come directly from teaching in primary school classrooms.

difficulties experienced by a teacher if the researcher occasionally takes over the class.

In this study, the researcher (and in one investigation, two research colleagues) adopted a range of positions on the observer-participant continuum. These were:

(i) the researcher acting as class teacher - Chapters 5 and 6;

(ii) the researcher acting as observer - at one site in Chapter 6;

(iii) the researcher and two colleagues acting as observers, but also being drawn into consultant roles - Chapter 7.

Cohen and Manion (1980) point to the value of co-operative research involving researcher and teachers in action-research studies concerned with innovation and change. In some of the investigations reported in Chapters 6 and 7 of this study the teachers acted as collaborators.

Participants other than a principal researcher may contribute to a team research effort to implement and monitor an innovation (Cohen and Manion, 1980). With the present investigations two research colleagues participated directly in the collection of some field data - Chapter 7. These were Eleanor Hawe, a primary teacher seconded to the Learning in Science Project (Primary) for one school term, and Ken Appleton, a science education lecturer on six months sabbatical leave from a College of Advanced Education in Queensland. A fourth member of the team from the commencement of the study until its conclusion was Dr Roger Osborne, the Director of the Learning in Science Project (Primary). He was not directly involved in data collection but he regularly reflected on the data and challenged the researcher to do likewise (Young, 1974) so that the study could build on itself (Wilson, 1977).

The means of data gathering used in this study were:

(i) open-ended interviews (Rist, 1982; Smith, 1982; Spector, 1984);

(ii) classroom observations;

(iii) audio-tape recordings of classroom discussions;

(iv) collection of copies of children's and teachers' written plans and notes;

(v) written recording of children's questions;

(vi) field notes.

RELIABILITY AND VALIDITY

Strategies used in naturalistic research to ensure reliability and validity differ from those employed in experimental or more quantitatively-based research (Bogdan and Biklen, 1982; Bolster, 1983; Easley, 1982; LeCompte and Goetz, 1982; Smith, 1982; Spector, 1984; Walker 1980). Issues of reliability and validity in this study are considered within a framework provided by Le Compte and Goetz (1982).

Reliability

At a general level, reliability in this study was enhanced in two ways: first, by ensuring that the 'world view' underlying the methodology is congruent with the theoretical underpinning of the study, and secondly by using a multi-modal approach to data collection and analysis. Qualitative data were **collected** in several different ways (observation, participation, interview), and some simple quantitative strategies, as well as grounded construct techniques, were used in the **analysis** of data.

More specifically, **external reliability** was enhanced by

(i) the researcher playing a non-threatening role of fellow teacher/collaborator;

(ii) giving a careful description of those providing the data;

(iii) observing teachers during both the development and trying out of the alternative teaching approach over a period of approximately two weeks in each case;

(iv) using jargon-free terminology to interpret the data so that the findings could be communicated clearly to teachers to illuminate their work;

(v) using a grounded theory approach (Glaser and Strauss, 1967) for data analysis so that important factors which had previously remained hidden from science education researchers might be revealed;

(vi) using a 'constant comparative method' (Wilson, 1977) of data collection which involves constantly testing emerging hypotheses against the reality being observed;

(vii) specifying carefully the social context of each of the investigations involving classroom teaching and learning.

Internal reliability in this study was enhanced in five ways.

(i) All interviews and as much as possible of the classroom sessions conducted by the researcher acting as teacher were recorded on audio-tape and later transcribed for analysis. Classroom observations were likewise audio-taped and later transcribed, with the exception of observations of two teachers where it was felt that the use of tape-recorders would be too intimidating.

(ii) Field notes recorded by the researcher (and his two colleagues) attempted to record actual behaviour and activity in the classrooms, including what seemed to be important pieces of conversation, rather than high-inference interpretative comments.

(iii) Regular interchanges between the researcher and teachers were held to check that aspects focussed on by the researcher were also considered significant by the teachers.

(iv) The researcher himself frequently acted as the class teacher, especially in the early phases of the study (those reported in Chapters 5 and 6).

(v) Peer examination of the research was conducted regularly, especially by Dr Roger Osborne, the Director of LISP(P), who critically scrutinized both the data and the interpretations placed on them by the researcher and his colleagues.

Validity

Several strategies were used to ensure that constructs developed within the study fitted the reality of the contexts being investigated, rather than being a reflection of some value system smuggled unwittingly into the analyses by the researcher (Walker, 1980).

Internal validity was enhanced in four ways.

(i) The results were compared with data from comparable school classes collected earlier in the Learning in Science Project (Primary) by free-flow observations to distinguish intervention-induced change from naturally-occurring change. Children and teachers involved in the study were interviewed to obtain their views on what effects the intervention was having on them.

(ii) Missionary zeal was scrupulously avoided to counter the threat of researcher-induced distortion. Low-key, fellow-teacher roles were adopted by the researcher and his colleagues, any advice solicited from the researchers by the teachers and any means by which they perceived they had been supportive of the teachers were recorded, and teacher reactions to the presence of researchers were identified through informal interviews.

(iii) A diversity of children and teachers in different locations were chosen as participants and informants for the study to combat the threat posed by selection and regression factors. The researchers were constantly on the alert for discrepant responses - what Walker (1977) calls negative evidence and Rist (1982) refers to as critical incident exceptions - that might point to processes or factors that had remained hidden to that point. The constant questioning of assumed meanings through teacher and peer review also helped reduce this threat.

(iv) The threat of spurious conclusion was reduced by collecting data from several sources, and by having a researcher present in the classroom engaged in free-form observation for the duration of each field trial.

External validity is concerned with whether illumination of processes, mechanisms and relations is sufficient to enable similar factors in other contexts to be identified as such (Easley, 1982; LeCompte and Goetz, 1982). In this study, external validity was enhanced by

(i) bringing the researcher's intimate acquaintance with classroom life to bear on the study;

(ii) having teachers as collaborators in the research so that observations could be collected from more than one perspective;

(iii) constantly cross-checking interpretations with teachers;

(iv) systematically identifying the interactive dynamics of the settings;

(v) triangulating a variety of data sources;

(vi) peer auditing to ensure that assumptions, especially about mundane phenomena, were examined rather than accepted without question.

SUMMARY

Research methodology issues of congruency, procedure, reliability and validity have been considered in this chapter, and ways that the present study addressed these have been outlined. A number of the strategies used to reduce threats to reliability and validity were able to serve more than one function.

The discussion of methodological issues has been at a relatively general level. Specific methods used in each of the investigations are described in the chapters which follow.

The investigations to be described build upon each other. Following Bogdan and Biklen (1982), it was assumed that not enough was known about what might emerge as important concerns in the course of the investigations to enable a complete research programme to be drawn up prior to the study. It was therefore anticipated that emerging questions would help to shape later investigations.

CHAPTER 5

QUESTIONS CHILDREN ASK ABOUT NATURAL AND TECHNOLOGICAL PHENOMENA

This chapter presents data to address three questions:

1. Can questions about science topics be elicited readily from children in New Zealand primary schools?

2. What are the characteristics of questions asked?

3. What influences the number and type of questions asked?

In the first section of the chapter, data are presented to indicate that questions about natural and technological phenomena can be reasonably readily, or very readily, elicited from approximately half the children in primary school classes the first time this is attempted.

The second section shows that a significant proportion of questions asked are formulated by children in more than one classroom, that the children usually have ideas about possible answers to their questions, and that a majority of their questions are potentially investigable. The questions also provide teachers with insights into the children's thinking.

The third section suggests that the number of questions asked reflects children's prior experiences of a topic, the type of topic, and the social climate of the classroom. The investigations also revealed a 'ripple' effect within classrooms. The initial questions of a few children suggested to their classmates ideas for further questions to ask.

DATA COLLECTION

The main data of this chapter comprise 741 questions about seven topics obtained from children in 45 class-rooms. Following Symington (1980), all were elicited after the children had been involved in some kind of introductory activity and associated discussion. A list of the introductory activities used and questions elicited is contained in Appendix 1.

The questions were recorded in the children's own words on a blackboard, chart or note paper in front of the children. Frequently the request for questions was framed in several alternative ways such as, "Now, I'm wondering what questions you might have about [name of topic]?" or, "Are there any things you have wondered about [name of topic] that you would like to know?" or, "Is there anything to do with [name of topic] that has been a bit of a puzzle to you that you'd like to find out about?", or "What would you like to ask about [name of topic]?"

The children were also told that it was quite usual for different children to ask quite different questions, and that these were all valuable. The intention was to establish a non-judgemental atmosphere where the children felt they could ask about aspects of a topic that genuinely interested them.

Most of the questions were elicited by the author who worked with children in their usual classroom settings in several locations in New Zealand. Some questions were contributed by five classroom teachers and a science adviser who took an early interest in the work of the Learning in Science Project (Primary), and one set of questions was contributed by Dr David Symington, a colleague from Victoria College, Melbourne, who acted as a consultant to the Project.

Supplementary data about three further topics comprise 113 questions obtained from children in three classrooms (see Appendix 2). These questions are designated supplementary since only one class of children contributed questions about each topic, unlike the main data where several classes provided questions about each topic.

Later in the chapter limited reference is made to some questions elicited from children during individual interviews.

THE NUMBER OF QUESTIONS ELICITED

Details of the supplementary data are recorded in Table 1 below.

TABLE 1: Number of questions elicited from three classes of children on three separate topics

Topic	**School**	**Class**	**No.Qus**	**Elicited by**
Slater	Eureka	S1/2	6	Author
Birds	Stoke	S3	39	Jenny Earl, class teacher
Time	Ohau	S3-F1	68	Barbara Matthews, tchr

The type and location of Eureka and Ohau Schools are included in Table 2 below. Stoke School is an urban school in the Nelson district.

Details of the main data are shown in Table 2 below.

TABLE 2: Number of questions elicited from 45 classes of children about seven topics

Topic	School	Type	Location	Class	No.Qus.
Floating	Pukehina	Rural	Bay of Plenty	S4 (9chn)	9 d
and	Ohau	"	Horowhenua	S3-F1	>43 d
Sinking	Tamahere	"	Hamilton	S3	11
	Tamahere	"	Hamilton	S4	6
	Fifth Ave	Urban	Hamilton	S2/3	6
	Knighton	"	Hamilton	S3	4
	Hillcrest	"	Hamilton	S4	6
	Fifth Ave	"	Hamilton	S4	12
	Glenview	"	Hamilton	S4	14
Plástic	Tamahere	Rural	Hamilton	S3	7
	Eureka	"	Waikato	S2/4	9
	Hillcrest	Urban	Hamilton	S3/4	12
	Glenview	"	Hamilton	S4	19 d
Rock	Hautapu	Rural	Waikato	S3/4	17
	Whatawhata	"	Waikato	S2/3	18
	Knighton	Urban	Hamilton	S3/4	8 a
	Titirangi	"	Auckland	S4	13 b
	Robertson Rd	"	Auckland	S4 (a)	13 d
	Robertson Rd	"	Auckland	S4 (b)	12 d
	Weymouth	"	Auckland	S4 (a)	9 d
	Weymouth	"	Auckland	S4 (b)	15 d
	Toorak Central	"	Melbourne	(S4)	17 d

Metal	Tamahere	Rural	Hamilton	S2	7
	Tamahere	"	Hamilton	S3	31 d c
	Tamahere	"	Hamilton	S4	15
	Matangi	"	Waikato	S3/4	12
	Bishopdale	Urban	Christchurch	S3	15
	Glenview	"	Hamilton	S4	>20
	Hillcrest	"	Hamilton	S4	14
	Knighton	"	Hamilton	S4	19
Spider	Matangi	Rural	Waikato	S2/3	14
	Whatawhata	"	Waikato	S4	17
	Harewood	"	Christchurch	S4	21
	Aranui	Urban	Christchurch	NE-J1	13 d
	Roydvale	"	Christchurch	S1	18
	Fendalton	"	Christchurch	S4	25
	St Albans	"	Christchurch	S4	35
Skele-ton	Harewood	Rural	Christchurch	S3	19
	Marshland	"	Christchurch	S3/4	23
	Fendalton	Urban	Christchurch	S3	20
	St Albans	"	Christchurch	S3	19
	Bishopdale	"	Christchurch	S3/4	28
Flowers and Seeds	Taupiri	Rural	Waikato	S3/4	25
	Papanui	Urban	Christchurch	S2/3	20
	Glenview	"	Hamilton	S3	31 d

KEY: > Indicates that more questions could have been recorded but there was insufficient time to do so.

a These children were the 'remnants' of two classes who had gone on a school camp.

b These children asked their questions at Lopdell Centre before an audience of inservice course members.

c These children had been interviewed individually about the topic within the previous week.

d These questions were obtained by people other than the author, as follows:

SCHOOL	PERSON	DESIGNATION
Pukehina	Brian Olds	Class teacher/Principal
Ohau	Barbara Matthews	Class teacher/D.P.
Glenview	Nevil Robson	Class teacher (S4)
Robertson Rd	Eric Jackson	Science Adviser
Weymouth	Eric Jackson	Science Adviser
Toorak Central	Dr D Symington	Science Ed. Lecturer
Tamahere	Bill McMinn	Class teacher
Aranui	Natasha Newton	Class teacher
Glenview	Juliet Roger	Class teacher (S3)

The data in Table 2 are summarised below in two further tables. The first of these, Table 3, shows the number of schools, and their location, from which the 45 classes of children were drawn.

TABLE 3: Number of schools, and their location, where children's questions were elicited

Location	**Rural**	**Urban**	**Total**
Hamilton/Waikato	6	4	10
ChCh/Canterbury	2	6	8
Auckland	-	3	3
Other	2	1	3
TOTAL	10	14	24

Table 4 collates the data from Table 2 and includes the median number of questions asked by the children for each topic.

TABLE 4: Summary of number of questions asked by the children about each topic

Topic	**No.Classes**	**Class Levels**	**No.Qus**	**Range**	**Median**
Float/sink	9	S2-F1	111	4-43	10
Plastics	4	S2-S4	47	7-19	10.5
Rock	9	S2-S4	122	8-18	13
Metal	8	S2-S4	133	7-31	15
Spider	7	J1-S4	143	13-35	18
Skeleton	5	S3-S4	109	19-28	20
Flower/seed	3	S2-S4	76	20-31	25
TOTAL	45		741		

The mean number of questions asked per class across all seven topics was 16. This suggests that questions about science topics **can** be elicited reasonably readily from children in New Zealand primary schools.

This conclusion is supported by data based on the author's subjective experience of eliciting the questions. When the children did not respond readily less than seven questions were elicited. When the children were reasonably forthcoming the number of questions elicited ranged from seven to fourteen. When the children were enthusiastic more than 14 were forthcoming. Table 5 is constructed of categories based on these perceptions.

TABLE 5: Number of classes with different-sized question lists

No. of Qus asked	**No. of classes**
< 7	4
7-14	17
> 14	24

Table 5 reveals that in 41 of the 45 classes the children's questions were reasonably readily, or very readily, elicited.

Two other observations with respect to the readiness with which children asked questions are relevant. First, when the children in a class were invited to ask questions they responded in a manner which became predictable. After one or two children had asked questions other members of the class gradually joined in the asking.

Secondly, a significant number of children in the classes did not ask any questions in the initial question-asking session. Data were kept on the number of children from 15 classes who participated in question-asking. This is recorded in Table 6.

The data in Table 6 reveal that, with the exception of the Ohau School children (who worked with their own teacher), the percentage of children in each class who did **not** ask questions in the first session of question-asking ranged from 43% to 79%, with a mean of 58%.

TABLE 6: Number and percentage of children in 15 classes who asked questions

Topic	School	Class	No.Chn	No.asking	No.Qus
Float/sink	Ohau	S3-F1	31	25 (81%)	>43
Time	Ohau	S3-F1	30	21 (70%)	68
Slaters	Eureka	S1/2	21	5 (24%)	6
Rock	Whatawhata	S2/3	25	11 (44%)	18
Metal	Matangi	S3/4	19	6 (32%)	12
"	Bishopdale	S3	33	7 (21%)	15
"	Tamahere	S4	37	14 (38%)	15
"	Glenview	S4	28	14 (50%)	>20
Spider	Matangi	S2/3	20	9 (45%)	14
"	Harewood	S4	23	13 (57%)	21
"	Fendalton	S4	32	17 (53%)	25
Skeleton	Harewood	S3	27	15 (56%)	19
"	Fendalton	S3	33	12 (36%)	20
"	Bishopdale	S3/4	30	15 (50%)	28
"	Marshland	S3/4	25	12 (48%)	23

The results of this first section of the chapter indicate that when children were first invited to ask questions one or two in each class did not hesitate to do so, and eventually between one-fifth and four-fifths of the children in most classes responded reasonably readily or very readily with questions.

CHARACTERISTICS OF THE QUESTIONS ASKED

Seven features of the children's questions seem to have relevance for a possible teaching approach incorporating such questions. These have to do with their function for children, form, language of communication, commonness across school classes, appeal for children, investigability and compatibility with science programme suggestions. In addition, children were found to have a propensity for suggesting possible answers to some of their questions. These, added to the questions, provided teachers with insights into their children's thinking.

Questions serve various functions for children

From the questions asked, together with the tone in which they were perceived to be asked, it can be inferred that questions served different functions for different children. It is conceivable that some were offered to please the researcher, or to draw attention to the children themselves. For the most part, however, the questions seemed to be genuine.

Most questions appear to serve the function of **filling self-recognised gaps** in the children's knowledge. This is illustrated by some S3 children from Harewood School who asked about skeletons,

Why do creatures have skeletons?
Are the teeth part of the skull?
How can some people tell your age from your skull?

and some S3-F1 children from Ohau School who asked about floating and sinking,

Do all stones sink, even if they're little?
Why does ice float?
How do air balloons float?"

Another group of questions appear to serve the purpose of **resolving unexpected puzzles** the children have experienced when expectations they held no longer seem valid. For instance, after looking at pictures of skeletons and a model of a human skeleton one of the S3 children at Harewood School wanted to know,

> *How come the legs are so long because when you are alive it doesn't look so long?*

and another asked,

> *When we die, how come there are bigger holes where the eyes have been?*

A few examples from the children at Ohau School about floating and sinking further illustrate this function:

> *Why don't ferries sink, because the cars and trucks are heavy?*
>
> *Why do paper clips sink, when other heavier things can float?*

A few of the questions asked suggest that the children have an idea of a likely explanation about some phenomenon and are **seeking confirmation** for their hypothesis. For instance, in the context of the topic 'skeletons', a S3 child at Fendalton School, asked,

> *When they are old bones, does the bone marrow go hard?*

and a S3/4 child at Marshland School wondered,

> *Do the teeth automatically fall out?*

In the midst of collecting questions, the researcher was consistently impressed with the eagerness of the children to make sense of the various phenomena **in their own terms**.

Form of the questions

Only very rarely was a question framed in a non-standard way. One example occurred at the end of an interview about floating and sinking when a Melville High School F4 student was asked if he had any questions. He returned to an observation he had just made that was completely contrary to his expectations, namely that a plasticine 'boat' displaced more water when floating than when completely submerged. He said, *I was a bit confused about that, how when it was floating, while it was on its side [under the water]; I thought myself it would push out the same [amount of water] both ways, but obviously it didn't.*

The tone of the statement suggested that the student was asking, "Why did it push out more water when it was floating?"

Occasionally two questions would be wrapped into one. For example, a S3/4 pupil at Bishopdale School asked,

When you've got a broken leg, does your bone actually break and, if it does, what makes it heal?

Very occasionally too, a child would have difficulty forming a question, as was illustrated by another S3/4 child from Bishopdale School,

How come when babies are born, if you drop them sometimes they'll get, their brain goes all funny when they grow up?

A simple, direct mode of language is used

The relatively unsophisticated vocabularies and language structures of primary school children mark out their questions as different from those typically asked by adults. The simple, direct mode of their questions appears in many of the examples given above. Two examples from S4 children at Glenview School about 'plastics' illustrate this further:

How do they make some of it see-through?

Why do they use it on calculators and stuff, instead of steel?

A phrase that occurred reasonably frequently in the questions asked was 'how come', usually meaning 'why'. It appeared more often in questions about biological than physical science topics but 'floating and sinking' questions provided a number of examples, as illustrated by S4 children from Hillcrest School and Tamahere School respectively:

When people drown they usually drown under the water and a few days later they come up again; how come they float?

How come submarines sink but battleships float, and yet they're made of the same material?

Some of the questions asked by children seem to adult observers to have a 'freshness' about them; they either reflect wonderment about the world which adults may have experienced as children, or they suggest ways of looking at the world which have never occurred to most adults. The topic 'floating and sinking' again provides some examples. A S4 child at Hillcrest School asked,

Why does oil float on the top of the surface; it seems like a liquid itself?

and a S3 child from Ohau School wanted to know,

If space was filled with water, would the world sink?

Commonness of questions

When questions about a topic were elicited from several classes of children, common questions emerged. Table 7 shows the most common aspects of six topics about which the children asked questions.

TABLE 7: Most common aspects of topics that were the focus of children's questions

Aspect	**Example of Question**
METALS	
Composition	What are metals made of?
Production	How are metals made?

Colour	Why are they different colours?
Number	How many sorts of metals can you get?
Discovery	Who discovered metal?
Melting point	What temperature does metal melt at?

PLASTIC

Origin or	Where does it come from?
composition	What is plastic made of?
Shape	How do they get it into the shape?
Colour	How do they get the colouring into plastic?
Hardness	How do they make it hard or soft?
Thickness	How do they get the different thicknesses?
Symbols	How do they get the writing onto plastic?
Coating	How do they get the coating onto things?
Melting	How does it melt?

FLOATING & SINKING

Things in general	Why do some things float?
Things in particular	How do boats float in water?
	How do little things like earrings sink and ships float?
People	Why do some people float, and some people sink?

SKELETON

Function	Why do creatures have skeletons?
No. of bones	How many bones has a person got?
Composition	What are bones made of?
Structure	What actually joins the bones together?
Becoming a skeleton	How long does it take the flesh to go off the skeleton?
Identification	How do you tell which sort of skeleton it is?
	How can you tell if a skeleton is a boy or girl?

SPIDERS

Types	How many known species are there?
Poison	How do they produce poison?
Webs/silk	How do they get all the stuff to make their web?
	How do spiders spin webs?
Body parts	Why do spiders have eight eyes?
	Why do spiders have so many legs?
Prey	What do they eat?
Habitat	Why do some live underground?
	Why do they usually live in dark places?
Reproduction	How do spiders mate?
or growth	Why do spiders carry their eggs on their back?

ROCK

Origin/composition	What are rocks made of?
	Where do they come from?
Texture	Why are rocks sometimes smooth & flat?
	Why do rocks have holes in them?
Colour	How do they get their colour?
Shape	How do rocks get their shape?
Hardness	Why are they hard?
Weight	Why are some rocks different weights than others?

Primary school classrooms in which similar questions were asked by children extended beyond New Zealand. Table 8 below compares some questions about 'rock' asked by Australian children at Toorak Central School with questions asked by New Zealand children of comparable age.

TABLE 8: A comparison of questions about 'rock' asked by 10 to 11-year-old Australian and New Zealand children

Aspect	**Aust. children's qus**	**NZ children's qus**
Composition	What are rocks made of?	What are rocks made of?
Texture	Why are some surfaces rough and some smooth?	Why are some rocks rough and bumpy?
	Why do rocks have holes in them?	Why do some have holes in them?
Colour	What gives rock its colour?	How did they get their colour?
Shape	Are all rocks the same shape?	Why do they have different shapes?
Hardness	Are all rocks hard?	Why are they hard?
Weight	Are all rocks heavy?	Why are they heavy?

The fact that a number of the questions asked by children about a particular topic can be predicted is helpful from a curriculum development perspective. It suggests that if a suitable approach can be devised that uses children's questions, then teachers could be forewarned and forearmed about questions that children are likely to ask about a topic.

Appeal of the questions for children

When the children were asked which question of those listed most interested them, they all responded without hesitation with their preference. Further, most preferred just five or so questions. This narrowness of preference can be illustrated from the data on children's questions about 'metal'. Table 9 sets out the number of questions, out of those asked, which were chosen by the majority of children in six schools for which data were available.

TABLE 9: Number of questions of greatest interest to the majority of children on the topic 'metals'

School	**Class**	**No.Children**	**No.Qus chosen**
Tamahere	S2	23 out of 23 (100%)	4 out of 7
Tamahere	S4	26 out of 37 (70%)	5 out of 15
Matangi	S3/4	19 out of 19 (100%)	4 out of 10
Glenview	S4	23 out of 28 (82%)	5 out of 20
Hillcrest	S4	22 out of 27 (81%)	5 out of 14
Knighton	S4	19 out of 28 (68%)	5 out of 19

Although it is not shown in Table 9, some children chose questions other than their own. This becomes clear when data from Table 6 are considered in conjunction with that from Table 9. Illustrative data are provided in Table 10.

TABLE 10: Comparison of number of children in three schools asking questions about 'metals' with number of questions chosen as being of greatest interest

School	**Class**	**No.Qus asked**	**No.Chn asking**	**Total No. Qu chosen**
Glenview	S4	20	14	10
Tamahere	S4	15	14	12
Matangi	S4	10	6	4

Table 10 reveals that, since the number of questions preferred in each case was less than the number of children asking them, at least four children at Glenview School and at least two children in each of the other two schools must have chosen as the question of greatest interest to them one which was other than their own.

The children's willingness to choose questions of interest suggests that the children could help compile from their original list a manageable set to investigate.

Investigability of the questions

Alfke (1974) was concerned with helping children to ask productive or operational questions, and if that meant the demise of children's 'why' questions then, in her view, that was welcome. She would probably not have viewed as desirable the substantial proportion of 'why' questions (over one-third of all questions) asked by the children in the present study. The number of 'why' questions asked by the children (including 'how come' questions which meant 'why'), together with the number judged by the researcher to be investigable, are shown in Table 11 below. 'Investigable' questions have been classified into those which could be investigated in the usual 'hands-on' way, and those which could be investigated by communicating with an 'expert' or 'experts' (authors of books, or knowledgeable people in the local community or beyond). The basis of the judgement is the researcher's determining from the point of view of a busy primary teacher the practicability or otherwise of mounting such investigations. In this sense the classification scheme reflects the criteria used by Symington (1980) but broadens 'practical investigation' to include consultation with 'experts', an extension Symington concluded was needed. Like Symington, the author felt that restricting the selection of children's questions for primary science to the productive or operational kind that Alfke (1974) and others had in mind, would fail to do justice to both science and the curiosity of children, especially the latter.

One further point about the investigability of questions relates to the availability of resources. Whereas some questions asked by children in a particular location may be judged by their teacher to be investigable, the same questions asked by children in a different location may be judged non-investigable since appropriate resources are not readily available. For example, many of the children's questions about 'plastics' could be investigated if the school were located in, or within reach of, a city such as Hamilton or Christchurch where access is possible to factories producing plastic products. In contrast, a teacher in a rural area may find that more of the children's questions about a topic such as 'rock' are investigable since there is greater likelihood of access to suitable locations and resources than would be the case for city children. In Table 9 it is assumed that access to suitable resources is generally possible; a slight over-estimate of the investigability of the children's questions is therefore likely.

TABLE 11: Number of children's 'why' questions and questions judged investigable.

School	**Class**	**No.Qus**	**No.'Why' Qus**	**No. Investigable Qus 'Hands-on'**	**Other**
METAL					
Tamahere	S2	7	-	1	5
Tamahere	S3	31	2	7	16
Bishopdale	S3	15	-	-	13
Matangi	S3/4	12	2	4	7
Glenview	S4	20	7	-	17
Tamahere	S4	15	7	1	12

Hillcrest S4	14	1	2	11
Knighton S4	19	4	1	16
	133	23	16	97
ROCK				
Whatawhata S2/3	18	5	6	10
Hautapu S3/4	17	4	5	8
Knighton S3/4	8	2	0	3
Robertson S4	13	4	2	6
Robertson S4	12	4	2	6
Weymouth S4	9	6	1	7
Weymouth S4	15	7	1	13
Titirangi S4	13	4	-	4
Toorak (S4)	17	6	5	6
	122	42	22	59
PLASTICS				
Tamahere S3	7	1	6	-
Eureka S2/4	9	-	9	-
Hillcrest S3/4	12	1	11	-
Glenview S4	19	7	11	8
	47	9	37	8
FLOATING AND SINKING				
Fifth Ave S2/3	6	5	5	-
Knighton S3	4	4	2	1
Tamahere S3	11	8	5	-
Ohau S3/F1	43	34	15	1
Pukehina S4	9	2	4	3
Glenview S4	14	8	8	-
Tamahere S4	6	3	5	-
Hillcrest S4	6	5	3	1
Fifth Ave S4	12	11	5	-
	111	80	52	6

SKELETON				
Harewood S3	19	10	5	4
Fendalton S3	20	8	4	9
St Albans S3	19	4	1	7
BishopdaleS3/4	28	5	6	17
Marshland S3/4	23	7	9	11
	109	34	25	48
SPIDER				
Aranui J1	13	3	4	7
Roydvale S1	18	9	6	6
Matangi S2/3	14	4	3	7
Harewood S4	21	8	7	6
Fendalton S4	25	4	5	15
St Albans S4	35	22	7	14
Whatawhata S4	17	8	6	8
	143	58	38	63
FLOWERS AND SEEDS				
Papanui S2/3	20	11	11	5
Glenview S3	31	12	7	13
Taupiri S3/4	25	3	18	6
	76	26	36	24

The figures for the individual schools in each of the topic areas have been included in Table 11 so that variations which may be obscured in a composite table are available for analyses. At the same time, however, it is useful to have a summary of this data, and this is provided in Table 12 below.

TABLE 12: Summary of the number of children's 'why' questions and questions judged 'investigable'

Topic	No Qu	No.'Why' Qu	Investigable Qus Hands-on	Other	Non-Inves.
Metal	133	23 (17%)	16 (12%)	97 (73%)	20 (15%)
Rock	122	42 (34%)	22 (18%)	59 (48%)	41 (34%)
Plastics	47	9 (19%)	37 (79%)	8 (17%)	2 (4%)
Floating	111	80 (72%)	52 (47%)	6 (5%)	53 (48%
Skeleton	109	34 (31%)	25 (23%)	48 (44%)	36 (33%)
Spider	143	58 (41%)	38 (27%)	63 (44%)	42 (29%)
Flower	76	26 (34%)	36 (47%)	24 (32%)	16 (21%)
	741	272 (37%)	226 (31%)	305 (41%)	210 (28%)

Table 12 shows that overall almost one-third of the children's questions would be investigable by 'hands-on' means. If these are pooled with those where an 'expert' could be consulted, then approximately two-thirds of the children's questions would be investigable. This suggests that a teaching approach which incorporates children's questions would not founder for want of investigable questions asked by primary school children about natural and technological phenomena.

A note of caution needs to be added since the table also shows that there is considerable variability among topics with respect to the number of investigable questions asked by the children. This ranges from a low of 52% of all questions asked about 'floating and sinking' to a high of 96% for the topic 'plastics'. Even within some topics, there was considerable variability across schools. For example, although the across-school variability with respect to the percentage of investigable questions asked was only 14% in the case of 'plastics' (range 86% - 100%), at the other extreme it was 62% (range 31% - 93%) in the case of 'rock'.

Children's questions are not necessarily compatible with the science programme emphases

Questions about science topics that most interest children do not necessarily lead in the directions specified in the widely used New Zealand Department of Education resource units on those topics. For example, on the topic 'spiders' the data reveal that the children were particularly interested in how spiders produce poison but do not poison themselves, and how they produce silk in which they themselves do not get caught. The resource unit on the other hand, while mentioning silk, tends to emphasize habitat and the place of spiders in the food chain.

However, some questions about a topic which interest children **could** lead in the direction indicated in the resource unit on that topic. For instance, on the topic 'metals' the children were most interested in the discovery, number of types, and production of metals which, taken together, have something in common with the resource unit emphasis on sources of metal.

If a primary science teaching approach is to make use of children's questions, then teachers are likely to require information about these features of children's questions if they are to be adequately prepared to deal with them.

Children could provide possible answers to questions

When the children's questions were listed, an opportunity was taken in a number of classes to see whether the children had any ideas about possible answers to one of their popular questions, or to a question which the researcher thought was important for developing understanding of a particular topic.

The children were invited to jot down on a piece of paper, either individually or with a partner, what they thought might be good answers to the question selected. The pieces of paper were then collected by the researcher and later analysed. On some occasions there was time for a number of children who did not mind public scrutiny to suggest their possible answers in the class group before the researcher left the room.

The children's responses showed they had no shortage of ideas, or were able to construct possible answers from the fabric of their experiences. For example, the S3/4 children at Marshland School proposed 14 possible answers to the question, "Why do animals have skeletons?" These related to movement by, protection of, and support for the animals. Most of their suggested answers were very sensible ones, as indicated by the following, which also illustrate the three categories of answers outlined above:

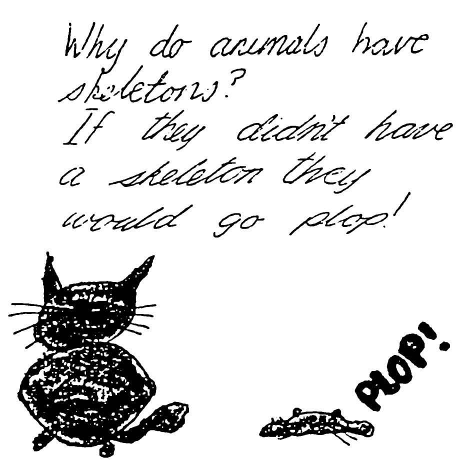
Because if they didn't have a skeleton they wouldn't be able to move around.

To protect organs of the body.

If they didn't have a skeleton they would go plop.

The last child spontaneously added the drawing in Figure 1 below to emphasize the point.

FIGURE 1: S3/4 child's drawing to illustrate the supportive function of a skeleton



This fortuitous event suggested that children's drawings might have a place in a teaching approach that made use of children's own questions.

Another advantage of having children suggest possible answers to some of their own questions became apparent when a class of S4 children at Glenview School suggested 30 answers to one of their own questions, "Where does metal come from?" These included the following:

Mostly North America.

Caves.

Mines and quarries.

It is formed by minerals and other substances and it is mixed together.

From old stones.

It's mined.

The suggested answers can give the teacher a clue to the way in which various children **interpret a question**. In the above case different children seemed to assume that the question was referring to one of the following: country of origin, type of natural location, man-made places of extraction, materials of which it is composed, materials from which it is extracted, and the means by which it is obtained.

Children's questions can reveal their thinking

Many of the questions asked by the children in this study revealed clearly their view of their environment, together with something of the intellectual strategies they were using to try to make sense of it. Many of their questions revealed gaps in their knowledge, some indicated that their present expectations were confounded by some phenomenon, and a few showed that they already had a possible explanation for which they sought confirmation. Their proposed answers further revealed their thinking and intellectual abilities. Examples of such questions are contained in the earlier section on functions that questions serve for children.

Some of the class teachers who stayed to observe the researcher elicit questions (and possible answers) from their children expressed amazement at the ability of some of their children, as revealed in the children's oral and written responses. For instance, the response of one S3 boy at St Albans School to the question, "Why do we need a skeleton?" suggested to the teacher that she had considerably underestimated the child's ability, or interests and out of school background. He said, "Well, it's kind of like a roll cage in a stock car; it protects you."

In this particular example, the **use of analogy** is evident. A number of the children seemed to have facility in this strategy. In the same class, and in response to the same question about skeletons, other children replied,

> *Because we would be like a floppy jelly, like a rag doll.*
> *It is like a frame to support your body from just being a lump of skin on the floor.*
> *We would be like a jellyfish, but not quite.*

Other questions asked by a few children, usually about physical rather than biological topics, revealed that those children were making **invalid assumptions** about phenomena which the topic raised in their minds. For example, several of the S4 children from Titirangi School assumed that diamonds and gold were forms of rock. When they were asked for their questions about 'rock' they replied,

> *Why are diamonds more valuable than most other rocks?*
> *When did gold 'come so expensive?*

Similarly, invalid assumptions about the notion of 'metal' are reflected in the questions of some S3 children from Tamahere School. The first two were obtained in a whole-class context, and the last three at the conclusion of individual interviews

Why do we use metal more than steel?
Is steel stronger than metal?
What is the difference between metal and iron?
Are the beer cans made of metal or tin?
Is the fridge made of metal, and the sink? I think it might be steel.

Still other children's questions suggest that the children's minds were jumping beyond the boundaries of the topic being studied. For example, of the 31 questions asked by the S3 children at Glenview School, seven had only a tenuous link with 'seeds', the topic under consideration. These seven mostly referred to 'trees'.

Is there a popular tree in New Zealand?
What is the biggest tree in the world?
How would a tree become extinct?
Where does oxygen come off a tree?

Questions which contain invalid assumptions or go beyond the topic might be considered unworthy of investigation, but there could be merit in a child being allowed to pursue such questions. An invalid assumption could be exposed, and perhaps considerable learning take place about an aspect of particular interest.

FACTORS THAT INFLUENCE CHILDREN'S QUESTIONING

The data provided in the Tables of this chapter and in Appendix 1 reveal trends in the data from which tentative conclusions are drawn about factors that seem to influence children's question-asking.

A factor which appeared to have no influence on the number of questions asked was residential location. Tables 2 and 4, and Appendix 1, reveal little consistent difference between children in rural and urban areas, or between children in Waikato and Canterbury.

The data suggest three possible sources of influence on the number and type of questions asked. They are the **age** and **prior experiences** of the children, the nature of the **topic**, and the **social context** in which the questioning took place.

Children's age and prior experiences as a factor in their question-asking

The limited data that were obtained from younger children tend to show that they asked fewer questions than their slightly older schoolmates. For example, the one class of Tamahere S2 children whose questions about 'metal' were solicited, asked only seven questions compared with a median of 15 questions for all classes. With respect to the topic 'plastics' the two classes of slightly younger children (Tamahere S3; Eureka S2/4) posed only 16 questions altogether, while the two classes of slightly older children (Hillcrest S3/4; Glenview S4) asked a total of 31 questions. Similarly, with the topic 'spiders' the three classes of younger children (Aranui J1; Roydvale S1; Matangi S2/3) asked a mean of 15 questions per class compared with a mean of 24 questions per class asked by the older children (Harewood S4; Fendalton S4; St Albans S4; Whatawhata S4).

There were occasions, however, when older children did not ask a greater number of questions, suggesting that other influences were at work. For example, a closer examination of the number of questions asked about the topic 'spiders' reveals that the J1 children from Aranui Primary School asked almost as many questions (13) as the S2/3 children from Matangi School (14 questions); similarly the S1 children at Roydvale School asked approximately the same number of questions (18) as the S4 children at Whatawhata School (17 questions). And in the case of the topic 'rock', the younger S2/3 children from Whatawhata School asked more questions (18) than any of the older children from the other eight schools (range 8-17 questions).

An alternative explanation is that the children's prior experiences were influencing their question-asking. This possibility is explored further in the next section.

'Topic' as a factor in children's question-asking

The medians given in Table 4, together with the percentage of investigable questions shown in Table 10, suggest that the type of topic has a considerable influence on the number and kind of questions that children are likely to ask about it.

First, Table 4 suggests that primary school age children are able to ask a greater number of questions about biological topics than physical ones. The median number of questions asked per class about the three biological topics (spiders, skeleton, flowers and seeds) was 20.0, compared with a median of 12.5 per class for the four physical topics (floating and sinking, plastics, rock, metal). This trend is consistent with a finding by Baker (1969) who reported that elementary children are most interested in animal life and very interested in the construction and function of the human body. Interest may provide one possible explanation.

Another, which can be inferred from the data contained in Appendix 1 and the Tables above, is that the children drew upon their background experiences of phenomena associated with a topic as a source of questions; since these experiences were richer with respect to some topics than others, there was variation in the number of questions they were able to ask.

The topic 'spiders' may be taken as an example. Here the questions of many of the children went beyond the simple stimulus materials provided and indicated clearly that the children were drawing upon their prior experiences of spiders as a basis for asking questions. At Harewood School, for instance, the S4 children were shown two pictures of spiders, one of which was on a web, and were able to observe live spiders in small clear plastic containers. Their questions, however, included ones about mating, cocoons, baby spiders, underground habitats, venomous species, and whether it will rain next day if you squash a spider. Other children who had simply viewed photographs of spiders asked a similar number and kind of questions.

On the other hand, with a topic such as 'rock' the children seemed to lack a rich background of experiences to draw upon and consequently asked far fewer questions. The majority of those they did ask seemed to arise from the stimulus materials themselves.

The data in Table 12 (the number and percentage of investigable questions asked by the children) seem to intersect with the pattern above. This time the greatest percentage of investigable questions did not attach to the biological topics. Most questions were asked about two physical topics (plastics 96%; metal 85%). The smallest number were also asked about physical topics (rock 66%; floating and sinking 52%). The three biological topics came in the middle in terms of the percentage of investigable questions asked about them (flowers and seeds 79%; spiders 71%; skeletons 67%).

It seems that those topics which embody materials, objects, actions or events which are part, or have the potential to be part, of the everyday lives of children stimulate the greatest percentage of investigable questions.

'Social context' as a factor in children's question-asking

From the data collected in this study, classroom context seemed to influence the number of questions asked by the children, in at least two ways. One involves the stimulus effect of initial questions, and the other the children's sense of security in the classroom environment.

(i) Stimulus effect of initial questions

It was noted earlier (p.70) that at question time a pattern emerged where one or two children would begin the question -asking and then other children would gradually join the process. When a few children began asking about certain aspects of a topic it seemed to stimulate other children to give these some thought too. There is evidence of this in the sequences of questions recorded, particularly with topics where the children had little prior experience to bring to the task. For instance, the questions of the S4 children from Titirangi School about 'rock' reveal that when one child asked,

How long does it take for a tree to go into coal?

another promptly asked,

How long does it take for a tree to turn into petrified wood?

Then in the same class 'diamonds' was introduced into the questioning thus,

Why are diamonds more valuable than most other rocks?

This was soon followed by the query,

Why are diamonds harder than any other type of rock?

and the inquiry,

How are diamonds formed?

Children themselves have confirmed that other children's questions have opened up lines of thinking for them. At the conclusion of a few of the 'lessons' conducted by the researcher, an opportunity was taken to ask the children what they thought of the experience. Some said that they had not really thought much about a particular topic until other children began asking questions about it. For example, two S3 children at Bishopdale School offered,

You don't really think about it much.

You just take these things for granted.

When others began asking questions, however, new trains of thought were initiated.

It's interesting and it makes you think.

In this context it is even possible for teachers to include a question of their own that will be accepted by the children, although three conditions are probably necessary for its acceptance, namely that it be in language which the children normally use, that it be meaningful to them and that it appear to be a genuine question. An event at Glenview School highlights this point. The researcher observed a 'lesson' taken by the class teacher in which the S3 children generated 31 questions about 'seeds'. When these had been recorded by the teacher the researcher suggested that he would like to know, "Do animals have seeds inside them?" Two groups of children in the class asked the class teacher to write this question on the board as they considered it the most interesting of all the questions and wanted to use it as the basis for a study.

The researcher found that it is also possible to introduce and have accepted a question asked by a child in another class. When the researcher visited the S3/4 children at Hautapu School he introduced to them the question, "Why do rocks have different colours?" which had been asked by a S2/3 child at Whatawhata School four days previously. The Hautapu children accepted this as an interesting question and wrote 26 different possible answers to it.

(ii) Children's sense of security in the classroom environment

When the children were invited to propose questions, all were being asked to adopt a new role in the classroom setting. The data reveal that the children in classes taken by their own teacher asked more questions than children in classes taken by the researcher, despite the researcher's best efforts to set the children at ease. Table 13 summarises the number of questions asked by children in the former classes and compares it with the number asked by children in other classes.

TABLE 13: Comparison of number of questions elicited by class teachers and the researcher

No. of teacher-elicited questions			Comparative data	
			Median	Most Qus,
Topic	Class/School/No.Qus		No.Qus	other schs
METALS	S3 Tamahere	31	15	20+
PLASTICS	S4 Glenview	19	10.5	12
FLOWERS/SEEDS	S3 Glenview	31	25	25
FLOATING/SINK	S3/F1 Ohau	>43	10	14
TIME	S3/F1 Ohau	68	None available	
BIRDS	S3 Stoke	39	None available	

SUMMARY

In this chapter data have been presented that suggest the following:

(i) Children's questions about natural and technological phenomena can, for the most part, be reasonably readily elicited or very readily elicited, even by a researcher who is a complete stranger to the children. When children are first invited to pose questions, especially by such a researcher-stranger, up to about half the children in a class are likely to respond.

(ii) There are several features of children's questions which could have considerable value in a teaching approach that makes use of questions generated by the children. First, their questions can provide insights into their thinking; secondly, many similar questions about a topic are asked by children in different classrooms; thirdly, a majority of the questions asked are potentially investigable by children with teacher guidance; fourthly, children can propose possible answers to many of their questions.

(iii) The number and type of questions asked by the children are influenced by several factors. The type of logic, for example, affected the number of questions asked per class. In this investigation the number of questions on biological topics exceeded those on physical. Children's age and prior experiences were also apparently factors. Older children, perhaps predictably, tended to ask a greater number of questions. On the other hand prior experiences may have accounted for some groups of older children asking fewer questions; they had possibly learned not to ask questions in the school setting. Topics with which most children had had close and meaningful experiences, particularly the two physical topics of plastics and metals, produced the greatest percentage of investigable questions. The social context of the classroom also appeared in two respects to have a major influence on the number of questions asked. Children asked a greater number of questions when these were elicited by their own teacher rather than by the researcher-stranger. Within the classrooms the questions of some children 'triggered' ideas for questions in the minds of other children.

(iv) Children can accept questions generated in other classes and ones asked by their teacher, but this is probably dependent on the questions being perceived as meaningful and genuine, and being framed in language used by the children.

The comments made by some children at the end of the 'lessons' suggest that, given positive interaction within a classroom among children and between teacher and children, a teacher could introduce a wide range of topics that are close to children's everyday world with the likelihood that the children would develop an interest in them - provided the children's own questions formed the basis of their studies. When, in several classrooms, the children were asked by the researcher or their teacher what they thought of the 'lesson', they invariably replied that they enjoyed being able to ask questions and to base their work on questions that interested them. As one S4 girl said,

> *You can choose something that you haven't already learnt and that you can learn, what you want to learn about.*

The children considered that the approach challenged their thinking in a worthwhile way. A S3 pupil remarked,

> *It's good to make you think, and you can come up with some ideas and then you can think it's not correct, and you keep on trying.*

In this setting children learn things from each other, although they do not necessarily recognise the source of their learning. The spontaneous response of another S3 child who thanked the researcher for what he had 'taught' her during the 'lesson' reflects the children's own conventional belief that anything learned in a classroom has been taught by the teacher.

The novelty effect of the approach cannot be discounted but it would seem that if children's questions provided the basis of science learning conducted along inquiry lines then children's interest in science might be sustained and the gap narrowed between school knowledge and everyday knowledge (Barnes, 1976). Further support for this proposition comes from Riban (1976) who reported successful learning in secondary science at the West Leyden High School, Illinois, using a similar approach, and from Duckworth (1974) who contended that children's intellectual development depends on their testing out ideas which they find significant.

CHAPTER 6

TOWARDS A TEACHING APPROACH USING CHILDREN'S QUESTIONS

This chapter is in two main parts. The first contains a review of literature relevant to a teaching model based on children's questions, the second consists of a report on several small action-research studies which had as their goal the development of a viable teaching approach built around questions generated by the children themselves. The research question (Question 4) addressed in these studies was:
Can a viable teaching approach be devised that incorporates children's own questions as a central feature?

INSIGHTS FROM THE LITERATURE

It was noted in Chapter 1 that primary school teachers of science in New Zealand tend to inhibit children's question-asking. The literature provides some insights into the social mechanisms by which this occurs. More positively, it identifies factors that are likely to promote children's question-asking, and offers a number of guidelines for constructing a teaching approach that incorporates children's questions, including suitable roles for the teacher, appropriate resources, and relevant pupil evaluative criteria . These are examined in turn.

Factors inhibiting pupil questioning

In this section, some social factors which extend beyond the school are considered first, and then a closer examination is undertaken of factors operating within the school environment itself.

1. Adult influence on children's questioning

The way adults interact verbally with children seems to have a considerable influence on the children's question-asking, and also upon the view of reality they construct (Krantz and Bacon, 1977; Tizzard et al, 1983; Tough, 1973). For example, the study by Tizard et al (1983) showed a significant positive correlation between the frequency of mothers' questions and the frequency of their young daughters' questions; modelling by the parent seemed to play an important part in the child's questing behaviour.

Krantz and Bacon (1977) contend that adult responses communicate to children an attitude toward questioning. They contrast the effect on a child of adult non-explanatory responses with that of responses in which the adult accepts the challenge of a child's questions. In the former case the child learns that questions have answers, and that there is a definite boundary to questioning; in the latter case the child learns that there are no final, conclusive answers to questions, and that questioning is an open-ended, searching process. Children in the former category who experience adult answers of the type, "Because I say so" soon learn that asking questions has little value in helping them make sense of phenomena in their lives.

Krantz and Bacon (1977) also explain that adult responses to children's questions gradually shape the children's views of reality. As a result of adults interpreting and responding to children's questions in a way that accords with the adults' ideas of reality, children learn to ask questions that reflect the assumptions about the world held by the adults themselves. Further evidence that cultural and socio-economic factors influence children's question-asking ability is cited by Aliotti

(1979), Berlyne and Frommer (1966), Henderson and Garcia (1973) and Tizzard et al (1983). For example, Tizzard et al (1983) noted that middle class four-year-old children in their study asked significantly more questions in their everyday lives than their working class counterparts. Aliotti reported that in 1974 Henderson and Swanson found in their research that in traditional Papago American Indian culture, question-asking was not encouraged as a means of obtaining information, and hence skill in questioning among young children in that culture was not well developed.

The fact that children's questioning, being embedded in the language of the surrounding culture, comes to mirror the world view of adults significant in their lives may pose a dilemma for primary science education. In New Zealand primary schools today there are children from many different cultures and sub-cultures. If it is accepted that the purpose of primary science education is to help children make better sense of **their** world, then some assumptions within the culture of a particular child may be questioned. There is a possibility in this for liberating children from beliefs that may restrict their life chances, but equally there is a possibility for conflict between the cultural group and the school. A way must be found to meet this potential difficulty.

Perhaps earlier experiences, in which the children learned from adults around them that question-asking was not valued, contributed to the finding outlined in Chapter 5 that approximately half of the children in the classes where children's questions were first elicited were unable to pose any questions when first invited to do so.

2. Influence of schooling on pupils' questioning

Traditional, directive-type teaching seems to exact a heavy toll on children's question-asking ability (Cazden, 1970; Dillon, 1988; Goldberg, 1979; Holt, 1969; Huenecke, 1973; Isaacs, 1974; Kuslan and Stone, 1972; van Praagh, 1973; Voelker, 1975) such that children's questions about natural and technological phenomena soon shrivel away after entry to school, the children become dependent on their teachers (Munby, 1982) and in some cases learn to doubt their self-worth (Torrance, 1970b).

It could be argued that the observed paucity of questions posed by children in classrooms reflects a natural fall-off in curiosity, but a study by Peterson (1979) led him to conclude that more likely it reflects the lack of a stimulating environment, or opportunity to express the curiosity. The results of the study by Tizard et al (1983) support this view; they found that the four-year-old girls asked an average of 1.4 questions per hour in preschool, but 24 questions per hour at home. Further support for Peterson's contention comes from studies by van Hekken and Roelofsen in 1982 and Yamamoto in 1962 (Dillon, 1988) which revealed that the number of questions asked by children outside school actually increases as children grow older. The findings of the present study reported in Chapter 5, together with those of Symington (1980), also show clearly that when children are provided with the opportunity and encouragement in school to ask questions, a teacher may expect anything from a trickle to a torrent of questions to be forthcoming.

This inhibiting of children's questioning by teachers is contrary to the way children learn naturally and conflicts with what many teachers in New Zealand regard as one of their major goals in primary science education. In keeping with the

'Science Syllabus and Guide - Primary: to Standard Four' (Department of Education, 1978) many teachers say they want their children to be able to inquire and to be independent in their learning. Several possible explanations of why the practices of many teachers are inconsistent with their stated goals are outlined below.

First, the emphasis given to **teacher** questioning in both texts and teacher education programmes can convey the impression that questioning is a function of teaching, not learning (Zahorik, 1971). Torrance (1970b, 9) observed that when children arrive at school they tend to be overwhelmed by a plethora of teacher's questions.

> *By the time a child enters school for the first time, he is on his way to learning the skills of finding out by asking questions. When he enters school, however, the teacher usually begins asking all the questions,[7] and the child has little or no chance to ask any.*

Secondly, children who ask questions can be considered by teachers to be 'difficult' children since their questions either disturb carefully planned classroom procedures and organization, or they pose a threat to a teacher who relies on superior subject knowledge as a means of control in the classroom - as both Thomas A Edison and Albert Einstein found to their cost (Delamont, 1983; Torance, 1970b; Young, 1983).

Thirdly, many teachers have themselves a view of the scientific enterprise which bears little resemblance to the way

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7. Another effect of the teacher rushing in with well-placed questions, as Barnes (1976) observed, is that it can take the initiative for learning out of the hands of the pupils and reduce learning from active organisation of knowledge to mere mimicry of the teacher, mimicry in which it is the teacher who approves pupil answers.

scientists actually go about their work (Gauld, 1973; Macklin, 1973; Smolicz and Nunan, 1975), and hence try to conduct their pupils to the 'right answers' and 'correct methods' (Barnes, 1976; Holt, 1969; Howe, 1972; White, 1977) through teacher-question and pupil-answer methods. As Craig (1957) wrote, instruction that involves 'ferreting' answers from children assumes an absolute concept of knowledge which is contrary to the nature of modern science, and as Tizard et al (1983, 279) concluded,

> *The didactic, teacher-directed mode of interaction characteristic of later schooling was already established in the nursery [school], despite the 'non-school' milieu... this no doubt reflects the underlying power relationship between teacher and child: the children seem to learn very quickly that their role at school is to answer, not to ask questions.*

Fourthly, teachers may either be complacent about - even hostile towards - the spirit of inquiry (Ukens, 1974), or find it very difficult to adopt and sustain a teaching role which is congruent with it. Postman and Weingartner (1971) levelled some pointed criticism at teachers in the former category,

> *The most important and intellectual ability man has yet developed - the art and science of asking questions - is not taught in school! Moreover, it is not 'taught' in the most devastating way possible; by arranging the environment so that significant question asking is not valued.*
>
> *(Postman and Weingartner, 1971, 34)*

Welch et al (1981) reported that teachers in the latter category found inquiry difficult to manage in the classroom because it was contrary to their pursuit of pupil socialisation and discipline.

> *Most teachers attended to values which would support the careful, productive conforming aspect of schooling and socialization. The values associated with speculative, critical thinking were often ignored and sometimes ridiculed.*
>
> *(Welch et al, 1981, 39)*

Learning based on question-asking and inquiry usually requires a co-operative structure in the classroom, but as Johnson (1976) concluded, many teachers would feel uncomfortable with pupils working co-operatively rather than on their own.

Fifthly, the kind of evaluation procedures that are consistent with an inquiry approach may be considered by teachers to be so different from those currently used to measure learning and teaching (Lampert, 1984) that concern about the effects on their professional standing of departing from accepted practice may discourage teachers from attempting to incorporate their children's questions in science lessons.

Whatever the reason, the effect on children's questioning, as noted above, can be quite devastating. As Holt (1969, 156) observed, "Children come to school curious; within a few years most of that curiosity is dead, or at least silent."

Tizard et al (1983) and Haupt (Cazden, 1970) found that the 'deadening' process can begin in preschool. Another effect is that when constantly subjected to the social mechanisms described above, many children develop a strong set for **answering** questions (Torrance 1970a), not asking them. They may also learn from teacher modelling that the purpose of questioning is to test what people already know, rather than to seek knowledge (Hoskin and Swick, 1973).

Arnstine (1967) identified several other factors which can inhibit children's question-asking. One of these is the pressure of work. "So long as students are continually under pressure to complete assignments, all talk of cultivating curiosity is idle" (Arnstine, 1967, 272).

Inhibiting factors within children themselves (although externally induced) include strong needs, determined goal seeking, and habit, while factors often present in classrooms include threatening and anxiety-producing practices, and learning associated with topics which are either too familiar or too remote. In Holt's (1969, 50) experience, threat and anxiety are common features. "Even in the kindest and gentlest of schools children are afraid, many of them a great deal of the time, some of them almost all the time."

The findings of researchers such as Alton-Lee (Benton, 1986) and Cullen (1982) show that these factors are present in New Zealand primary school classrooms.

The problem, as Eisner (1965) saw it, is not to motivate pupils to ask questions, but to somehow prevent teachers from stifling their children's natural curiosity. The task cannot be underestimated since, as Hoskin and Swick (1973) pointed out, it is difficult to alter teacher behaviour. One of the reasons for this difficulty, they suggested, is that the surrounding culture tends to control the type of learning methods utilized in the classroom.

Factors that may promote children's questioning

To overcome the barriers to children's question-asking at school, positive strategies are required. A number which seem important are outlined in this section.

1. Provide suitable stimuli

Holt (1970) summed up this strategy well when he wrote that children need to be familiarised with a certain amount of interesting data before they are in a position to be able to ask significant questions about it. Kuslan and Stone (1972, p.198) expressed a similar view. "The teacher must set the stage in such a fashion that his children literally besiege him with questions in their eagerness to learn." They add that ideally problems will be generated by the spontaneous interaction of children with natural phenomena of their environment.

Others who stress that children need to be provided with active, well-planned, stimulating experiences to foster their questions include Carin and Sund (1966), Dewey (1963), Duckworth (1974), Isaacs (1930, 1974), McNeil (1984) and Zahorik (1971).

Berlyne and Frommer (1966) have suggested that experiences are likely to be stimulating if they are characterised by novelty, surprisingness, complexity, incongruity or subjective uncertainty. Huenecke (1973), Victor (1975a) and Vidler and Lawlor (1976) added that they would be stimulating if they perplexed the children or piqued their curiosity, and Suchman (1971) found that discrepant events motivate children's inquiry. Arnstine (1967) produced an almost identical list of features, including the elements of slight discrepancy and unexpectedness, and stressed that schools must tolerate a certain amount of leisure among children as they participate in such stimulating experiences if their questioning is to be truly fostered.

2. Model question-asking

Henderson and Garcia (1973) found, as a result of a study of a sample of Grade 1 Mexican-American children, that those whose mothers were trained to model questioning increased their question-asking significantly more than a control group. This suggests that teachers could promote question-asking among their children by asking appropriate questions themselves.

White (1977, 125) considered this could have value,

> *The initial stage of giving people the capacity to form questions could consist of providing examples... In subsequent sessions the teacher could reduce his level of involvement.*

This technique of having the teacher model questions initially for pupils and then gradually withdraw from this role is reflected in McNeil's (1984) suggested 'phase-in, phase-out' strategy to help children raise questions. The strategy was also proposed by the Schools Council with respect to learning mathematics.

> *If children do not ask questions about the natural happenings in their environment the teacher must stimulate and provoke them to do so. In the first instance she may need to ask the questions which later, she hopes, will come from the children.*
> *(Schools Council, 1965, 3)*

Others to propose that teachers model the type of questions they wish to encourage their children to ask include Lempers and Miletic in 1983 (Dillon, 1988), Zahorik (1971), and Zimmerman and Pike in 1972 (Dillon, 1988). Zahorik stressed that the teachers had to ask 'honest' questions, questions to which they did not know the answers. Torrance (1970b) advocated that such questions might at the same time be 'provocative' in the sense that they demonstrate to the learners that information can be examined in quite new ways.

Modelling, therefore, may be an effective way to help children learn to either ask questions, or ask questions of greater worth. The results reported in Chapter 5 of the present study suggest that the questions of other children may provide effective models too.

3. Establish an accepting classroom atmosphere

Alvino (1984), Baker (1969), Blough (1975), Glasser (1969), Maw (1971), Shymansky, Pennick, Matthews and Good (1977), Suchman (1971) and Symington (1980) believe that if children's question-asking is to be fostered then it is essential to develop a classroom climate that is receptive to children's genuine questions and ideas, a climate that does not ridicule or belittle children but helps them feel secure enough to risk exposing their inner thoughts and queries (Welch et al, 1981). Suchman's (1971) research indicated that when a classroom environment is structured to reinforce success, achievement and visible end-products, as measured by external criteria and judges, children's genuine inquiry is inhibited. The classroom environment should therefore be supportive of children, not manipulative or judgemental. Alvino (1984, 49) commented that, "Sometimes silence can be the best form of emotional approval", while Krantz and Bacon (1977) pointed out that those who ask questions place a great deal of trust in the people to whom the questions are directed.

One suggested way of supporting children in their question-asking, at least initially, is to show genuine interest in and offer praise for their efforts (Glover and Zimmer, in Dillon, 1988; Goldberg, 1979; Henderson and Garcia, 1973; White, 1977; Zahorik, 1971). Care needs to taken, however, that children do not begin raising questions simply to please their teacher. For example, in Goldberg's (1979, 8) view,

> *We can help children feel pride in asking interesting questions by showing pleasure in hearing them. Why not reward truly interesting questions by showing the enthusiasm we normally reserve for clever answers? ....We help children by displaying honest interest in good questions and encourging critical revision.*

Shymansky (1976) suggests that in developing a supportive classroom climate, care must be taken to avoid lengthy teacher-pupil interaction in a one-to-one setting as this may distract a pupil and reduce learning effectiveness.

4. Include question-asking in evaluation practices

White (1977) suggested that including question-asking in evaluation practices would be likely to increase the frequency of question-asking among students. Eisner (1965), who considered it important that the school foster children's desire to raise seminal questions, thought likewise.

> *Ask students when they complete a unit to list as many questions as they can that they think would be important for obtaining a fuller understanding of the material they have just studied. Such a list could be scored for the number and quality of the questions, quality being defined by the relevance and centrality of the questions raised.*
> *(Eisner, 1965, 628)*

5. Develop a co-operative, interactive learning context

Children's inquiry and learning is more effective when their feelings are engaged (Barnes, 1976; Francis, 1977) as well as their intellects, interests, imagination and prior understandings (Francis, 1977; Lawrence et al, 1960). Children's autonomy and independence are also considered critical factors in the question-asking process; they are necessary for children to engage in the inquiry process, and the process itself enables children to grow in these qualities (Goldberg, 1979, 1982; Karplus, 1980).

The kind of classroom considered necessary to engage children in these ways is one where children are encouraged to **co-operate** with each other in the problem solving and learning process, and to share and reflect on their ideas through writing and discussion (Barnes, 1976; Blake, 1977; Francis, 1977; Goldberg, 1979; Humphreys, Johnson and Johnson, 1982; Johnson, 1976; Kamii and De Vries, 1979; Kuslan and Stone, 1972;

Landsdown, 1969; Lawrence et at, 1960; Selberg et al, 1970; Sutton, 1980).

6. Other recommended strategies

Children should be provided with **opportunities** to ask questions about topics of interest to them, questions that will form the basis of their studies (Cazden, 1970; Crutchley, 1986; Kamii and De Vries, 1978).

There is some evidence that providing children with **answers** (Ross and Balzer, 1975) and with longer **wait-time** (De Ture, 1979) increases the frequency of their question-asking. So too, apparently, does **instruction** in the art of asking questions (Torrance, 1970a). Barnes (1968) advised that if children are to be encouraged to ask questions then **language that carries meaning** for the pupils, rather than technical language of the subject, should be used in informal ways. Finally, Tough (1977) contended that **teacher involvement** in children's investigations is required if children's impetus to explore and ask questions is not to be lost.

Some guidelines for an alternative teaching approach

Given that teachers are constantly 'on the run' managing their classes, it is the view of Blake, (1977), Carner (Hoskin and Swick, 1973), Easley (1982) and Olmo (1975) that **teachers need encouragement and specific suggestions** to enable them to structure a classroom environment that stimulates children to ask questions. Action-research by Wickless in 1970 (Hoskin and Swick, 1973) showed that teachers who undertook special inservice training became more able at involving their children in self and social questioning.

1. Possible components

A number of science educators (e.g. Alfke, 1974; Beauchamp, Mayfield and Hurd, 1965; Cain and Evans, 1979; D.Hawkins, 1974; Karplus, 1980; Kuslan and Stone, 1972; Lewis and Potter, 1961; Selberg et al, 1970; Waters, 1973) have proposed, used, or reported teachers using alternative approaches that incorporate children's own questions.

The components, or teaching-learning episodes, of these approaches have much in common:

(i) All begin with **exploratory-type activities** designed to suggest questions to the children.

(ii) These activities are usually followed by **investigations** into some of the children's questions.

(iii) Finally, **results** of the investigations **are shared** (e.g. through oral, written, visual presentation) **and critically reviewed.**

Not infrequently the ensuing discussion raises further questions, so that the components form a 'teaching-learning cycle' (Beauchamp et al, 1965; Karplus, 1980). The opportunity for children to learn from their mistakes is also stressed by some science educators (e.g. Goldberg, 1979; Selberg et at, 1970; Victor, 1975b).

2. Alternative criteria for evaluation

A set of criteria different from those normally used to evaluate children's development in primary science is needed when primary science education employs components similar to those outlined above. Waters (1973) contended that the criteria proposed by the Elementary Science Study illustrate what is needed. Information is sought about changes in the children's intellectual behaviour; whether their curiosity has been stimulated, whether they have asked more and better questions, whether they have been able to design experiments to test ideas, and whether they have become more critical of one-sided information.

3. Alternative roles for the teacher

An alternative teaching approach requires a somewhat different set of roles for the teacher. Crabtree (1982), Craig (1957), Goffin and Tull (1985), Good (1977) and Selberg et al (1970) recommend the teacher act as an activity facilitator, a co-investigator, a resource person, a listener, a discussion leader, and a guide or mentor in reflective thinking.

As Lawrence et al (1960) noted, there is evidence that where a teacher is prepared to learn with his or her children, a specialist knowledge of science is not necessary at the primary school level. This has significance for primary school teachers in New Zealand since as Chapter 1 revealed many, lacking confidence in science themselves, have avoided teaching children the subject.

4. Resources for learning

Various suggestions have been made about resources that would support a teaching approach of the kind described above (Abruscato, 1982; Blough, 1975; Blough and Schwartz, 1969; Carin and Sund, 1966; Craig, 1957; Elkind, 1975; Fisher, 1980; Goldberg, 1982; Huenecke, 1973; Hurley, 1975; Lee, 1967; Selberg et al, 1970; Suchman, 1977, Tough, 1977; Waters, 1973). These include, in addition to those normally associated with a primary science programe, the use of simple materials from the local environment; the inclusion of field trips to various sites (including museums); viewing films; consultation with knowledgeable people (including fellow pupils). The consultation could occur personally, or through reading what the people have written, provided it is in a form that is understandable by the children.

Summary of the literature

Since the goal of incorporating children's own questions into primary science has proved elusive in other countries in the past, it is important to consider all the insights that the literature has to offer.

'Lessons' from the literature include the following:

(i) Adult responses to children's questions, and adult questions themselves, can shape children's views of their world. While promoting children's own questions could help to liberate children from the confines of a narrow world view, the potential exists for conflict with some values of a child's culture.

(ii) Traditional views of science held by many teachers, together with traditional teaching practices, tend to inhibit children's question-asking. This suggests that the development of an alternative approach needs to take into account the present beliefs and strategies that teachers employ in their daily classroom work.

(iii) A range of strategies has been proposed to promote children's question-asking in primary science education. The challenge is to make them available to teachers.

(iv) Some features of a possible teaching approach, located in a supportive classroom climate, are also available, together with suggested alternative roles for the teacher, alternative criteria for evaluation, and a broader than usual range of resources.

The factors extracted from the literature provide clear advice about teaching practices that should be avoided if children's question-asking is to be promoted. They also provide reasonably coherent guidelines (e.g. the strategy of modelling question-asking fits well with the proposed teacher role of co-investigator) as to what an alternative teaching approach might look like that does justice to both children's ideas and science. There is some evidence that when children have an opportunity to learn in a 'user-friendly' climate that values their questions and contributions, their work attains a freshness and vitality previously lacking (Landt, 1968).

The challenge for this study was to fashion an alternative science teaching approach that would be acceptable to and manageable by New Zealand primary school teachers. The first steps in the fashioning process are described in the next section of this chapter. It should be noted that not all the insights mentioned above were available in 1982 when an effort was being made to construct an alternative teaching model, but there were sufficient to indicate possibilities and likely pitfalls.

ACTION-RESEARCH STUDIES TO DEVELOP AN ALTERNATIVE TEACHING APPROACH

The teaching model reproduced in Figure 2 below was contructed by Dr Roger Osborne, Co-Director of the Learning in Science Project (Primary), and the author from information gained from three sources, namely the insights gained from the literature, the author's experience in eliciting questions from the classes of children reported in Chapter 5, and from Osborne's own knowledge of how scientists actually go about their work (Biddulph and Osborne, 1982).

FIGURE 2: Proposed primary science teaching model

Step 1: CHILDREN IN INTERESTING SITUATION

A situation that stimulates the children to ask questions related to a science topic.

Step 2: CHILDREN'S QUESTIONS ON THE TOPIC

These could be publicly recorded, e.g. on the board.

Step 3: CHILDREN'S SUGGESTED ANSWERS TO A QUESTION

These could be written on paper by the children either individually or in groups and, if desired, also listed on the board.

Step 4: CHILDREN'S RESEARCH PROPOSALS

At this step the children either individually or in groups write a research proposal outlining:

(a) the question/answer they are going to check on
(b) how they are going to check on it
(c) where they are going to check on it
(d) how long they estimate they will take
(e) what equipment they will need

Teacher approval will be necessary before children embark on Step 5. (A teacher may decide to accept some proposals that are doomed to failure but from which children will learn something useful.)

Step 5: CHILDREN'S RESEARCH ACTIVITY

The children conduct an inquiry on <u>their</u> problem using <u>their</u> suggested activity. This may be

(a) observation or 'experiment'
(b) consulting books
(c) consulting knowledgeable people

Step 6: CHILDREN'S RESEARCH REPORT AND PEER COMMENTS

The children report their findings to the rest of the class. The other children, with teacher guidance, comment on

(a) whether or not the group or individual had really found out what they were trying to find out,

(b) possible alternative explanations, and

(c) other studies that might follow.

The results of four studies conducted with classes of S3 children are reported in this second section of the chapter. Each explored the viability of the teaching approach outlined in Figure 2 above. In the first two, the lessons were conducted by the children's regular class teachers with the author as observer; in the third and fourth, the author acted as the teacher and the regular class teachers remained as observers. The topic for the first series was 'seeds', while the topic for the next three was 'metals'. Each series built upon the insights gained from previous teaching/learning experiences.

The study on 'seeds' is reported separately, while the three studies on 'metals' are considered as a group.

The Investigation Relating to 'Seeds'

The S3 class involved in this study consisted of 29 children at Glenview School, Hamilton city. They were a mixed-ability class but considered to be largely average to above-average. Their teacher, Mrs Juliet Roger, was a first-year teacher with a B.Ed. degree which included a component of science education. She taught 12 lessons in all, spread over five school weeks.

Data were obtained through

(i) lesson plans and field notes written by the class teacher;

(ii) field notes kept by the researcher of observations and discussions (with both teacher and children) for lessons one to three;

(iii) an analysis of both the records of the children's initial questions and explanations, and the transcripts of audio-tape recordings made of six group and three class discussions during the first three lessons;

(iv) an analysis of the written work and evaluations produced by the children in the course of the unit;

(v) a review of the draft analysis of the data by the teacher.

THE LESSONS

Since this was the first time that full use was being made of the alternative science teaching approach, and since no information relating to children's questions and explanations about 'seeds' was available, the amount of support that could be offered the teacher was minimal. It was limited to:

(i) the researcher modelling for the teacher (and others) the first two stages of the alternative teaching approach with a different class and topic some weeks previously;

(ii) providing the teacher with an outline of the alternative science teaching approach;

(iii) brief discussion between the researcher and the teacher prior to lessons one and two which provided the teacher with an opportunity to clarify whether her planning was consistent with the proposed teaching approach.

At the invitation of the teacher, the children themselves chose the topic 'seeds' from a list of twenty topics they had suggested. This means of selecting the topic, based upon the children's stated interests, was the teacher's idea entirely and occurred a week or so prior to the first lesson. Each lesson was of approximately 30-45 minutes duration. As planned and developed by the teacher, they were as follows:

Lesson 1:

(i) The teacher showed the children a variety of seeds and the children were invited to comment on these. Their comments were often directed towards identifying the seeds.

(ii) The teacher asked the children if they had any questions about seeds, and she recorded these on the board (see Appendix 1).

(iii) The teacher then asked the children to form groups and choose a question that interested them from the list of 31 questions recorded. She also asked each group to write what they thought the answer(s) might be to their question. When they had finished writing, the teacher collected the question and answer papers from each group (see Table 14 below).

(iv) The lesson concluded with a teacher-led class discussion in which the children told the teacher what they thought so far of the alternative approach to learning science.

Lesson 2:

(i) This lesson was a little shorter than the first. It was devoted largely to the children discussing their research proposals with fellow group members and the teacher, and writing these out.

(ii) The lesson concluded in a manner similar to the first with a teacher-directed discussion in which the children reported on their research proposals.

Lesson 3:

(i) During this lesson the children completed details of their research proposals, had them approved by the teacher, and began their investigations. A feature of the lesson was the use made by the children of a biologist, Beverley Bell, who had been invited to the classroom to act as a resource person.

(ii) Again the lesson concluded with a teacher-led class discussion during which the children reported on what they had found out as a result of their investigations. The children also took the opportunity at this time to ask the resource biologist a number of questions that apparently interested them (see Table 15 below).

Lessons 4-7:

(i) These involved the children in their own investigations. In general, each comprised three flexible stages. The first consisted of a brief discussion during which the children shared any problems, discoveries or questions related to their investigations of the previous lesson. Ideas and suggested ways of improving each group's investigations were offered by both the children and the teacher. This period proved to be valuable in that it focussed the children's attention on their investigations again and clarified exactly what had to be done during each particular lesson. This first stage lasted approximately 5-10 minutes.

(ii) The groups then dispersed to carry out their investigations. At this stage the teacher was available as a resource person. An effort was made by the teacher to see every group each day in order to direct and guide the investigations, and also to ensure that good group dynamics were still operating. The investigations themselves made use of a wide range of skills. This stage usually lasted upwards of forty minutes.

(iii) The last stage of each lesson was a sharing time during which the children reported back to the class on their findings for the day. This stage differed from the initial stage in that it was concerned primarily with what the children had actually learnt about seeds. It was oriented towards highlighting the scientific ideas which were emerging from each group's investigations and the teacher took the opportunity to expand on and clarify these ideas.

Lessons 8 & 9:

These consisted mainly of the children organising their findings into a form which could be presented to the class. They also devised a list of criteria on which to judge the presentations. These criteria consisted of such things as the extent to which the group had answered their question, the clarity with which information was presented, and the interest value of the presentation.

Lessons 10 & 11:

In these each group presented the results of its investigations. Methods of presentation were flexible. Most groups chose to present their work in a chart or project form, but one group chose an audio-tape presentation and another used O.H.P. transparencies.

Lesson 12:

This final lesson was an evaluation of the approach in which the children were given an opportunity to say what they thought of the new method of learning. The form of the children's responses was directed to some extent by teacher-posed questions about the approach, namely what they had learnt, how they had enjoyed the study, and how the study could be improved. A free writing time was given at the end during which the children could add any other impressions of, and reactions to, the approach.

TABLE 14: Children's question choices and proposed answers about the topic 'seeds' in one S3 class.

QUESTION: "Will seeds ever grow on the moon?"

Group 1 (2 boys, 2 girls)

1. It might be possible that a plant could live on the moon but I don't think so. If a plant went on the moon I think it would die from the coldness and it would die from oxygen.

Group 2 (2 boys)

1. Karam and I think that plants will grow on the moon. They have already tried experiments with carbon dioxide.

Group 3 (4 boys)

1. If men went to space with seeds they will grow.
2. If lots of wind blow seeds into space.
3. If seeds grow on the moon it will be time.
4. Cut the seed open and put a hunk of steel in it.

Group 5 (2 boys)

1. Plants will because they could make a huge glass house and they could put dirt in it and grow plants in it.

QUESTION: "Do animals have seeds inside them?"

Group 6 (1 boy, 2 girls)

1. Yes, they do.
2. Some animals don't.
3. Apes do, eat bananas.
4. We sort of grow form seeds.
5. Fish don't have seeds.
6. The queen bee and ant lay hundreds of eggs.

Group 7 (2 boys, 2 girls)

1. Animals do have seeds inside them.
2. Animals have grass seeds in them.
3. Animals grow by seeds.

QUESTION: "Will there ever be a money tree?"

Group 8 (4 girls)

1. No, because it is impossible.
2. We never know.
3. Money never grows on trees. It's only a saying.
4. How would you get a money seed?

QUESTION: "What does a seed contain?"

Group 9 (4 girls)

1. Contains smaller seeds.
2. Powdery substances (our answer).
3. Sawdusty substance (proper answer).
   Its (bean) shell broke when we opened it.

QUESTION: "Will trees and seeds ever run out?"

Group 10 (2 girls)

1. No, because there is nothing to make them run out in the world, but if they ever did run out we wouldn't have oxygen and we wouldn't be able to live.

TABLE 15: Children's further questions in presence of resource biologist

1. Well, if a seed has a thick layer on top of it so nothing can get into it, how would the seed kind of burst out?
2. If a seed's in some real hard ground, and how will it get out if the sun was getting to it, and it was in clay; how would it get out, you know, if it was all dry, all the clay was dry?
3. If a seed's got a really thick skin on it, is that because a lot of animals like to eat it, or is it just so when it drops onto the ground it'll be...?
4. If the seed dies, if you look after it, do you know if it will come alive again?
5. If you just put seeds on the window sill would it just, would it grow by itself?
6. Well, if you had a seed and you put it in water, and you keep watching it and watching it all day and night, could you actually see it grow up?
7. If you got a little seed and it's got a little bit of water in it, got some water, and you looked after it very well, would it come, would the rot go away?
8. Is the embryo seed the, sort of part of it?
9. Do all plants have seeds in them?
10. Which came first, the seed or the tree?
11. In a pine cone, what are those little, those things sticking out?
12. If you had a seed and it didn't (unclear what was said here) out of the way, what would happen if, would it fade away, something like that?
13. Why are seeds so hard; is it just to protect themselves?
14. Why do they have that skin on?

RESPONSES OF THE CHILDREN TO THE ALTERNATIVE SCIENCE TEACHING APPROACH

The children's responses may be considered in terms of their question-asking, ideas and investigative strategies, and reactions to working in the alternative mode.

1. The children's question-asking

The children asked many questions, 31 initially and at least a further 24 during the first three lessons. The observer missed many others since it was impossible to record all the children's group discussions where questions were being generated.

The questions reflected a variety of interests in seeds (e.g. the cost, mobility, function, fate, origin, growth and structure of seeds). However, the children decided to further investigate just five of the initial 31 questions; indeed, two-thirds of the children concentrated on only two of the questions.

The fourteen questions asked of the resource biologist towards the end of lesson three have some interesting features that allow some inferences to be drawn about the alternative teaching approach being used. Four such features stand out.

(i) Some questions were reintroduced.

Four of the questions (No. 9, 10, 11, 13) are the same questions as the children asked initially in lesson one, but which were not chosen by the group to investigate. One of the questions, in fact, was identically worded, "Which came first, the seed or the tree?" Another, "Why are seeds hard?" became, "Why are seeds so hard? Is it just to protect theirselves [sic]?" It appears that some of the original questions continued to hold strong interest for a number of children.

(ii) Questions tended to be elaborated.

Compared with the original questions, many of these later questions were more elaborate in structure, and a number contained possible explanations within them. The last question above is an example. Another was that asked by the child who wondered why there is a thick skin on a seed. "If a seed's got a really thick skin on it, is that because a lot of animals like to eat it, or is it just so when it drops onto the ground it'll be [unfinished]?"

The approach seemed to be enabling the children to think in greater depth about the topic and at the same time was encouraging them to express their own thoughts.

(iii) The majority of questions went beyond the original ones.

This was illustrated by the girl who asked whether it would be possible to **see** a seed grow, something which had not occurred to any child during the first lesson. It seems that the interim experiences of the children enabled some to generate new questions.

(iv) Clarification and resolution-seeking questions were asked.

A number of the questions asked by the children appeared genuine attempts to seek clarification of an idea, or to resolve a seeming contradiction. The question asked by the child who was apparently puzzled about how an embryo plant could emerge from a thickly encased seed is a good example. Another instance occurred when the resource biologist used the word 'embryo' in one explanation and mentioned that it was the 'tiny wee plant' inside a seed. One girl immediately sought further clarification by asking, "Is the embryo seed the, sort of part of it?" It appears that the approach was not only enabling a number of children to articulate their ideas in a relatively sophisticated manner, but also to take a genuine interest in resolving certain issues that arose.

2. The children's ideas and investigative strategies

An analysis of the children's questions, explanations and discussions revealed five noteworthy features in their communication moves, their investigatory strategies and their thinking.

(i) Interaction during small group discussions was meaningful.

One of the most noticeable features of the children at work in small groups was the purposeful nature of their discussions. In contrast to typical teacher-directed primary school science classroom behaviour observed by the author, most of the children engaged in this study seemed to maintain a focus on the topic. Frequently they took their cues from each other, elaborating ideas in response to the comments of others. The following is an excerpt from a discussion by four children concerning the explanation they were going to suggest about whether seeds could ever be grown on the moon; it illustrates the purposeful and sustained nature of much of the discussion.

Bruce: Could be possible if you get a glass case and put oxygen in it.

Vivienne: It would have to be airtight though.

Bruce: Yeah.

Garrick: Probably die of cold.

Kate: Yeah, no, what would happen because there's no gravity?

Vivienne: I know [rest of statement unclear]

Garrick: The flowers would fly away.

Bruce: Just float away.

Kate: I know, and even a brick just floats up.

Vivienne: Why don't they, um,

Bruce: A ten ton weight doesn't.

Kate: Um, it's, oh what was the,

Garrick: [telling group recorder what to write] It might be possible, but that will be incredible.

(ii) Sometimes children acted on their assertions as if they were fact.

On a number of occasions it seemed that some children believed in their assertions and used them as a basis for further discussion. The assertion by one child that there is no gravity on the moon and the conversation that followed is an example. Another instance occurred when a boy in a different group told the observer that he didn't think seeds would grow on the moon. When the observer asked if he had checked to see if it was a good answer, the boy replied,

No [pause], but I don't think seeds can grow on the moon because when men go on the moon they need heavier stuff, and seeds are light and they would just float away.

Apparently the boy saw no need to check on such an 'obvious' thing.[8]

(iii) A written statement produced by a group did not necessarily reflect all the major points raised during discussion. As with a previous finding that the spokesperson for a group did not necessarily report the group view (Biddulph, 1982b), the written report of one of the groups observed during the first lesson in this study did not fully represent the group view. In answer to the question about whether seeds will ever grow on the moon the recorder had written,

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8. Van Aalst (1980) noted this type of thinking in children too and commented that to children, natural or commonsense knowledge is self-evident. Piaget (1977) has also described how children tend to believe without proof. Children seem to believe that the rest of the world thinks as they do and they therefore state their views without proof as they feel no need to convince others.

It might be possible that a plant could live on the moon but I don't think so. If a plant went on the moon I think it would die from the coldness and it would die from oxygen.

Apart from the fact that he meant 'lack of oxygen' other important points raised in their discussion which were not incorporated into their statement were:

It might be possible to grow them in a glasshouse with oxygen.

Scientists could grow them because they have all the gear and chemicals.

It would not be possible because there is no gravity on the moon and things just float away.

The observation suggests that the written explanations of the children may not accurately portray the substance of their discussions, or may fail to take into account important aspects of their discussions.

(iv) Children suggested a variety of investigatory strategies.

The children suggested a range of ways of investigating the things they wanted to find out about. For example, various children suggested **consulting reference material** which, in their view, included library books, articles, dictionary, spelling books, Science World of Knowledge, and encyclopaedia (although one girl said that encyclopaedia was, "the same as a dictionary really"). Other children suggested **consulting people** who might know, such as a scientist, the teacher, other teachers and children, parents and grandparents, neighbours and friends. They proposed doing this face-to-face, by telephoning, or by writing to them. One girl and boy voiced reservations about the helpfulness of parent replies; they considered it was nearly the same as asking their teacher because "you'll probably still get the same thing!" On the other hand, several children used the strategy of consulting people by surveying the teachers at the school.

Several children proposed other activities to check on their answers. These included **observations, field study** and '**experimentation**'. An example of observation was the suggestion by one girl to look to see if animals have seeds inside them,"What about if you sort of got an animal, you know, a dead one already, you know, frequently [she meant 'recently'] died."

An example of a field study proposal was that by the children interested in the money-tree question. One girl asked the teacher, "When we start doing our exploring and all that, would we be able to go and look at plants, like round the school and that?"

A number of groups decided to carry out an 'experiment' to test whether a seed could be grown on the moon by simulating moon conditions, as they understood them.

(v) A variety of children's ideas were revealed.

Ideas which children held with respect to various phenomena associated with the topic emerged during discussions as they worked in their small groups.[9] Some of the children's ideas would be acceptable to scientists and may indicate, as Oakes (1969) has suggested, that children can, and may be eager to, learn the scientific explanations of many natural phenomena. For example, two boys had a reason for thinking

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9. Such was their involvement that they did not seem in the least inhibited by the observer listening in quietly and having a hand-held tape-recorder recording unobtrusively at the same time.

that it does not rain on the moon.

> *Kate: Does it rain up on the moon though?*
> *Garrick: No, because it hasn't got any clouds.*
> *Bruce: No clouds*
> *Garrick: Because there's*
> *Bruce: It's [cloud] just around the world, the earth.*

A further example was an idea that a boy and a girl had regarding the relationship between a seed and an egg. This emerged during a conversation with the observer and it appeared that the children recognised some kind of equivalence between the two.

> *Alison: [talking about an ant's egg which she said she had seen a queen ant lay] The egg is sort of a seed, but it [the seed] could be inside.*
> *Richard: Yeah, because it's like a, when women have babies the baby is a kind of a little seed and it grows inside your body and when it's about, a little baby comes out and then it starts growing; so it grows inside.*

The learning context also allowed some of the children's less useful views to emerge clearly. The children's idea that the moon lacks gravity was an example, as was the view that scientists can solve any problem. The latter idea surfaced when children were considering whether seeds could grow on the moon. Children's answers included, "Yep, chemists will come up with something; there's nothing impossible these days." Others thought it would be impossible, "Unless you're a scientist" or, "Unless you're a very good scientist about the moon." A further example of children's less useful ideas emerging was the view of a girl who thought it would be possible to tell whether, if one little plant grew from their container, it came from the green catkin seed (rather than the brown), "Because it will sort of be a bit younger."

3. Children's overall views about the alternative teaching approach

The children's comments about, and written evaluations of, the approach reflected many positive reactions. In general, the children seemed to regard the work as more **relevant** because it was based on what they wanted to learn rather than what the teacher wanted them to find out. As one child said, "We asked the questions that we wanted to know the answers to."

The children also enjoyed listening to, and considering, the ideas put forward by their peers, for example, "It is interesting to see what other people think seeds grow from and that" and, "We came up with some queer things."

Other positive comments related to the opportunities to use resource material and equipment, to the opportunity to use their own investigative methods, and to the support they derived from working in groups. The fact that less writing seemed to be involved was also appreciated.

The children's positive response to the approach was also evidenced by the high degree of interest which was sustained throughout the study, by the children spontaneously including the observer in their discussions, and by them immediately making use of thé visiting biologist. The children were eager to continue their investigations outside school time and after the study had ended (Several long-term, growing experiments were conducted by the children after the seed study.)

The few negative comments stemmed from breakdowns in group co-operation. For example, there was some reported conflict within groups when one member wanted to take the study in one direction and the remaining children wanted to go in another. Initially, one or two groups had difficulty deciding who should record their group's ideas, and by the end of the first lesson the teacher found one girl who said that she preferred to work by herself instead of in a group, "I don't like in the group; I like doing it by myself."

FEATURES OF THE TEACHER'S EXPERIENCE USING THE ALTERNATIVE TEACHING APPROACH

During informal interviews, and in her field notes, the teacher reported her initial thoughts and concerns about using the approach, the difficulties she encountered, and the advantages she experienced during the teaching. Those perceived significant are outlined below.

1. Initial thoughts and feelings

This approach was quite different from other methods which this teacher had employed and for this reason she approached it, she said, with mixed feelings.

She found that formal planning was reduced to a minimum. Although she had certain broad aims in mind, specific objectives for the unit were largely formulated from the children's questions. Likewise, learning activities were mostly generated by the children themselves. For these reasons, the teacher embarked upon the study without firm ideas of how the study would proceed, beyond knowing she would need to elicit the children's questions. In the event, each group's, indeed each individual's, activities were different and she found it necessary to adopt a fairly flexible approach. She felt it was essential for her to be led by the children and their interests rather than further impose her own ideas of appropriate activities and learning outcomes. She considered that it was also essential to recognise teachable moments and to capitalise on these.

Initially she found it difficult to overcome a sense of 'panic' as each pupil pursued his or her own objectives. She reported, however, that this feeling abated as she became more accustomed to the alternative approach and came to realise the value of this type of learning.

2. Perceived difficulties

The approach was not without further difficulties. Since the children were carrying out many and varied investigations into seeds, there was a great demand for resources, especially books. The teacher provided as many resources as possible but a number of the children found these resources to be inappropriate in terms of reading difficulty and content. The teacher soon realised that, for the topic 'seeds', there was a shortage of resources which children at this level could use independently.

A second difficulty encountered by the teacher was the practical one of spreading her attention around each group so that the studies could continue in a successful manner. She recognised that for the approach to function effectively the children must receive adequate teacher guidance and unless the teacher is able to provide this, valuable learning experiences could be lost. She further realised, she said, that a good working atmosphere was essential and that the teacher herself must be prepared to devote all her time to the children. (Good control is also vital, a quality Mrs Roger possessed.)

Finally, a difficulty which she felt could apply to other classes as well was that of group relationships. As the study proceeded individual children found there were particular avenues they wished to pursue and their attempts to diverge, as well as the large number of ideas being generated, caused a strain in relationships in some groups. The teacher allowed those individuals who wished to branch out on their own to do so. This preserved harmonious group relations and enabled the children to concentrate on their investigations rather than to be distracted by problems within their group.

3. Perceived advantages of the approach

Despite the difficulties associated with the new approach, the advantages were such that the teacher believed the method very worthwhile because:

(i) The approach was directed totally towards the needs and interests of the children. Since the children themselves formulated the objectives, the danger of pursuing inappropriate objectives was greatly lessened, she felt.

(ii) It fostered a positive attitude toward science among her children as they answered their own questions, and pursued their own interests, using a variety of resources and research procedures.

(iii) As the children engaged in their inquiries, including discussing procedures and findings, they developed many useful intellectual skills.

(iv) From the children's questions, discussion and working strategies the teacher gained valuable insights into how they perceived phenomena around them.

CONCLUSION

This initial exploration of the proposed alternative teaching approach indicated that it looked promising, but also suggested that a more detailed investigation should be made of its potential use in the primary classroom for teaching children in science. In particular it was considered that it should be tried
(i) with a syllabus topic which children reported they were not particularly interested in;
(ii) with an experienced teacher whose approach to teaching was the common traditional one of teaching children the 'right' methods and answers;
(iii) with the teacher being supplied with some information on children's ideas and questions about the topic;
(iv) with children who were perhaps generally less able than the children who participated in this first study;
(v) in a form that required less than the 12 lessons of the study above. It was felt that if it were feasible to conduct a study along the alternative lines within the space of a week, rather than over several weeks, then this would be compatible with the length of time that some teachers devote to a unit in science.

The three studies reported below reflect this decision to explore the feasibility of the alternative approach in greater depth.

The Investigations Relating to 'Metals'

Three action-research studies were undertaken with the topic 'metals', one which a prior survey of primary school children revealed to be of little interest to most of the children surveyed.

The children involved in the first study of 'metals' (METALS 1) were in a S3 class at Tamahere Country Model School, Hamilton, and were of average to above-average ability. They were taught by their regular teacher, Mr Bill McMinn, an experienced teacher who previously sought to guide his children to the scientific answers, as he perceived them.

Two classes taught by the author were a S3 class at Bishopdale Primary School, Christchurch (METALS 2), and a S3 class at Glenview School, Hamilton (METALS 3). The Christchurch class was considered to be below-average to average in ability, while the Hamilton children were considered to be average to above-average. Mrs Patricia Williams, a second year teacher observed in the Christchurch classroom, while Mr Kevin Sheppard, a person with about five years teaching experience observed in the Hamilton classroom. Neither teacher had previously used children's questions in their science programmes.

During METALS 1 (six lessons in all) at Tamahere, **data** were obtained by

(i) observation (and field notes kept) by the researcher who was present in the classroom throughout the lessons;

(ii) observation (and field notes kept) by three assistant researchers (former primary school teachers) who were present during one lesson;

(iii) recording on audio-tape small group and whole class discussions, and also informal interviews with the teacher;

(iv) the researcher interviewing the children individually before and after the first lesson and at the conclusion of the series;

(v) having the teacher review critically a draft analysis of the data.

During METALS 2 and 3 (four lessons in each case) **data** were obtained by

(i) participant observation by the researcher;

(ii) recording informally on audio-tape the observations made by the two class teachers;

(iii) recording on audio-tape small group and whole class discussions;

(iv) collecting worksheets on which the children had recorded their ideas.

Each series of lessons followed the same general pattern:

(i) There was an introductory session, including discussion, to stimulate the children to ask questions about metals.

(ii) The children, in small groups or individually (as they chose), wrote possible answers to one or more of the questions.

(iii) The children chose one or more questions/ answers and carried out an investigation to check whether they were sensible and useful ones.

(iv) The children reported their findings to the rest of the class.

A number of issues emerged during METALS 1, which the researcher attempted to address during METALS 2 and 3. The issues were:

(i) What form of stimulus is appropriate for this topic?

(ii) Which of the children's questions and explanations should form the basis for their investigations?

(iii) Are appropriate resource materials readily available on this topic for children of this age?

(iv) Do children of this age have investigatory and processing skills adequate to the task?

(v) Are children interested in the reports of others?

(vi) Do children show interest in the topic?

(vii) What do the children learn?

(viii) What is the teacher's experience, especially his/her sense of control of the teaching/learning process, using this approach?

The remainder of this section of the chapter explores these issues in the context of METALS 1, 2 and 3.

1. Stimulating children's questions

The teacher of METALS 1 introduced the topic using a 'class interview-about-instances' technique. Various common objects were shown to the class one at a time and the children were invited to say which group they would put each object in, 'things made of metal' or 'things not made of metal', and why.

The difficulty with this introductory activity, the teacher found, was that at the end of it a common meaning for 'metals' had not been established. In METALS 2 and 3 the researcher tried to remedy this by clarifying with the children at the outset what **he** meant when he was using the term 'metals'. Like the class teacher, he took into the classrooms a number of common objects made of metal (e.g. a gold ring, silver spoon, stainless steel knife, aluminium milk bottle top) and showed them to the children one at a time. This time, however, he told the children that the objects were made of gold, silver, steel (as was appropriate) and that these were metals. From the children's comments it became clear that many had not previously thought of a number of the objects (particularly the aluminium foil and 2 cent coin) as being made of metal.

Both approaches resulted in children generating a considerable number of questions, many of which went beyond the stimulus materials presented. **Every** child in the METALS 1 class responded and 31 questions were asked, the most popular being, "How can we tell if objects are really metal?" In the METALS 2 class the children responded with 15 questions initially and another 25 in a later lesson, while the children in the METALS 3 class asked 35 questions.

2. Choosing children's questions for investigation

The issue of how to choose a suitable question or questions for further study by the children was addressed in several ways during the three series of lessons.

In METALS 1 the teacher allowed the children, in their groups, to choose which questions they would like to answer. The result was that 17 of the 31 questions were chosen. Because he felt that he could not manage this number he selected four of the children's questions for further investigation, and asked the children in their groups to choose one for further study. The questions were:

How do you make metal?
How can we tell if objects are really metal?
Why is aluminium light?
Are many boats made from metal?

Different criteria were used in this selection. The teacher thought that questions 1 and 2 might help the children gain basic understanding about metals, he wondered what would happen if children attempted question 3, and question 4 had been a popular question when the children first chose questions to answer.

In METALS 2 and 3 the researcher chose one of the children's questions in each case for further study. "How do you make metal?" and "Where does most metal come from?" The researcher chose these questions in the hope that they might somehow lead the children to some basic understanding of metals. He also knew that these questions were commonly asked by children of this age.

The researcher selected just one question in each class because of

(i) an expectation that the teaching would be more manageable;
(ii) a perceived need to model in METALS 2 with a less self-disciplined class of children what investigating entails;
(iii) an opportunity to explore further in METALS 3 the development of a 'compact' unit on the topic that would fit into the time-frame that some teachers use for a science unit.

Neither the teacher nor the researcher had a sound understanding of 'metals' and consequently found it difficult to recognise which of the children's questions had greatest potential for assisting them toward worthwhile knowledge.

Experience with METALS 1, 2 and 3 suggests that teachers using children's questions as a basis for teaching primary science require access to the scientific views about the topic, and clear guidelines about how questions can be chosen for investigation.

3. Resource materials for children's research

Three categories of resources, objects, people and text material were used in METALS 1, 2 and 3. The first two categories were used successfully, but difficulty was experienced with the third.

Objects included common metal objects or pieces of metal brought to school by both teacher and children, pieces of metal from the school science resource kit, and pieces of various kinds of metal ore supplied by the researcher. The ore samples were omitted in METALS 3 because the researcher decided teachers would not normally have access to such samples.

In some cases the children seemed to succeed in using their parents as resource people. For example, during METALS 2 three boys, whose language ability was very limited according to their teacher, surprised her by recording on their worksheet in response to the question of how metal is made, "My dad said that they dig it up, then they squash it. Then they put it into the shape that they wanted."

In METALS 1 the teacher and children went to considerable effort to provide the best collection of books available, but the books proved too difficult for many of the children. The children could say the words but they did not have the background to understand them. Further, the texts did not really address the things the children were interested in, and consequently were of little use in providing answers to their questions.

For METALS 2 the researcher decided to write his own small resource booklet (see Appendix 3) using language familiar to nine-year-old New Zealand children, and based on the four most common questions that children of this age had asked about metals. When the booklet was introduced, one group of children out of eleven copied information from it, but nine groups used it to gain information which they structured in their own words. Similarly, in METALS 3 two groups of children out of 15 copied from it, but 12 groups reconstructed the information in their own terms. In almost all cases, the meaning taken by the children was that intended by the author. One exception involved two boys who concluded, by a process of association, that the lead in their pencils was gold!

One group in each of the METALS 2 and 3 classes worked from encyclopaedias or their own books rather than from the resource booklet, but these children tended to copy sentences which they had difficulty in reading, let alone understanding. For example, one group wrote,

> *Some metals are formed in the pure state but most of them are found in combination with other elements. These metals are in the form of sulphides, oxides, carbonates, and silicates usually mixed with rock and earthly materials.*

That it made little sense to others in the class who heard it, is illustrated by one boy who commented, "I don't understand what none of it says."

4. Children's investigative and processing skills

During each of the three series of lessons it became apparent that the children's intellectual and social skills were adequate to the tasks in some respects, but not in others.

An example of the adequacy of the children's intellectual skills occurred during a researcher-guided discussion in METALS 3. The researcher recalled to the children that the previous day a group had found out that nobody actually invented metal. Five children talked about the matter as follows:

Michelle: *Why?*
Justin: *But just after the cave men it would be*
John: *They just, who invented*
Susan: *If we didn't invent it, we wouldn't have it right now, so I don't really understand.*
Chris: *No, nature made it. Nature put the rock there, so it's really nature. It could have been there when the cave men were there.*
Susan: *[a few moments later] If nobody invented metal, then it sort of leaves another question; who discovered metal?*

In contrast to this ability to grapple with an issue logically, at times children were observed to

(i) lapse into making unjustifiable verbal assertions during discussions;

(ii) focus on organisational matters (such as the use of felt-tip pens) rather than on the subject matter at hand;

(iii) lack an appreciation of the purpose and critical elements of an investigation, or what is needed to conduct fair tests;

(iv) revert to finding the 'right' answer to their original questions, rather than checking that a particular explanation was a reasonable and sensible one;

(v) lack the ability to co-operate on an investigation in groups containing more than two or three children.

An example of children not appreciating critical elements of an investigation occurred when the teacher in METALS 1 suggested that one test that might be used to check if an object was made of metal was to tap it to see if it made a ringing sound. One child simply waved an object in the air and said, "This doesn't make a ringing noise." Two others used a tuning fork to test various objects and then held the **tuning fork** to their ear! Everything they tapped seemed to them to be made of metal.

A further example, in this case involving book research, was a boy in METALS 1 who read to the researcher his finding that an oil tanker is made of copper. When the researcher asked him how he knew, he located a picture of an ore carrier, confidently pointed to the title on the front of the book and announced to the researcher, "Because the whole book's only about copper." He added, "It's all about copper, so it's got to be copper."

The observations of these children at work suggest that:

(i) If children at this level are to conduct meaningful investigations then they will require careful guidance for some time.

(ii) It is more realistic to invite them to find answers to their questions, than the more sophisticated process of checking whether their possible answers are reasonable and useful ones. They could then reflect on how their findings compared with their initial ideas.

(iii) Group size limited to a maximum of three pupils is required if children of this age are to co-operate as a group on independent investigations. In METALS 2 and 3 this proposal was implemented and the groups functioned successfully as groups rather than breaking down into sub-groups.

5. Children's reporting of, and interest in, their findings

Children's interest in the findings of others was sustained when the sharing of findings was done briefly, informally and relatively frequently, but not when a more formal reporting-back session was conducted at the end of a series (as was tried in METALS 2).

6. Children's responses and learning

In each series of lessons the children expressed interest in this less popular topic, and considered that they had learned worthwhile things about it. On the other hand, one child experienced a sense of frustration with respect to an investigation, in a few instances children's developing ideas ran ahead of their ability to communicate them easily, and there was evidence of some children retaining non-scientific views.

Forty-nine children who offered comments said that they liked the lessons and enjoyed learning about 'metals'. Their experience is perhaps summed up in the words of one child in METALS 3,

> *I thought it was quite interesting and sort of helpful to our lives, 'cause some of us might want to work with metal now and they might have thought in the first place that it is just a boring thing. I learnt quite a lot of things.*

When questioned about what they thought they had learned, some children from each of the three classes had an idea that they had learned something but couldn't quite recall what it was.[10] One girl, for example, said, "I'm not quite sure what I've learnt but I know I've learnt something."

Many children, however, had a clear idea of what they had learned. The thing that most had learned, they said, was that various materials which they had not thought of as being metals **were** metals. One boy put it this way, "I didn't think copper or aluminium was a metal. I thought metal was just metal and there weren't any different sorts."

Another thing which a number of children (ten in METALS 2) said they had not realised before was that metals, for the most part, had to be extracted from rock. This was illustrated by one child who said, "I didn't know that you got metal out of rocks."

During METALS 1 the researcher encountered one boy who experienced a degree of frustration when he sought the teacher's help as a resource person. He wanted to know

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10. Nuthall and Alton-Lee (1982) refer to this type of response as a 'vague feeling of knowing'.

whether aluminium could be used to make boats but the teacher, unsure of his role, turned the question back on the boy by asking him what **he** thought, and what kind of metal aluminium was.

This raises the important issue of what roles a teacher should adopt in using this approach. Experience gained in these studies suggests that

(i) when children are genuinely seeking information which the teacher possesses, they appreciate the teacher providing them with it;

(ii) if the teacher does not have the information then an honest reply to this effect is also appreciated, especially if it is accompanied by some advice about how the information might be obtained;

(iii) children can accept as genuine, teacher-simulated lack of knowledge, particularly if guidance is then offered toward a relevant source of information. A teacher might adopt this latter role to give children who are capable of doing so, the opportunity and experience of independently accessing information.

With a few children, their initial words of communication did not necessarily convey the meaning they intended. One girl, for instance, seemed to realise in mid-sentence that her spoken words were not conveying what she intended, so she rephrased them, "I didn't know that magnets only stuck to some types of metal [pause], I did know that, but I didn't know which types they would only stick to."

There was also evidence of children retaining non-scientific views, despite their involvement in activities designed to challenge them to develop a sound understanding. For example, at the end of METALS 1 five children still believed that 'heaviness' is an important criterion for determining whether an object is made of metal, and one child clung to the view that ability to stick to a magnet is a determining factor.[11]

7. The teachers' experiences

The comments in this section stem from the experiences of the teacher who taught METALS 1, the observations of the researcher during METALS 1, the experiences of the researcher who taught METALS 2 and 3, and the observations of each teacher who was present during the latter two series of lessons.

(a) Aspects of concern

(i) There was a lack of suitable written resources.

(ii) Too much time could be spent on headings.
The time required by the children to head a simple card on which to record their results was often excessive. The teacher of METALS 1 suggested having a worksheet with printed headings for younger children. In METALS 2 and 3, the researcher built upon the teacher's experience and introduced both a booklet and children's worksheets, with some success.

(iii) Lack of clearly defined purposes can result in uncertainty in teaching.
The teacher of METALS 1 experienced a sense of uncertainty

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11. This is consistent with a study by Symington and White (1983) who found that despite children's involvement in activities designed to shift their thinking, most 10-year-old pupils in two Australian classes retained the ideas they either brought with them to the lessons or constructed at the beginning of them.

about the direction of the study; because he was not sure what he was trying to achieve with the children he did not know whether to answer some of their questions or to guide them further to find answers for themselves. Toward the end of the series, he decided to guide the children in two activities which he thought would provide them with some worthwhile understanding of metals, namely using specified tests to check whether various objects were made of metal, and trying to identify the type of metal contained in several samples provided. Perhaps lack of sufficient guidance (Brown and McIntyre, 1982) in the new teaching model led the teacher to revert to his former role of director of all activities, just as Victorian primary school teachers in Australia had done (Landt, 1968).

(iv) An inner conviction of child-centred learning required by the approach is difficult to develop.
Henry (1976) noted that when Crossland investigated the uptake of Nuffield Primary Science in Britain he found that for Nuffield ideas to work in practice, an inner conviction was required by teachers that child-centred learning was the best way to proceed, and that more conventional teachers experienced anxiety in trying the approach. The responses of the teacher of METALS 1 suggest that by the end of the lessons he had not become committed to child-centred learning.

(v) Deciding which questions to investigate is not easy.
When the researcher taught METALS 2 and 3 he found it difficult to decide which, if any, of the children's questions would provide a worthwhile study. This stemmed from his own relative lack of understanding of the topic and hence his inability to recognise questions of worth.

(vi) The children had difficulty structuring valid investigations.

Many of the children seemed unable to structure valid investigations by themselves. This suggested that considerable teacher guidance would be required, at least initially.

(b) Positive aspects

(i) The children were highly motivated.

The teacher of METALS 1 felt that his children had responded very well and had shown a great deal of interest in the whole approach. He thought that the questions clearly pointed to deep thinking and a desire to know on the part of the children. He was surprised at both the number and depth of the questions asked. He also noted that the study had prompted the children to engage spontaneously in various kinds or research at home.

The teacher who observed METALS 2 considered at the conclusion that they had been, "a marvellous experience for the kids." She added,

> *They've really enjoyed looking up things for themselves. I think it's far better than me standing up the front telling them things. They will remember it longer and appreciate it more. I think some of them worked really, really well.*

The researcher also felt that the children had worked well. On the first day he had to direct one group of boys several times to remain on task, but on the second day he became aware part-way through the lesson that all groups were working away quietly at their tasks and that none needed direction as on the first day.

(ii) The children's thinking was revealed.

An aspect that the first teacher liked particularly was the part played by the children in designing the study. He said that it gave him insights into their thinking that he felt he had missed previously. He became very aware that in the past he had probably assumed that the children had certain ideas or meanings which they did not have. He now realised, for example, that the term 'metal' probably meant something different to every child in the class.

At the conclusion of METALS 3, the children's own teacher expressed to the researcher his interest in seeing the children's ideas revealed. He said,

> *I was quite interested in finding out what these kids know about these sorts of things. It's hard sometimes to find it out. You can discuss it [as a class] but quite often you don't get those sort of ideas because there are four or five actually discussing and the others knock off and take a back seat, and leave the others to do the work.*

(iii) Children's co-operation enhanced their achievement.

During METALS 2 the three least able readers (boys) in the class formed a group. The teacher was somewhat concerned that they might not cope with the reading and written aspects, but to her real surprise the three boys among them produced work of which the teacher did not suspect they were capable. The earlier mentioned statement about one boy's father saying that 'metal was dug up, squashed and shaped' was their work.

(iv) Many children were able to reflect on their own learning.

The children's responses during the final lesson of METALS 2 supported their teacher's view that they had learned a number of things. With two exceptions they did not hesitate to say what they had learned, and these learnings were in the direction intended by the researcher.

REVIEW AND IMPLICATIONS OF THE FINDINGS OF THE FOUR ACTION-RESEARCH STUDIES

The literature cited at the beginning of this chapter suggested what might be the features of a viable teaching approach that makes use of the children's own questions. These were incorporated into a teaching model constructed by Dr Roger Osborne and the author. The four action-research studies conducted by two classroom teachers and the author sought to explore the viability of this teaching model for primary school teachers in New Zealand.

The results of the studies indicate that with some modifications the alternative approach could be a valuable teaching model in primary science.

Perhaps the main modification required would be to encourage children to conduct investigations to find answers to the original question, which they could then compare with their proposed answers, rather than trying to have them test their suggested answers for usefulness or reasonableness. The latter seems to be a process which is too sophisticated for most primary school-aged children.

The enthusiasm, purposefulness and increasingly thoughtful questions and ideas which were generally forthcoming from the children in the course of studying the topics described in this chapter convinced the teachers that the approach had merit. The children readily adopted the new roles required of them, even if their intellectual skills did not always allow them to fulfil the roles effectively. The teachers, on the other hand, found it far more difficult to adopt roles consistent with the approach being tried. This suggested that for greater viability the roles required of the teacher (e.g. resource person, co-investigator, guide, mentor or challenger of thinking) need to be made explicit, and some advice provided about when the various roles are appropriate.

For teachers using the alternative approach for the first time, even for a teacher with a strong interest in science education such as Mrs Juliet Roger, the mere outline of the approach as shown in Figure 2, seemed to be insufficient. With hindsight this is understandable; it is so different from the approach used by most teachers that it is difficult for them to visualise what it means in practice. The implication of this is that, at least initially, most teachers will require the approach to be translated into practical teaching suggestions within the context of a particular topic.

Some other important factors that seem to be necessary to make the approach a viable one include the availability of resource materials with which children can interact with understanding, background information on the topic for the teacher, group cohesion within the classroom (that is, co-operation, or 'good group dynamics' as Mrs Juliet Roger called it), a non-judgemental classroom climate, and a willingness by the teacher to guide children in their investigations. With respect to the last factor, contrary to their expectations, the teachers and researcher did not find the prospect of offering children guidance a daunting one. Adult common sense (rather than scientific expertise) seemed entirely adequate to detect and help children overcome shortcomings in their thinking and investigative strategies.

Experience in trying the approach indicated that it could be quite flexible, in several ways. It allowed not only for a variety of teaching roles to be used as appropriate, but also for variety of classroom structure ranging from a very loose structure for well-behaved and capable children to a very tight structure for managing a more 'difficult' class. It also allowed for individual or co-operative group work, for children working at a pace and depth of understanding which suited them, and for children to pursue questions which had cultural relevance for them. Further, it catered for children who had learned not to ask questions since there were usually plenty available to choose from, and it enabled a study to be completed within a week, or to be extended to several weeks. Often there were many questions left unanswered when the teachers felt time available for the study had run out; this suggests that the same topic could easily be taken up later in the year or perhaps the following year, in contrast to teachers' present practice of arranging the school scheme to avoid 'repetition' of a topic.

In the course of the studies the close observation of children revealed many examples of children constructing their own knowledge, thus giving support to the constructivist view of learning. The teachers and author were also aware that when they managed to play their required roles faithfully they were actually assisting children in this process; indeed they were empowering children in their own learning and, since the emphasis was upon **ideas** held by various people rather than 'right' answers, were at the same time enabling the children to gain a constructivist perspective on knowledge itself.

The promising findings from these studies suggested that it would be worthwhile to augment the approach as outlined above, perhaps with a topic considered 'difficult' at the primary level, and explore its viability with another group of teachers. An account of such an extension to the research is provided in the next chapter.

CHAPTER 7

AN INVITATION TO ADOPT AN INNOVATIVE TEACHING APPROACH: THE RESPONSES OF SEVERAL CLASSROOM TEACHERS

INTRODUCTION

> *What goes into persuading a body of teachers to think about trying new ideas? Can such ideas and curricula practices be communicated using written materials alone? These are hard questions - but they are important ones, if only because written materials represent, when contrasted to in-service courses, workshops, and the like, a potentially most cost-effective way of influencing teachers.*
>
> *(Westbury, 1983, 2)*

The author, and other members of the Learning in Science Project (Primary), recognised that the questions posed by Westbury were important ones. The interactive model (with some modification) could be disseminated widely to teachers through written materials at relatively modest cost. The fate of the approach in the hands of a range of teachers who read booklets describing and illustrating it was investigated. The major research question (Question 5) which guided the investigation was:

Can teachers adopt the science teaching innovation as intended by the developers?

Subsidiary questions were:

(i) In what ways would the teachers' actions be consistent with the suggestions in the booklets?

(ii) In what ways would the teachers' actions deviate from those intended by the authors of the booklets?

(iii) In what ways would the teachers modify the ideas contained in the booklets during implementation?

(iv) What features of the suggested teaching approach would present difficulties for the teachers and children?

The topic 'Floating and Sinking' (considered difficult at the primary school level) was the vehicle for introducing the interactive teaching approach to teachers in written form. It was thought that if teachers could manage this topic as intended by the authors, then it was likely that other topics would present few difficulties.

The trial reported in Chapter 6 also suggested that some teachers may need, and may appreciate, less advice than others[12]. To cater for at least two groups of teachers whose advice needs differed, two different sets of guide materials were written (see Table 17 below).
An attempt was made to construct the two sets of guide materials (booklets) in a way that would enable the teachers to reconceptualise their teaching task from what Smith and Anderson (1983) characterise as activity-driven, didactic or discovery teaching, to conceptual-change teaching.

The author was aware of a further dilemma; sufficiently detailed advice to provide real insights into practice could result in teachers either reading it superficially or not being able to assimilate it (Smith and Anderson, 1983). This risk had to be taken, with the teachers' responses becoming one focus of the research.

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12. Mrs Juliet Roger, for example, after some initial uncertainty, soon found that the approach was compatible philosophically with her view of how she wanted to work with her children. She was therefore able to translate the teaching outline into practice and use it flexibly. Another teacher, Mr Bill McMinn, was unclear what roles were expected of him, since the outline was not explicit in this regard. He would have appreciated more detailed guidance.

The investigation

Five teachers were observed translating the written guide materials into teaching practice. Details of the investigation are summarised in Tables 16 and 17 below.

TABLE 16: Details of five teachers who tried out written guide materials, and the settings.

TRIAL	TEACHER(S)	EXPERIENCE AS TEACHER	KNOWLEDGE OF LISP FINDINGS	SCHOOL IN HAMILTON	CLASS
1	Ms P Gregan	Year 2 tchr	No	Glenview	S3
2	Mrs E Hamill	Very experienced	No	Glenview	S3
3	Mrs J Roger	Year 2 tchr	Yes	Glenview	S4
4	Mr J Faire	Very experienced	Yes	Newstead	[S2-4[a]
	Mr J Duncan	Very experienced	Yes	Newstead	[S2-4

a. This was a combined class of 40 children taught co-operatively by the two teachers in an open-plan classroom

TABLE 17: Further details of trials of written guide materials undertaken by five teachers.

TRIAL	BOOKLET[a] USED	NUMBER OF LESSONS	TIME PERIOD	CLASSROOM OBSERVER
1	1	6	2 weeks	Ms E Hawe[b]
2	2	4	2 weeks	Mr K Appleton[c]
3	1	7	2 weeks	Mr K Appleton
4	1 & 2	4	2 weeks	Author

a. Booklet 1, entitled 'Floating and Sinking: Some teaching suggestions', was written by the researcher, assisted by Professor Peter Freyberg and Dr Roger Osborne and designed for teachers who might prefer detailed guidance. It is reproduced in this report as Appendix 4.

Booklet 2, entitled 'Children's questions and science teaching: An interactive approach', was again written by the researcher, assisted by Dr Roger Osborne and was designed for more confident teachers. It is reproduced as Appendix 5.

b. Ms Hawe, was a very experienced teacher seconded to the Learning in Science Project (Primary) for one school term.

c. Mr K Appleton was a science educator on leave from the Capricornia Institute of Advanced Education, Rockhampton, Australia.

Data Collection

Methods of data collection are summarised in Table 18 below.

TABLE 18: Methods of data collection in the four trial settings

	TRIAL 1	TRIAL 2	TRIAL 3	TRIAL 4
CLASSROOM OBSERVATIONS	Yes, by E Hawe	Yes, by K Appleton	Yes, by author	Yes, by K Appleton
FIELD NOTES	Of informal discussions with tchr & classroom observations	Of informal discussions with tchr & classroom observations	Of informal discussions with tchrs & classroom observations	Of classroom observations
TAPE-RECORDED INTERVIEWS/ PROCEEDINGS	With 9 chn one week, post-trial	With 11 chn & teacher one week, post-trial	None	With 4 chn pre-trial, & two weeks, post-trial. With tchr pre & post-trial, & end each lesson. Proceedings of each lesson.
WRITTEN MATERIAL	Teacher evaluation of trial, and comments on draft report.	Teacher comments on draft report.	Teacher planning and evaluation notes. Chn's activity guides. Chn's questions & written responses.	Chn's worksheets. Chn's pre & post-trial surveys on meaning for 'floating'.

Trials 1 and 2 were conducted at the same time, while Trials 3 and 4 were conducted simultaneously several weeks later.

Using the classroom analysis methodology of Tasker and Osborne (1983), an attempt was made to compare the suggestions of the booklets with the teachers' **intentions** for instruction and their **actual** classroom instruction (Smith and Sendelbach, 1982).

TEACHERS' ACTIONS CONSISTENT WITH THE SUGGESTIONS IN THE BOOKLETS

In all four trials, various planning and teaching moves were in accord with the intentions of the authors of the booklets.

Trial 1

This young teacher's intentions and actions matched those in Booklet 1 in two respects.

1. Most of the activities suggested were planned for and attempted in the order in which they appeared.

The teacher indicated in her initial planning that she intended devoting one lesson to each of investigations 1-4, and this she did. Lesson 5 was spent on experimental investigation 1, because it "looked interesting," she said. She decided further that the suggested non-experimental projects would be a good way to 'round off' the study so she had each child in the class work at these for homework (consulting people and books) and used lesson 6 to review their findings.

The questions which appeared as the headings for each of the proposed activities in the booklet were used by the teacher to introduce, and provide a focus for, each lesson. She began lesson 5 (Experimental Project 1), for example, by saying, "Our question for today is: How can we make non-floating things float?"

Later interviews with a sample of children confirmed that this aspect of consistency translated to the children's learning. For example, the extension activity of Experimental Project 1 (shaping a non-floater to carry the greatest possible load) was apparently a vivid episode for at least four of them. One boy, for instance, said, "It's good fun, making a little boat out of the spud or else out of the plasticine, see how many marbles we can fit in, see if they float and sink still."

2. The suggestions in the booklet for recording the children's responses were used.

This is illustrated by the teacher's preparation for lesson 1. She had drawn a blackboard copy of the first suggested recording chart (see Figure 3 below), and emphasized that the children should make their predictions and give their reasons before they undertook the tests.

FIGURE 3: Suggested recording chart for Investigation 1 in Booklet 1.

<u>Recording</u>

(a) Mini-group or individual

Material	We expect it will (float/sink)	Why we think that	We find it (floats/sinks)

The approach did not pass unnoticed by the children. During the later interviews, three of the nine children commented spontaneously on the way they had made their predictions first. One girl, for example, said that she found it very interesting when, "we listed the objects down and then we put why we thought they would float or sink, and then we put if they did float or sink."

Trial 2

The actions of the experienced teacher who tried out Booklet 2 were consistent with the suggestions in the booklet in one respect. The first two lessons followed reasonably closely steps 1 and 2, and part of step 3, of the suggested teaching approach. This included providing a stimulus, eliciting and recording children's questions, requiring children to select some investigable questions, and discussing with them how they might carry out their investigations.

Trials 3 and 4

All the actions of the teacher involved in the third trial based on Booklet 2, and of the two teachers who undertook the fourth trial using Booklets 1 and 2, were consistent with the suggestions in the booklets.

DEVIATIONS FROM THE INTENTIONS OF THE AUTHORS OF THE BOOKLETS

There was evidence of the Trial 1 and 2 teachers departing from the intentions of the authors of the booklets in several respects. No such divergence occurred in the third and fourth trials.

Trial 1

This teacher diverged from the Booklet 1 intentions in four main ways.

1. The children were offered **cues** about how to make non-floating materials float.

When the teacher introduced Experimental Project 1 she did more than provide the children with non-floating materials (potatoes, plasticine) for them to experiment with. She also provided them with **knives** and emphasized that care should be taken when they **cut** or **hollowed out** the materials. In saying this she gave the children cues as to how she expected the activity to proceed. The cues offered the children by the use of such words, together with the means (knives) to give them effect, were not intended by the authors of the booklet. The teacher may not have meant to give such cues either, as suggested by her remarks to the observer at the end of the lesson, "It's a good type of activity for the children as they are left to work out the problem themselves."

In commenting on a draft report of the investigation prepared by the researcher and two observers, the teacher confirmed that she had given cues unintentionally. With reference to the cutting and hollowing out she remarked, "Did I really say that?" However, the booklet apparently did not make it sufficiently clear to her that a different type of approach was being advocated.

2. An experiment was turned into a competition

The extension activity of the experiment just mentioned was converted into a competition by the teacher. The children competed to get the most marbles into their floating potato or plasticine in the shortest possible time. One of the children who mentioned this activity during the interview commented,

> *We hollowed them (potato and plasticine) out and we had to put marbles in and the group that got the most marbles in without it sinking won the competition, but we didn't get anything for it.*

The authors' intention, on the other hand, was that the children each be given an **equivalent** amount of the **same** material (e.g. plasticine) and allowed to experiment with constructing a floater to carry the greatest possible load. However, the words they used in the booklet were:

> *If a number of children are each given an equivalent amount of plasticine they can experiment to see who can construct a floater to carry the greatest possible load.*

A busy teacher could construe this suggestion to mean 'make it a competition', especially if competition provided a useful motivation and control technique, something which the observer noted, and which the teacher later confirmed, it did in this case. It is also not difficult to see that under such circumstances the finer details of 'equivalent amounts' and 'same material' could be overlooked.

3. Groups of children different in number from those suggested were sometimes used.

The booklet suggested the use of three different sized groups for various activities, namely whole class, individual child, and mini-group, the last being two to three children. Of these, it was the mini-group which the teacher modified; she allocated from four to eight children to a group. For example, during Investigation 1 (what things float and what things sink) she detailed children off into groups of four to six members, and at the commencement of the 'experiment' (competition) involving the marbles she divided the children into four groups of from six to eight members each. The effects of having these larger groups was that at least half the children in each case were not able to participate actively in the investigations/experiments; some of them tended to engage in unintended activities.

The interviews with, and observation of, the teacher suggested that practical constraints of management and equipment influenced her decision to enlarge the groups.

4. There was little or no attempt to challenge the children's ideas.

The authors of the booklet attempted to produce a guide that would enable teachers first of all to recognise children's ideas and then to **challenge** and **develop** them towards those which would ultimately be useful to them. In the present case their intention about recognition seems to have been conveyed satisfactorily - the teacher told the observer that it was useful to find that the ideas of her class were no different from those of other children, as disclosed in the booklet - but their intentions with respect to 'challenge' and 'develop' were not. This was suggested by a number of things noted by the observer. For example, during group activities the teacher moved about the groups attending to managerial matters, but as far as the observer could see she seldom questioned the children about why they thought such and such was the case. Further, on those occasions when she assembled the children to record a class summary she tended to fill in the chart with the first statement offered by a child, without questioning others about their views on the matter, and again without questioning the children about why they considered certain things behaved the way they did.

Challenging and developing the children's ideas was considered by the authors a critical component in their suggested approach.

Several factors may have accounted for the teacher not translating this component into practice:

(i) Although the booklet itself mentioned challenging and developing children's ideas, it did not emphasize these, and did not give specific advice about how this could be done. For a teacher used to teaching in a different way there is little in the booklet to alert her to, and guide her in the use of, a new and somewhat complex teaching strategy.

(ii) The teacher appeared to plan for the lessons in a hurry. She told the observer after the first lesson, "I only read the unit last night and was in a rush to get it ready today." It appeared to the observer that the reference in the booklet to challenging children's ideas was overlooked as a result.

(iii) The way the teacher organised the groups and completed the charts suggests that she saw her work as providing activities for and receiving answers from the children, but not as challenging or developing their ideas.

(iv) The teacher felt inhibited by the observer's presence. After looking through the draft report of the investigation, mentioned above, the teacher remarked that she had not helped the children develop their ideas as much as she might have because she was forever conscious of having a 'senior' teacher in her room as observer.

(v) The teacher seemed to be oriented toward a **stage theory** of intellectual development which in practice meant that she tended not to attempt to influence children's ideas if she suspected the children were not at the 'stage' where they were 'ready' for it. By the end of the first lesson she had decided that the children's responses during her brief attempt to question them indicated that there was little she could do to move them towards the scientific view apart from telling them the answer, and she didn't want to do that, she said. She told the observer that the children were very 'hung up' on light and heavy as explanations for why things float or sink; she didn't think they were ready yet to understand 'abstract notions' such as light or heavy for their size (and she may have been right). In the written evaluation which the teacher provided at the end of the series of lessons she expressed this view again. She wrote,

> *The children, however, once hooked onto an instant solution to a question [about why things float] seemed to develop a mental block and could not be questioned further.*

When the teacher read the draft report of the investigation she confirmed that she had previously thought in terms of stages of development. She added, "We've always been told that if children are not ready to learn, that is, they're not at a stage to understand concepts, they won't."

Thus in offering the children cues, introducing a competition, operating with relatively large groups and not challenging the children's ideas the teacher diverged from the intentions of the authors of the booklet. Some of the reasons for this relate to beliefs held by the teacher, and others appear to stem from a lack of clear advice in the booklet itself. Issues that arise from this are considered in the last section of this chapter.

Trial 2

During this trial the teacher departed from the approach envisaged by the writers of Booklet 2 in three significant ways.

1. A different initial stimulus was used.

In the appendix to Booklet 2 the authors suggested several possible initiating activities but the teacher used something of her own to get the children to generate questions about floating and sinking. She showed them two pictures, one of a waterfall and the other of pack-ice, and used these to introduce the topic 'Water and Floating'. The children responded by asking questions about water and ice, rather than about floating and sinking. For example, they asked,

How do we keep the same amount of water?
What is water made of?
Why in some places is water running, and in others it is frozen?

When this occurred the teacher asked for more questions about 'floating'. A little later, when questions about water and ice were still being asked alongside those about floating and sinking, she introduced a further stimulus - discussing what happens when a person gets into a bath of water - to focus the children on floating and sinking. This additional stimulus was only partially effective in focussing the children's questions in the way the teacher intended. In the end, of 30 questions asked by the children, only nine related to floating and sinking.

An informal discussion the teacher had with the observer after the lesson indicated that she did not use the stimulus suggestions provided in the appendix because she hadn't yet looked carefully at the appendix. There seemed to be two reasons for this.

(i) She did not realise that the new approach might initially require more planning time than she normally allocated for science lessons. She had been given the booklet on a Friday and began the unit the following Monday. In retrospect, perhaps it could have been suggested to her that she take more time before starting. Further, she said that she had had no time on the Monday to find a stimulus other than the two pictures, already mentioned, which she had 'grabbed' from the library at the last moment. In the later interview she reflected on this teaching experience and decided that she would have planned the first lesson differently if she had realised what was involved. She said,

> *I would have made more of the actual experiences at the very beginning of step 1, and then got the questions from the children because... of course they got onto 'water', not just sort of 'floating and sinking'. They wanted to know where water came from and what it was made of. Then I just had to cull out the questions and get them to keep to 'floating and sinking'.*

(ii) The teacher hadn't looked carefully at the appendix. It seemed to the observer, from informal discussions, that the teacher did not realise that the information in that section - located as it was in the second part of the booklet - was intended to be used in conjunction with the suggested teaching approach in the first part.

2. Alternative activities were substituted for later steps of the proposed teaching approach.

Whereas the authors of the booklet intended that the teacher help the children formulate research proposals, guide them during their investigations and assist them record, interpret and report their findings, the teacher substituted activities of her own for these steps (that is, steps 3, 4 and 5), activities which were at variance with the authors' intentions.

For lesson 3, instead of helping children plan investigations to answer their questions, she involved the whole class in an activity to test which of a range of objects float and which sink. The children tested the various objects provided and then extended the activity themselves by manipulating some of the objects to see if their floating or sinking properties could be changed. For example, plasticine was tried in various shapes, and objects (such as a nail and cork) were joined with string or plasticine. The observer took the opportunity to ask a number of the children how they thought the activities related to their questions. None of the children spoken to saw any connection between their questions and the activity they were involved in. The lesson concluded with a short, teacher-led class discussion focussing on the children's observations of what had floated and what had sunk, after which the children were asked to draw a picture and write a sentence about what had happened.

The teacher had several reasons for substituting the 'testing of objects' activity for the other steps in the booklet.

(i) She told the observer that the suggested teaching approach in the booklet did not seem to be leading the children quickly enough to practical activities, something which she felt they enjoyed and which enabled them to find out things. Although she said she realised that the activity was of little help in providing answers to the children's questions, she felt she should provide a more appropriate and interesting stimulus. Teacher-provided science activities as a means of enjoyment and involvement for the children were not the intentions of the booklet authors who envisaged activities being devised by the children themselves as they sought to answer their own questions.

(ii) She was uncertain about how to help the children investigate their questions. During the post-trial interview she alluded to this, "Some children come up with some questions that would never cross your own mind and you think, where do I go from here?"

She told the observer at the beginning of lesson 4 that the booklet did not provide sufficient guidance in this respect. She needed specific suggestions on how to move from children's questions to investigations based on the questions, and she found that an appeal to the observer for guidance on this and other aspects proved unhelpful as the observer was non-committal.

(iii) She was concerned that sufficient and appropriate resources were not available for the children to carry out their own investigations. She referred to this during the interview, "They [the children] did come up with some quite good questions [but] there wasn't really anything for them to go and find their answers in." A little later in the interview she commented,

> *I think the problem everyone's going to have with this [approach] is having enough resources later on for the children to find out, because they do usually want to find out.*

(iv) She felt it was **her** responsibility to provide activities for the children, activities which would provide children with valuable helping experiences, even answers. This reason emerged in discussions with the observer and in the interview. During the interview, for example, she said, "I would like to be able to provide some experiments... have some experiments set up that gave them the answer."

Another reason she felt she should try to provide activities for children, she later told the interviewer, was that she thought the task of devising their own experiments was too difficult for nine-year-old children, unless they had had considerable scientific experience, which her children had not.

3. The teacher tried to provide answers to questions.

In her final lesson, lesson 4, the teacher also failed to follow the later steps suggested in the guide booklet. The teacher said during the interview later that she was conscious of the fact that the children really did want to find answers to their questions and she mentioned to the observer that she was concerned that she could not tell from the booklet **what** the children could do to obtain answers to them. She had decided, therefore, to involve them in an activity which she hoped might supply some of the answers they were seeking.

She began by having the children recall from the previous lesson which objects floated and which sank. These she listed on the blackboard, putting together contrasting pairs wherever possible; for example, golf ball (which sinks) was listed with table tennis ball (which floats), and similarly 'rock' with pumice. She pointed out this difference in flotation of objects of similar size. Next the children were formed into groups and each group was given a lump of plasticine which they were asked to experiment with to see if they could get it to float. They were also asked to think of a reason why it floated - if they could get it to float. When the children had spent some time at this - all groups managed to get their plasticine to float - they came back to a whole class group and the teacher asked for their explanations of why the plasticine floated. The two main reasons offered by the children were that it had air in it, or it had something to do with the size and the shape.

As the teacher explained in the interview later, she thought that the experiment hadn't really provided the children with a satisfactory answer to their questions - which ones she had in mind was not clear - and that many of the children were keen to have a better explanation. She therefore read from a book an explanation of why some things float and some things sink. This explanation mentioned the relationship between weight of water displaced and weight of the object. When the teacher asked the children if they wanted any further explanation many said they did. She then attempted an explanation in terms of the particulate nature of matter; she told them that some molecules are close together and some are further apart, that when you squeeze the plasticine out the molecules are spread out more and so the plasticine, now having more volume for the same weight, floats. This explanation is not consistent with the scientific view but something about it (perhaps the name 'molecules' or perhaps that it was given by their teacher) must have appealed to the children as eight of the eleven children interviewed later gave this as the explanation for why things float. (Six children also gave 'having air in' and four gave 'because it's light' as reasons why things float.)

The lesson concluded with a teacher demonstration and a teacher-led class discussion. The children were shown a long candle floating in a container of water and asked to predict at which level a small piece broken from the long candle would float. They were also shown the levels at which a piece of polystyrene and piece of wood floated. Finally they were asked to say what they had learned, their attention having been directed by the teacher via her questions to the size and weight of some of the objects they had seen floating or sunken.

Part of the reason the teacher tried to give the children answers to their questions and a scientific-type explanation of why some things float and some things sink has been suggested already; she thought the children were not sufficiently skilled to devise their own experiments, and she herself was at something of a loss to know how she **could** help the children devise suitable investigations. She was unable to work it out from the booklet and had little else to fall back on. She explained during the interview that she had no personal experience of the approach, "We never did science like this ourselves," and she found she had an inadequate understanding of the topic herself,

> *I thought I knew what it meant but then when the children came up with their questions I couldn't really answer them properly. You know, I couldn't guide them, I felt, to find their own answers.*

Since she sensed that the children still wanted answers she seemed to feel an obligation to try to supply them herself. In trying to do so the teacher found herself in a dilemma. On the one hand she didn't really believe that she should be supplying the answers because she tended to view learning in science as an inductive or discovery process, that is, a process in which scientific answers - somehow contained inherently within good activities - are found by children without the need for active teaching.

On the other hand, when she found that from the activities provided the children did not seem to be able to 'discover' answers to their questions (six of the 11 children interviewed confirmed that they had not been able to get answers to their questions), particularly the 'right answer' about why some things float, she began to think that perhaps she should tell them. She described her thinking on this to the interviewer, "Really it falls back on the teacher. If the children are desperate you've got to tell them, haven't you." However, when she attempted to do this she realised that she did not know enough about the topic herself to explain it to them. Reflecting on it later, she told the interviewer,

> *I felt that I needed to know more about the actual topic itself. I was floundering round trying to find things out. I was getting a bit desperate about it and we were talking about it in the staff room and I thought, well, I'll just ask everybody in the staffrooom what they think floating and sinking is. Well, I just came out more confused than ever because everybody had a different view.*

Thus the teacher diverged from several key steps in the booklet. Issues which arise from this are also considered in the final section of this chapter.

MODIFICATIONS TO SUGGESTIONS IN THE BOOKLETS

The three teachers who undertook Trials 3 and 4 were observed to modify four of the proposals in the two Booklets in order to make the teaching approach viable. These modifications were consistent with the overall intent of the authors of the two booklets.

1. An activity suggested by a parent was included.

This occurred during Trial 3. A child brought to school an idea for an activity which his father had given him, recalled from his own schooldays, which involved making a potato float by adding salt to the water. The teacher encouraged the children to try it and several did.

2. Criteria were devised for evaluating the programme.

At the beginning of Trial 4 one of the teachers devised a set of criteria to enable judgements to be made about the success of the teachers' work with the children.

> *This unit will have been successful if:*
> *(i) you have identified children's views and questions,*
> *(ii) you have challenged those views,*
> *(iii) you have resolved <u>some</u> of the questions they have asked,*
> *(iv) you have allowed the children to develop ideas which will help them make better sense of their world - which will help rather than hinder their learning,*
> *(v) you arouse pupil interest.*

This was the first time that such criteria had been made explicit.

3. Activities were provided for children who needed special help.

Activities were devised for pupils who were unable to propose investigations of their own, or who were less interested in pursuing their own ideas. This occurred during Trial 4 where the teachers provided activity cards based on other children's questions, or on investigations in Booklet 1. In lesson 3, for example, one-third of the children used these cards, and associated equipment, as the basis for their investigations.

The teacher who undertook Trial 3 also saw a need for providing some children with specific activities. At the conclusion of Lesson 3, for instance, she expressed concern that some children seemed to need more structure to help them plan their 'experiments'.

> *Kids like Matthew are a bit slow. They just don't have any idea what they should be writing. In some cases I feel like saying, "Right, do this, do that." You know, I probably should do a bit more of that with those kids who are struggling.*

4. Children's questions and explanations were clarified.

When eliciting the children's questions the teachers tended to help the children rephrase their questions so that their meaning was clarified, and they were amenable to investigation by the children. Such clarification took two main forms:

(i) clarifying meanings for words and phrases, and

(ii) clarifying whether certain questions were based on knowledge or assumptions.

The clarification procedure challenged children to reconsider their meanings for words, their interpretation of observations, and their possible explanations.

DIFFICULTIES ENCOUNTERED

The majority of difficulties reported were mentioned by the teacher who undertook Trial 3. The two experienced teachers who undertook Trial 4 encountered a number of similar difficulties but, working co-operatively, devised strategies to overcome them and at the end of the trial no longer regarded them as difficulties.

1. Written materials used to assist children with investigations were of limited value.

Materials introduced to help children plan, conduct and report fair tests (e.g. worksheets, guide notes, activity plans, check-lists) and consider alternative ideas, including the scientific view (e.g. a children's booklet about the topic) failed to meet the teachers' expectations in both schools. The children began by following the guide materials as requested by their teachers, but in each case soon deviated to explore in their own (sometimes impulsive) way the environmental materials provided. For example, two children in Trial 4 briefly followed a guide card provided, but soon abandoned it and began exploring freely the flotation properties of various objects and materials to which they had access. This is illustrated by their exploration of a metal dish. The first child placed the dish in the water and it floated, but when the second child had a turn he inadvertently dropped it in sideways and it sank. When asked by the observer whether it was a 'floater' or 'sinker', the first child said a 'floater' and the second a 'sinker'. They did not bother to consider the matter further, but immediately sought other objects to drop into the container of water.

During Trial 3, children were observed to take little heed of reminder checklists designed to help them investigate some popular questions. Some children, for instance, immediately mixed all their liquids together and put the objects into the mixture, instead of testing objects in different liquids as the checklist indicated.

The fate of the children's booklet introduced in Trial 3 is discussed in No.7 below under the heading 'Some children were unwilling to change their fixed views'.

2. An overlong session can affect children's thinking and questioning.

The first session of Trial 4 was about an hour long and consisted of an extended class 'interview-about-instances' designed to probe the children's meanings for 'flotation' and provide an initial stimulus for the topic. In retrospect, the two teachers felt that the session was too long for S2-4 children and that their thinking and questioning suffered. The questions asked did not fairly represent the children's real abilities. This was confirmed when the children asked more substantive questions at the beginning of next day's science session.

3. The topic was a hard one to understand and teach.

As reported earlier in this chapter, the teacher who undertook the second trial found the topic a difficult one to understand herself. The Trial 3 teacher confirmed that the topic was a difficult one at the primary school level. She felt that its relevance as a topic worthy of study was not obvious. Further, because her own understanding of the topic was extended to uncomfortable limits, she believed that many primary teachers would be unable to cope with it because of their own inadequate understanding.

Her doubt about the merits of the topic were highlighted when many of her children failed unexpectedly to reach important conclusions, such as realising that things float because they are light for their size. She felt that other topics should have greater priorty.

4. There was a lack of suitable resources.

With the teaching approach proposed, various resources are required by both teacher and children. Some of these were readily available - for example, the children themselves, the teachers, the guide booklets and even some of the children's parents acted as resources for ideas for investigations - but others were not! Text and audio-visual material on 'Floating and Sinking' compiled in terms with which the children could identify were virtually non-existent[15]. As the Trial 3 teacher said, "What I've found is you get books that are either far too advanced for them or far too babyish."

This was also the case with the earlier feasibility trials (reported in Chapter 6), and Trials 1 and 2 reported in this chapter. It seems likely that this could be a general problem for many topics.

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15. On the other hand, the teachers in the rural school found that they did not really require these types of resources for the investigations that their children undertook. They did, however, provide a considerable amount of equipment for the children to use.

5. Many children lacked the intellectual skills needed for the task of investigating.

During Trial 3, most children planned investigations in a general way. They did not consider details needed to ensure fair tests. One group, for instance, made no plans for comparing the flotation levels of two objects, was observed to carry out no check, but nevertheless drew conclusions as if they had. Another example was the group of children who set out to compare objects floating in different liquids but who mixed all the liquids together and 'tested' objects in the mixture! Frequently the children's 'experiments' were simply trial and error play.

6. The Trial 3 children tended to work as individuals.

Each child showed a preference to experience the various activities individually. Although on one occasion the teacher formed the children into groups of four or five around the water containers so that they could conduct the investigation as a team, they actually worked as individuals[16]. For instance, a child would test an object that had just been tested by another member of the group.

7. Some children were unwilling to change their fixed views.

The teacher in Trial 3 found that a number of children became fixed in their view that things float because they are light, or have air in, with the result that the special children's booklet,

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16. Only where equipment was very limited did they share findings. However, when something exciting happened a child would tell the whole group and even other groups.

introduced to alert them to the scientific view, had almost no impact on them. In the post-trial survey, for example, only six of the 28 children referred to those ideas and even then there was some doubt that they really understood them.

8. Booklet 2 gave inadequate advice about how to help impulsive children and children who lacked the necessary intellectual skills.

The Trial 3 teacher found that the approach did not work well with impulsive children who were usually not disposed to think and reflect on what they were doing or had done. She found the Booklet little help in this respect as it did not contain strategies for dealing with such children. Likewise it failed to provide advice about how much guidance to give children. For example, it did not advise whether to provide activities for children who were unable to devise their own investigations.

9. Some management problems became apparent during Trial 3.

Although she had good management skills, the teacher who undertook Trial 3 experienced a number of management problems when trying to implement the proposed approach. Several 'behaviour-problem' children caused difficulty, a few seemingly very 'slow' children (with whom other children were not keen to work) failed to grasp what was going on, some children did not persist with a task, and others were reluctant to engage in any task other than 'hands-on' work.

Management issues for the Trial 3 teacher stemmed from how much control she felt she had over classroom events, particularly in respect to ensuring that all children were engaged in meaningful tasks. Similar difficulties were experienced in the earlier feasibility trials reported in Chapter

6. The teacher who undertook Trial 1 was also concerned about management, and unwittingly distorted aspects of the interactive teaching approach to maintain control in the classroom.

Management was not such a problem during Trial 4, perhaps because the class sizes were smaller and the children had more self-control.

10. Many children were reluctant to record findings.

Most children were observed to be reluctant to record anything while involved in 'experimenting'; rather they were impatient to get on to the next part of the activity. This was particularly evident in the exploration phase. When the Trial 3 teacher helped the children plan a table or the like for recording data from tests, the children tended to use these properly but some children opted out of this by leaving it to another member of the group. The same children tended to avoid writing descriptions of work done or conclusions reached. Many children showed signs that they found this latter form of recording boring and tedious.

These experiences and responses raise questions about not only the purpose of recording data, descriptions and conclusions, but also the form the recording should take and the use to which it is to be put in the wider context of the approach. Teachers' purposes for children's written recording may at times go beyond the needs of the investigation. For example, a teacher may feel an obligation to have the children prepare an attractive display or book to show administrators and/or parents. This particular perceived obligation, the teacher during Trial 3 said, was in the back of her mind.

OTHER SIGNIFICANT OBSERVATIONS

Twelve important observations were made during Trials 3 and 4 that indicate some effective implementation strategies, and likely responses from children.

1. A special inservice programme was developed at the beginning of Trial 4.

On the basis of a little prior experience of attempting the interactive teaching approach, the first teacher considered that the teacher-planning phase was crucial to its successful implementation, especially with a topic such as 'Floating and Sinking'. Since the second teacher was not particularly familiar with the Learning in Science Project (Primary) philosophy when the two teachers agreed to undertake the trial, the first prepared a set of DISCUSSION NOTES which included sections from each of the teacher guide booklets. These notes were intended to contrast the traditional teaching approach with the proposed alternative, and to spell out possible implications of the alternative for teaching this topic. For example, with respect to the second purpose, the notes indicated that early in the study the children's existing ideas should be identified,

> *Identify children's present ideas and interests so that they can be used as a starting point for the development of the topic.*

and,

> *At this point we are interested in the children's responses [to OHP transparencies depicting instances and non-instances of floating] whatever they are, not in changing them.*

These discussion notes were then examined in detail by the teachers and provided the foundation for a planned sequence of experiences for the children.

At the end of the study the two teachers told the observer that the DISCUSSION NOTES had been very helpful in two important respects:

(i) they had enabled the teachers to gain considerable appreciation of the topic and children's views on it, and

(ii) they had assisted the teachers to clarify their teaching roles, especially that of 'Devil's advocate'.

> *Perhaps more important than the activities themselves is the role the teacher adopts as challenger of pupils' present ideas.... Some teachers find it useful to think of their role primarily as one of being Devil's advocate.*

The form of teacher questioning that this analogy suggested was illustrated in the notes by the following:

> *For example, some questions you might ask as Devil's advocate include:*
>
> *Why do you think that?*
> *How will doing that help you?*
> *Have you heard of this idea... what do you think of it?*
> *How could you check on that suggestion?*
> *Is that a sensible conclusion?*

2. Prior consultation was undertaken by the Trial 3 teacher.

Although the teacher was familiar with the teaching approach outlined in guide Booklet 2, she decided to check that her idea of what was likely to be involved matched that being proposed in the booklet by:

(i) using a pre-trial interview with the observer, Mr Ken Appleton, to clarify details of the approach and its implementation. For example,

> *Teacher: I know that obviously there's going to be questions which probably don't relate to floating and sinking. What do you do there? Do you put up those questions or do you say, "We're not looking at that."*
>
> *Observer: Well, again as far as I can gauge from this (booklet) you can go whichever way you want to.*

(ii) discussing the booklet with Mrs Elizabeth Hamill, the teacher in the same school who had conducted the second trial.

3. Special guide materials were used.

The teachers who undertook Trials 3 and 4 used written materials of various kinds (see Appendix 6) to probe their children's understanding and interest, and to help the children with their investigations. A few of these materials were offered by the researcher and observer (a Floating and Sinking survey, a children's booklet on the topic), but most were constructed by the teachers themselves (an interest inventory, worksheets, activity plans, guide notes, checklists). The survey and interest inventory were successful with the children, writing the guide notes was a valuable experience for the two Trial 4 teachers, but the remainder of the materials failed to meet the teachers' expectations.

4. Children's ideas and interests were revealed.

The teachers in Trials 3 and 4 considered that the approach gave them insights into their children's views. The Trial 3 teacher said it revealed clearly those children who are 'thinkers', while early in Trial 4 the two teachers realised that it revealed both the children's meanings for 'floating' and their ideas about the topic. For example, they were a little surprised when, with reference to one OHP transparency, a child asked, "Do you have to say 'yes' or 'no'?" She considered the drawing of the spider standing on the surface of a pond to be neither floating nor sinking, "It's not sinking but you can't say it's floating either. [How do you mean?] Well it's standing on the water, not lying on it."

The inventory used to identify the children's interest levels provided the teachers with useful insights into their children's commitment to the study. During Trial 3 overall interest was retained or increased by 15 children, and 10 children lost interest or remained uninterested. However, a few children commented that they were no longer interested because they had answered all their problems, and this may have been the case with others as well. The majority of children in Trial 4 were found to have developed varying degrees of interest, a result which was in accord with the teachers' and observer's impressions.

5. Children's commitment extended to exploring the topic beyond school.

The teachers in Trials 3 and 4 found that a number of their children continued investigating aspects of the topic that puzzled them in their own time. The Trial 4 teachers mentioned that these children would come and talk to them about their extended investigations, while the Trial 3 teacher said that many of her children reported conducting 'experiments' at home.

6. Children needed adequate time initially to explore phenomena and events included in the study.

The importance of allowing children sufficient time initially to explore informally materials or other phenomena involved in a study became evident, especially during Trials 3 and 4. Early in each trial children were observed to dispense with teacher guide notes and work rapidly and excitedly on floating and sinking activities of their own making. They tested in water any object they could get their hands on, discarded it and immediately tried something else. Only when some unusual event occurred did they repeat a particular activity.

Since such exploration occurred with very well-behaved children, as well as with less well-behaved pupils, it would seem necessary to include it as a component in the interactive model. Indeed it might comprise the whole initial stimulus for some topics. The finding provides further support for Symington's (1980) view that a period of 'free play' with materials has value in primary science education, especially in generating children's questions.

7. More worthwhile questions were asked by children after reflection on introductory experiences.

The Trial 4 teachers found that questions asked by their children at the beginning of the second day of the study, and those which arose from an exploration phase on the second day, were better quality questions than those which emerged from the first lesson. For example, two questions which stemmed from the exploration phase were:

> *Play-dough when it's rolled into a ball goes right to the bottom but when it's a boat shape it stays floating. Why is that?*
>
> *Why do light things like wire gauze sink rather than float?*

In the course of the study, the Trial 3 teacher recorded 28 questions, while the two Trial 4 teachers managed to record on notepaper 46 questions asked by their children. (These questions are contained in Appendix 7.)

8. Recording children's questions publicly stimulated other children to consider alternative aspects of a topic.

During Trial 4 the teachers found that obtaining and recording their children's questions in public provided a stimulus to other children in the class to consider aspects they may not yet have thought of. This supported an earlier finding (reported in Chapter 5).

9. Class discussion at the end of each learning session helped clarify present understandings and future directions for children.

The Trial 3 teacher in particular found that end-of-lesson class discussions were a valuable means of identifying where children were at in their investigations and thinking, and of challenging them to consider alternative possibilities. The key role played by her in this process is exemplified in the following excerpt about floating in the Dead Sea.

Teacher: *But how, why does the salt hold it up? I mean it's not as though the salt's, the salt's dissolved I would have thought. Why do you think it holds people up, Joseph?*

Joseph: *[Inaudible...] jumped into the top [of the Dead Sea] and he tried to go right under but he couldn't.*

Teacher: *Right. Why would that be happening though? You can't actually see the salt, can you? Julian?*

Julian: *Um. The salt may be at the surface. Except if you could push your way under the salt you might sink, still sink.*

Teacher: *Do you think so. So it might be layers do you think. What do you think about that Billy?*

Billy: *Um. There's so much salt in it that's (sic) still* ***can't****, so you can't really go under it.*

Another child: *[interjecting] Like a cushion.*

Teacher: *Like a cushion?*

After one such discussion the teacher commented to the observer, "It's quite amazing how it just sparked off a bit of a discussion, isn't it. I noticed how they're getting a little bit critical of the other kid's thinking."

10. Planning and teacher roles were manageable.

The teachers in Trials 3 and 4 found that planning presented few problems (despite the topic being a relatively difficult one), and that they were able to sustain the roles required of them, including the one that required them to establish a trusting classroom climate.

In terms of preparation, the Trial 3 teacher said she did not consider that using the interactive approach involved more work than a more conventional approach. One reason for this was that she was generally aware of the types of activities the children might be involved in. She commented to the observer, "I'm pretty much aware of the kinds of things they might be doing and the kinds of things I'm going to have to provide." She also had some idea of how she would go about helping the children.

> *When they come back and say, "Well, we're going to investigate it this way, we're going to investigate it that way," I'm going to say to them, "Well, let's think about that. Is that going to be what you do? Is it possible?"*

The second teacher in Trial 4 found that, after he had devised a number of activity cards which helped him clarify in his own mind what is involved in an understanding of floating, he was able to challenge children's ideas and proposals in a constructive way since he could recognise the importance of what they were saying. For example, when a group of children found that the length of a floating material (wax candle) made no difference to its level of flotation, he 'innocently' suggested that if it had a hole through it then it might make a difference. The children accepted this as a real challenge; some thought it would make a difference and some thought it would not. They immediately wanted a hole put through the candle so they could find out. When they had difficulty themselves trying to make a hole with a nail, the teacher helped out. As the hole was finally pierced the children's comments suggested that they knew the moment of truth had arrived,

> *Jeremy:* *It's going to sink.*
> *Melanie:* *Float*
> *Carolyn:* *[As the teacher lowered the pierced candle towards the water] This is it!*

11. Many children changed their views.

Despite the difficulty, mentioned in the preceding section of some children retaining fixed prior ideas, there was evidence of many children changing their views about some aspects. The teachers in Trial 4 in particular considered that they had helped their children move beyond a restricted prior notion that things float because they are 'light' or 'small'. They had also managed to influence the meaning a number of the children gave to 'floating', as revealed by an end-of-study check using the OHP transparencies of instances and non-instances (see Table 19 below).

The children's responses indicated that at the end of the study a greater percentage of children considered objects both on top of the surface and freely suspended within water to be floating.

There was evidence of change in the Trial 3 children's ideas too, as revealed in a post-trial survey designed to probe their views about floating materials (see Table 20 below).

TABLE 19: Comparison of percentage of Newstead S2-4 children who considered three representative items to be floating

CONDITION	OHP TRANSPARENCY ITEM	% OF CHILDREN WHO CONSIDERED IT TO BE FLOATING	
		Prior to study	At end of study
Partly immersed	Apple	92	93
On top of surface	Spider	69	90
Fully immersed, but freely suspended	Submarine	56	68

TABLE 20: Comparison of pre- and post-trial S4 Glenview children's responses on two 'Floating and Sinking' items with which they had had some experience during the study

ITEMS	NO. OF RESPONSES	
	Pre-trial	Post-trial
Q3: When you fill a floating material with water it will:		
Sink	20	1
Float lower	6	12
Float same	0	16
Float higher	1	1
Q4: When floating material has a hole in it, it will:		
Sink	19	4
Float lower	1	11
Float same	4	12
Float higher	3	3

Although there was considerable change, not all children changed their views in the direction intended. Some apparently did not observe the floating level carefully, or relied on hearsay conclusions from other children whose observations were no better, or 'observed' what they expected to see.

12. Booklet 2 provided some useful advice.

During the post-trial interview, the Trial 3 teacher mentioned a number of positive features of Booklet 2 and the teaching approach suggested in it:

(i) the Booklet provided a good summary of the teaching approach;

(ii) she appreciated the scientific view included in it as she considered it necessary for her as a teacher to have access to this;

(iii) the Booklet provided worthwhile practical suggestions.

SUMMARY AND CONCLUSIONS

The four trials reported in this chapter addressed the question of whether primary school teachers could, after reading about it in guide booklets, adopt a science teaching innovation as intended by the developers. The results indicate that faithful adoption depends on the extent to which the teachers' prior views about their work match those of the developers of the innovation. The results also suggest implications for curriculum development in primary science education, for promoting teacher change, and specifically for revision of the guide materials.

Factors relating to adoption of the innovation

The research revealed that the two teachers who undertook Trials 1 and 2 held beliefs about their teaching role, and how children learn - including the place of activities in that learning - that were at variance with those of the booklet writers. Consequently they construed the booklets in their own terms and implemented the interactive teaching approach in ways which differed markedly from those intended by the developers. For example, contrary to the approaches advocated in the booklets, neither teacher challenged the children's ideas, one because she saw herself as the manager of group work and believed that the children were not 'ready' to develop their ideas further, and the other because she thought they should 'discover' ideas for themselves or, failing that, that she should give them the scientific view as she understood it.

In contrast, the teaching beliefs of the teachers involved in Trials 3 and 4 were reasonably compatible with those of the developers of the innovation, and the result was two series of lessons that were consistent with the intent of the booklet authors.

In retrospect, the outcome is perhaps not surprising. There is evidence in the literature that the fate of an innovation is determined by how teachers think about their work (Olson, 1982a, Smith and Sendelbach, 1982). In particular, when teachers who hold a conventional view of teaching (Butler, 1978; Fox, 1983; Larson, 1983) are invited to implement a teaching innovation that emphasises the intellectual development of individual learners and the creation of an environment to support pupil-initiated learning, they can experience considerable difficulty in trying to change their teaching and adopt the new roles required (Brehm, 1975; Bolster, 1983; Butler, 1978; Cain and Evans, 1979; Dooley, 1977). As Bolster wrote,

> *Most importantly, teachers' knowledge of teaching, once achieved, tends to be highly resistant to change. Principles of practice, honed in the demanding arena of the classroom, are not easily discarded or revised.*
> *(Bolster, 1983, 299)*

One of the conventional principles is that of the teacher as presenter of ideas or dispenser of knowledge. In Brehm's view, modification of this toward the principle of 'teacher as guide' is not easy. "It is this role, that of the guide not the teller, that is often the most difficult for some teachers to assume" (Brehm, 1975, 186).

In the present study the Trial 1 and 2 teachers, who held conventional ideas about teaching, were unable to change their teaching approach in response to the written guide materials. If anything, the booklets confused them and made their task more complex than usual (Olson, 1982b).

Their teaching response was remarkably similar to that of a Grade 6 teacher in the United States reported by Smith and Sendelbach (1982), and highlights the need for developers of teacher guide materials to identify the beliefs and assumptions that underpin teachers' classroom practices.

Curriculum innovation requires empirical research

The results of these investigations also clearly support Anderson's (1979) contention that curriculum innovation must be grounded in classroom reality. Innovations can easily be distorted by school and classroom systems of which the developers may be quite unaware.

Further, teacher self-reports can not be relied upon as a source of data since teacher perceptions of their teaching can differ markedly from the systematic observations of a researcher. Beliefs and assumptions, and the manner in which these influence the interpretation of guide materials, can only really be identified by having observers present in classrooms to note what happens when materials are used. It was clear from the actions of the Trial 1 and 2 teachers that they viewed the guide booklets as somewhat similar to the published science resource units with which they were familiar, rather than as guide materials suggesting a dramatic change in teaching style. For instance, the first teacher thought she had followed the suggestions in Booklet 1 fairly closely but the observer in the classroom was able to identify discrepancies between what was taught (e.g. cuing children to shape plasticine and potatoes into hollow-shaped objects) and what the authors of the booklet intended, discrepancies which escaped the notice of the teacher.

Promoting teacher change

The two teachers who undertook Trials 1 and 2, like most New Zealand primary teachers, had no special expertise in science education (Biddulph, 1982a). The first two trials therefore provided a realistic indication of the extent to which the booklets **alone** could influence teacher practice.

The literature suggests that the adoption of a teaching innovation also depends on the degree to which the teachers themselves **desire** to change (Dooley, 1977), the provision of systems of personal **support**, both human and material (Brown and McIntyre, 1982; Dooley, 1977), and the extent to which opportunities are available for them to undertake **retraining** (Cain and Evans, 1979; Harlen, 1984; Harris, 1983), perhaps in collaborative action-research form (Olson, 1982b).

1. System of support

The support system could include textual material in the form of teacher notes or handbooks. In Olson's (1982a) view, such material, if it is to communicate to teachers a different approach, must appear as **guidance** or **advice**. It should also be in language which teachers can understand (Olson, 1982b). The two booklets used by the teachers in the trials described in this chapter were written in language that it was thought would be meaningful to teachers. However, the first two teachers, and to some extent the others as well, clearly needed greater guidance or advice.

2. Inservice education to promote teacher change

The various constraints evident in the issues outlined in this chapter, together with the constraints of time experienced by most primary school teachers (who have to plan for a range of curriculum subjects) led the researcher to doubt that guide materials alone, even if written innovatively in the language of teachers (Olson, 1983), could promote in teachers who did not already hold it a conceptual-change view of teaching, a view necessary to challenge children to develop their ideas. In the light of the experiences gained from these trials, it would seem that written communication needs to be supplemented by interactive communication in the form of special inservice education if the practice of most teachers is to be influenced in the direction intended. For example, effective discussion in which the class is focussed on the problem in hand requires great skill on the part of the teacher, particularly in large classes. Teachers usually need help to develop this skill (Westbury, 1973).

Implications for revising the guide materials

The writers of the booklets did not appreciate the mental structures which guided the teaching actions of the first two teachers (Smith and Sendelbach, 1982). Consequently the guidance offered did not match the teachers' schema or planning frames. Teacher guide materials must take this into account in any revision.

Eight other **principles** for the revision of the guide materials can be identified from the data of the investigation reported in this chapter.

1. A single set of guide materials incorporating the ideas of the two booklets is required.

It was thought that the Trial 2 teacher may have felt reasonably confident using the less structured booklet, but in fact she sought more structure than that provided. Identifying teachers for whom the less-structured version might be suitable would be highly problematical. The alternative is one guide booklet for any specific topic.

2. Advice should be provided at the front of revised materials about the need for a teacher to look carefully through the entire guide booklet on a topic before launching into a study using the teaching approach proposed.

Although considerable thought had been given to the presentation of the ideas in the booklets, including the seeking of advice from some teachers, the teachers who undertook the first two trials nevertheless experienced difficulties with aspects of the presentation. Neither realised, for example, that an entirely different teaching approach was being advocated, and the second teacher did not recognise initially that the appendix to Booklet 2 was an integral component of the guidance being offered.

3. The guide materials should be flexible.

They need to be sufficiently flexible to allow conventional teachers to try parts of them as a transition measure to the alternative being proposed, and they should be written in such a way that teachers can adapt or vary the suggestions to suit the needs of their children. For example, there should be provision to allow teachers to adjust their teaching according to their children's level of self-control and experience in working this way, and according to their own management skills. Initially this may mean that a teacher limits the number of questions selected, the number of investigations carried out, and the number of small groups functioning.

Needs of the classroom, including sustaining children's interest, varying the activities and classroom rhythm, being able to help children when and as they require it, and being able to oversee and co-ordinate groups of children, must all be met, irrespective of the approach suggested by research theorists (Lampert 1984). The importance of these factors in the classroom work of the teachers who undertook the first two trials, and their difficulties in resolving the conflict between what was proposed and their view of what was practical, cannot be under-estimated. Teacher guide materials which do not take these practical issues into account face possible distortion in the classroom. In this regard, the first two trials were a salutary experience for the researcher.

4. The approach suggested in the guide materials should indicate that a teacher needs to clarify with the children at the beginning of a study what the topic is about.

5. Ample time for children to explore materials that are new to them should be built into the approach.

This will probably occur before questions are gathered but may occur at other times as well, for example, prior to the commencement of an investigation.

6. The materials should provide advice about how teachers can actively challenge children in all phases of the study, from redefining their questions, through investigation design, to reflecting on findings.

7. Roles for the teacher appropriate to the alternative teaching approach need to be specified in the guide materials.

8. Suggestions should be included about how children might be expected to record or report findings.

Conclusion

The results of these trials suggest that if the proposed teaching approach is to be managed by primary teachers as intended by the developers,

(i) a set of modified, integrated guide materials to communicate the components and strategies should be written;

(ii) the majority of teachers need to have access to a supportive inservice course that introduces them to critical aspects of the interactive approach.

CHAPTER 8

THE EFFECT ON CHILDREN AND THEIR TEACHERS OF A TEACHING APPROACH USING THE CHILDREN'S OWN QUESTIONS

INTRODUCTION

The guide materials referred to in the previous chapter were rewritten by the researcher to take account of the principles outlined[17] and these were introduced progressively to groups of other teachers through inservice courses. A small-scale investigation was undertaken to identify the experiences and views of a sample of children and teachers who had begun using the interactive teaching approach after the majority of the teachers learned about it at the first such inservice course. The results are reported in this chapter. Research questions which guided the investigation were:

QUESTION 6

What is the effect on children of experiencing a science teaching approach that has their own questions at its centre?

QUESTION 7

What is the effect on teachers of using a science teaching approach that has their children's own questions at its centre?

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17. The integrated guide booklet was eventually published as the monograph "Making Sense of Our World: An Interactive Teaching Approach" (Biddulph and Osborne, 1984). The major components and teaching roles of the Interactive Teaching Approach are shown in Appendix 8.

DATA COLLECTION

Data were collected from a sample of children by means of individual interviews, and from a sample of teachers and science advisers by several means.

Data from the children

Details of the children who were interviewed are summarised in Table 21 below.

TABLE 21: Details of children from whom data about interactive learning[18] were obtained.

AGE	NUMBER	ABILITY	LOCATION OF SCHOOLS
7-8yr	24	Represented a	The children came from
9-10yr	34	range of ability	3 Waikato rural schools, and
11-12yr	3	- as judged by	3 Hamilton city schools
Total	61	their teachers.	- approximately 10 from each school.

The interviews were open-ended but generally sought to probe the children's reactions to learning based on their own questions, compared with the more usual way of learning based on activities or problems generated by their teacher. These interviews were recorded on audiotape, and later transcribed and analysed.

18. The children had experienced at least two series of lessons conducted by their own teachers using the interactive teaching approach. In five of the six classes from which the children were drawn, the two series of lessons conducted along interactive lines represented their class teachers' first attempts to use the children's questions as a basis for their studies in science.

Data from the teachers

Details of data collection from teachers are summarised in Table 22 below.

TABLE 22: Means of data collection from teachers about their experience of interactive teaching.

SOURCE OF DATA	NUMBER	YRS TCHG	LOCATION	MEANS OF COLLECTION
1. Teachers in 11 different schools.	14[a]	Ranged from 1-20yr but majority 5-15years.	Half Waikato rural & half Hamilton city	Individual interview[b]
2. Science Advisers	2[c]	Not known	Hamilton & Rotorua	Individual interview
3. One-day, follow-up inservice course comments	12[d]	1-20yr	Waikato, Rotorua & Hamilton	Recorded on audio-tape & later transcribed
4. Seminars, Univ. of Waikato, Nov. 1984	2[e,f]	Not known	Horowhenua & Auckland	Written reports

NOTES:
a. Four of these teachers, at various times, had worked in close association with the researcher and/or other members of the Learning in Science Project (Primary). The other ten teachers had some months previously each attended a week-long inservice course at which they learned about the interactive teaching approach and other findings of the Learning in Science Project (Primary). A week or so prior to the interview, these 10 teachers had also attended a one-day, follow-up course during which they talked about their experiences in trying to use the interactive teaching approach with various science topics. At the time of interview each of the 14 teachers had used the interactive teaching approach with at least two series of lessons.

b. The interviews with the teachers and advisers were also open-ended but generally sought to probe any value and/or difficulties the teachers experienced in using the interactive teaching approach. They were also recorded on audiotape and later transcribed and analysed.

c. The two science advisers (Mr John Charteris, Hamilton; Mr Brian Gore, Rotorua) had worked closely with the teachers who had attended the inservice course. It was thought that they might provide an independent perspective on the classroom experiences and responses of the teachers.

d. In seven of the 12 cases, the inservice day comments recorded were made by teachers who were later interviewed individually (although at the time of interview the inservice day transcripts were not yet available).

e. Mrs Barbara Matthews, Ohau School, spoke about her experience in using "Children's questions as a basis for learning and teaching in primary science". She kindly made available to the researcher a copy of her seminar notes on the topic.

f. The other data came from a presentation by an Auckland Teachers College science lecturer who had attended a Lopdell Centre course on the Learning in Science Project (Primary) conducted by the researcher and had subsequently taught an advanced studies course on interactive teaching for a diverse group of 29 practising teachers. Her paper, entitled "Interactive teaching can work" (Eggleston, 1984) recorded the reported experiences of the teachers in using the interactive teaching approach with their children for the first time.

In all, the direct comments of 61 children, two science advisers and 20 practising teachers were obtained. As well, the summarised comments of a further 29 practising teacher were available via the paper presented by Mrs Norma Eggleston.

The Inservice Course

Important features of the week-long inservice course are outlined to indicate the nature of the introduction that 15 of the teachers had to interactive teaching. The course was conducted by Dr Roger Osborne, assisted by the researcher, and was held at Hamilton Teachers College. Teachers who attended the course were selected by local science advisers from around the Hamilton Education Board region on the basis of their likely ability to implement the innovative teaching approach and to help colleagues in their respective schools do likewise.

Components of the course included:

(i) a review of the research which led to the development of the interactive teaching approach;

(ii) presentations by local teachers who had already tried the approach (Ms Eleanor Hawe, Mrs Juliet Roger, Mr John Faire and Mr Jim Duncan);

(iii) interviewing children to gain sensitivity to ideas children have about a topic;

(iv) observing the researcher take a demonstration 'lesson' with a class of children at Knighton School, Hamilton, to show what the first components of the teaching approach looked like in practice;

(v) finding out about other Learning in Science Project findings;

(vi) examining guide materials produced by the researcher and other members of the Learning in Science Project team. At this time guide materials were available on the interactive teaching approach itself, and on the topics 'Spiders' and 'Floating and Sinking'. Course members were able to take these materials back to their schools, along with reports on children's ideas about these topics.

The course tutors made a conscious effort to conduct the course itself along interactive lines so that course members could experience for themselves the alternative mode of learning which it was hoped they would implement with their children. To facilitate this development:

(i) a supportive learning climate was built up;

(ii) course members were frequently invited to ask questions which had come to their minds;

(iii) their own views about learning, teaching and science were sought;

(iv) they were challenged to consider alternative ways of thinking about learning, teaching, evaluating and science.

COMMENTS OF THE CHILDREN

The large number of children's comments fell into two main categories, those related to the children's preferred way of learning in science, and those to do with questions asked by their classmates.

The children's preferred way of learning in science[19]

Fifty-five of the 61 children claimed to prefer learning science from their own questions. While this may simply reflect their recent use of the approach, its novelty, or the children's desire to be supportive of their teacher to an outsider, their reasons are nevertheless of interest. Their main reasons were as follows:

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19. Prior to interviewing the children in each school, the researcher obtained from their teachers a list of the science topics taught earlier in the year, together with an indication of which studies had been based on the children's questions. At the beginning of the interview the interviewer recalled with the child the science topics which had been studied during the year, and the fact that particular studies had been based on the teacher advising the children what to do, while other studies were based on the children's own questions. The children were then asked whether they liked doing science best from their own questions, or by following what their teacher had asked them to do.

1. It's fun because you do lots of interesting research.

Fifteen children replied in this vein. A typical response was that of the eight-year-old who commented, "I like doing it that way because when you answer you've got to find out things, and it's quite fun doing experiments."

2. You find out things you want to know about.

The responses of two 10-year-olds summarise the views of the 11 children who gave this as a reason for learning science the interactive way.

> *That way you enjoy it because you get **your** questions; then you've got to find the answers to them. You know what you're looking for.*

> *I like doing it that way because if you did it some other way you might not find out the questions that you want to ask. Like, when **you** ask questions, you find out what you really think you need to know about.*

3. You learn more things.

Eight of the children offered this as a reason. An eight-year-old said,

> *I like doing it that way because it's better. You learn all kinds of things with it 'cause other people have more ideas than you sometimes, and they give you good answers and stuff.*

4. Can't explain it; just like it better that way.

Six children replied along these lines. Another eight-year-old commented, "I like it this way when we ask questions and we find out. [Why is that?] Orh, I just do; I just like it."

5. It's easier, or you learn more easily.

Five children couched their reason in these terms. An example of this type of response, which tended to be given by the younger children, was that of a seven-year-old who said, "It's more easy; it's an easier way. [How do you find it easier?] Um..."

6. A variety of other reasons.

Nine of the children gave other thoughtful responses. For example, a ten-year-old mentioned the appeal of the sharing. "Well, I rather like doing it that way because everybody shares what they've found out."

Of the six children who did not express a definite preference for working from their own questions, three said that they liked working from them **sometimes**, but the other three preferred the teacher to give them specific things to do. Their reasons varied. A ten-year-old gave an organisational-type reason; she didn't like having to work with junior children on questions. An eight-year-old said that he didn't like having to ask things and talk about them, while a seven-year-old commented that he was just 'beginning' science and he liked the teacher to tell him what to do.

The children's comments about questions asked by their classmates[20]

Fifty of the 61 children replied in a positive manner saying that they found some of their classmates' questions good or interesting. Their reasons for saying so fell into three main categories.

1. They were questions that make you think, help you learn things, or ones you would like to know the answers to yourself.

Thirty-one of the children gave a reason which came within this category. The comments of a seven-year-old and a ten-year-old respectively illustrate the reasons given. "Some of them [questions] were very interesting because I wanted to find out [the answers to] those questions too." "Most of them [questions] were very good because they were sensible and you didn't really know how it worked out when they said it."

2. The questions were about things you would not think of yourself.

The responses of 10 of the children came within this group. For instance, an eight-year-old said, "Some of them [questions] are quite interesting. Like some people think of questions that other people can't think of."

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20. As a means of gaining further insight into the children's ideas about the use of their questions in class lessons, the opportunity was taken during the interviews to explore with the children what they thought of the questions asked by other children in the classroom. The children were first invited to reflect on the fact that their peers had raised questions on particular topics, and then each was asked the general question, "What do you think about the questions that the other children asked?"

3. The person asking the question is genuinely interested in it and does not know the answer.

Five children made this unexpected response. They assessed the questions of others in terms of their value to the children asking them. As an eight-year-old and a ten-year-old observed, "It's something that they don't know about, and they really want to find out." "You can tell that they're interested in it. If they just ask it off-hand, you can tell they're not really interested in it, but you can tell if they've really thought about it."

Of the 11 children who were less enthusiastic about their classmates' questions, three said that they found some of the other children's questions interesting and some not, while eight focussed on negative aspects. This latter group of eight children commented that some of the other children's questions were silly, stupid or not interesting because the children asking the questions either knew the answers already or should have. For example, a nine-year-old said, "Like [name of child] asked a question that he already knew the answer to."

The remark of a seven-year-old best summed up from the children's point of view whether a question will provide a worthwhile investigation. "If you just make questions up and you know the answers, it's not worth [investigating] it, but if you don't know the answer, it's worth doing it."

COMMENTS OF THE TEACHERS[21]

The comments of the teachers and advisers fall into three main categories:

(i) the benefits which they considered the approach had for the children taught;

(ii) the benefits they perceived for themselves as teachers;

(iii) the difficulties they encountered in trying to implement the approach.

Perceived benefits for the children[22]

Two main benefits were suggested.

1. The children's interest in science topics was stimulated.

All the teachers mentioned that when the children worked at investigations based on their own questions, their interest in the topic they were studying was stimulated. For example, a S3-4 teacher described the effect it had on a group of slower children in her class.

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21. This section summarises the comments obtained directly from 20 teachers. Reference is also made to the reported comments of the 29 teachers who participated in the advanced studies for teachers course in Auckland (Eggleston, 1984). These teachers had taken just one series of lessons using the interactive teaching approach. Since the frequency of remarks made by these teachers was not reported, their comments will be treated as that of just one teacher for the purpose of recording the prevalence of particular views held by those who use interactive teaching. Thus the total number of 'teachers' referred to in this section is 21. Finally, observations made by the two science advisers are used to amplify and illustrate some of the comments made by the teachers.

22. In the course of the interviews the teachers were asked whether they felt that the use of the interactive approach had benefited their children The teachers suggested several ways in which they thought their children had benefited. They also offered a number of observations and reasons to support their perceptions. Teachers on the inservice course made a number of similar suggestions about benefits for their children.

> *This big group of slow people who don't do much and who aren't particularly interesed in anything,* ***they've really got going****. They have come in and told me things before school, and asked me questions on things they have been doing.*

Three factors appeared to stimulate the children's interest.

(a) The children were able to find out what they wanted to know.
This factor was mentioned by 14 of the teachers. It was clearly expressed by a S2-F2 teacher who said, "The kids were particularly keen on working this way because they were looking at questions that they were wanting to find out [about]."

(b) The children felt their contributions were accepted.
Six teachers considered interest was stimulated because the children believed their contributions and suggestions were being accepted by their teachers and peers as worthwhile. This view was illustrated by the teachers on the advanced studies course whose remarks were summarised by Eggleston (1984). "The children felt very involved and were really delighted to have their questions recorded and accepted as worthwhile."

(c) The children were stimulated by the questions of other children.
Three teachers considered this to be an important factor. It is exemplified by the comment of a S3-4 teacher who said,

> *Children that hadn't thought up something, someone else's question then set them going on a question of their own, particularly children who normally never ask anything.*

The children's interest in the topics was **exhibited** in a range of ways. The degree of interest displayed by a number of the children had clearly impressed their teachers since a variety of illustrative episodes sprang easily to the teachers' minds. At least four categories were mentioned.

(a) The children studied beyond the allocated time and place.

Nine teachers mentioned that the children sustained interest in the topics beyond the unit of work and beyond school. For example, a J2-3 teacher and a S2-F2 teacher commented respectively,

> *Something will happen during the day and it'll trigger something else off, and they'll ask other sorts of questions, even though it's not science time.*
>
> *The reaction from parents has been that their kids are **still** interested in spiders. Even till now [four months beyond the study] they're still talking about spiders at home. It's probably been the most successful unit that the school's ever done.*

(b) The children were involved in their work.

Five teachers mentioned that in their opinion the children went about their work seriously, constructively and happily. A science adviser also noted this behaviour.

> *[The children] They're happy. They busy themselves with their own little investigation. They appear to me to feel more worthwhile in themselves; they're important. They're doing something which they see as constructive and they see that their teacher thinks it is constructive. Their ideas are accepted and they are not fearful of anything. They're happy, constructive, seriously busy.*

(c) The children really listened to visitors.

Four teachers remarked on the attention children gave visiting 'experts'. Most teachers are apprehensive about inviting members of the community to speak to their children; visitors sometimes speak 'over the heads' of the children who become restless and irritable. However, these four teachers reported that their children were totally absorbed in listening to the 'experts' answer **the children's own** questions. A S3 teacher's comment was typical.

> *This idea of getting the expert in was really exciting. We had a man whose whole hobby in life is trees, and he came in and spoke to them [the children] and I have never seen my children so absolutely engrossed. They were like blotting paper.*

(d) The children exhibited a range of worthwhile attitudes. Three teachers commented particularly on how their children showed curiosity, willingness to communicate their ideas, and open-mindedness. A S4 teacher, for example, remarked, "I think the kids are far more curious, far more open, far more willing to be wrong, willing to speak up and put forward a view."

Another S4 teacher expanded on the open-mindedness aspect.

> *I think it's teaching them open-mindedness in a fairly informal way. And I think they're more confident, yes more confident in questioning adults - at least that's the way I've found them. They don't necessarily accept the adult's view as being the one they've got to accept, and I think that's really marvellous.*

The third teacher, also with a S4 class, considered that the teacher probably provided an important model to the children in developing their open-mindedness. Remarking on the idea of considering the viewpoint of others she said,

> *I think they [children] probably model that on the teacher's attitude as well - if the teacher is willing to listen to the children's points of view, rather than just asking the questions she knows the answers to.*

2. The children's intellectual and investigatory skills showed considerable improvement.

Seven teachers commented on the marked improvement in their children's intellectual and investigatory skills in the course of studying topics using the interactive teaching approach. A S3-4 teacher and a S2-4 teacher remarked, "Investigatory skills, we found, after four units had improved markedly." "I really feel they're [the children] getting as much [skill development], if not more, this way."

A teacher with a S1-4 class was more specific. He commented on his children's improvement in observation. The class was studying 'spiders' and one morning the teacher threw a fly into the spider's web. The teacher described the children's response,

> *They didn't see the spider come out and grab the fly - it happened so quickly! It took them two or three turns before they started to observe what the spider was up to [but] once they started to observe, their observation techniques improved markedly.*

Some of the teachers recognised that skill development includes helping children to identify which questions are investigable. One S2 teacher was delighted with her children's development in this respect.

> *[The children] They realised themselves, once they saw them [their questions] come up, that some questions just can't be answered. I didn't have to tell them that.*

Perceived benefits for the teacher[23]

The perceived benefits fell into seven main categories.

1. The teachers began to feel more confident about teaching science.

All the teachers remarked that using the interactive teaching approach had made them feel more confident about teaching

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23. During the interviews the teachers were asked if they felt that they as teachers benefited in any way from using the interactive teaching approach. Again, those interviewed had little hesitation in mentioning a number of benefits. Teachers on the one-day inservice course commented along similar lines.

science. Two of them added that they had had to make a considerable change in their own teaching to accommodate children's questions. One, a S2-F2 teacher, said,

> *I've always been one to shy off science a little bit and when I did take it I was fairly structured. I remember taking F1 and 2 science from those green books, and I would follow lesson by lesson through those green books. So doing it this way is radically different for me, and yet I'm having no problems with it, following the kids' interests.*

The other, a S2 teacher with about 20 years teaching experience, commented,

> *I'm still learning to be more child-centred in my teaching. I've been fairly teacher-directed right through and I've tried other ways and haven't always been happy with it, and I've gone back to being teacher-directed because I've kind of always felt in my mind the kids are wasting time. So at last I've got something [a teaching approach] I can grab hold of that is more child-centred. I know where I'm heading and I can see worthwhile learning coming out.*

The teachers attributed their greater feeling of confidence in teaching to four factors associated with using the interactive teaching approach.

(a) A different view of science education

Six teachers specifically referred to their changed view of science education. The teachers expressed relief at not having to ensure that their primary school level children had acquired full scientific understanding of a topic by the end of a series of lessons. Two examples show how teachers felt about this. A S2 teacher admitted,

> *I certainly feel a lot more confident about taking science with the children because I know that I'm not expected to make them understand things that they're not ready to cope with. And I just feel so much more relaxed about that part of it.*

A S4 teacher put it this way,

> *Another thing I like about the approach is that you're* ***not*** *setting out to achieve some specific objectives such as, 'Today we're going to learn that sound travels in all directions' and then think at the end, 'Gosh, half these kids haven't got this'. No, with this approach I say to them, 'What have you learnt today?' and hands will shoot up everywhere and I will probably find that the children have each learned something different, but they* ***have*** *learned something, and have certainly been interested in the topic.*

(b) There was a growing feeling of succeeding in science teaching.

Three teachers referred to a feeling that they were no longer failing in their science teaching. These teachers considered that the different set of evaluative criteria they were now using meant that they were oriented toward success rather than failure. One S4 teacher, for example, commented,

> *Your evaluation isn't as confined and your feeling of failure at the end isn't as drastic. And if the children are still curious and asking questions, you feel you've achieved something, so I think perhaps our self-esteem isn't so deflated.*

Six teachers said that when they saw how keen their children were during investigations of their own questions, it gave them confidence that they were indeed able to teach science in a way which was meaningful to the children. One S2 teacher confided,

> *I've found that I'm more interested in the study myself because I'm more in key with what the children are thinking and what they're interested in. And I love seeing them at work investigating, observing, and it's really good to see the [keen] attitude coming through.*

A science adviser noted a similar response among teachers with whom he had worked. He reported,

> *They say things like, "For the first time that child, or that child, or that child" - and they'll point to four of five children - "have really got something out of doing science. They've enjoyed it and you can see they've*

> *really got something out of it." I think teachers really get a great kick out of seeing children responding like this, especially kids that they've seen have been in difficulty.*

(c) There was recognition that the teachers did not have to be science 'experts'.

Eight of the teachers commented with considerable relief that in using the interactive teaching approach they no longer felt that they had to know all the answers. A J2-3 teacher said,

> *That's what I like about this, that you yourself don't have to be an expert. I've got support and I can go to people for help. It makes me more relaxed in taking science because I know I don't have to have all the answers - and that's the beauty of it.*

Eggleston (1984) found similar reactions among the teachers on the advanced studies course in Auckland. They reported, "This approach takes the pressure off the teacher for being an authority with all the answers."

(d) The role of co-investigator began to appeal.

The relief that teachers felt at not having to know all the answers enabled some of them to enjoy a new sense of being able to investigate questions along with the children. This is illustrated by this comment by a S1-2 teacher. "I like doing all these things, you know, finding out with the kids. In fact I get quite engrossed sometimes."

2. The teachers can more readily perceive what the children understand, what skills they have, and what they consider important.

Eleven teachers believed the interactive teaching approach provided them with strategies to listen to, and work closely with their children so that they became far more aware of what it was the children were bringing to, and gaining from, a particular science study. This advantage is illustrated by the S2 teacher cited previously who said that she was 'more in key' with what her children were thinking and what they were interested in. A remark of one of the science advisers who observed teachers interacting closely with their children endorses the view.

> *I've seen a lot of people [teachers] getting right down beside the kids, going from child to child and group to group, sitting with them, talking up close and that means questioning up close, listening and maybe even planning out, jotting out things on paper for a small group, looking at their work; whereas before it was the teacher up the front.*

The responses of several other teachers further illustrate this perceived benefit to teachers. A S3-4 teacher remarked,

> *This business of thinking children know things that they don't know - that stands out a mile. We assume they know things, and suddenly from their questions you straight away realise that they don't.*

A S2 teacher noted,

> *Even though you're busy the whole time I've got a much better idea of how my children think in science, and their concepts about science, now than I used to have.*

3. The children's real abilities become evident.

Seven teachers mentioned how, in the course of working closely with their children, they realised that some of their children knew more, or had more ability, than the teachers had previously suspected. A S4 teacher said,

> *It was very rewarding to find that a number of children who I didn't expect much of, came up with some great ideas which they had thought up entirely by themselves.*

A S2-4 teacher added,

> *There are definitely some children who show up, either because of the maturity of their questions, or because they find interesting ways of finding answers, or they know things you didn't suspect they knew.*

4. The approach helps to develop a sense of 'community' in the classroom.

Only three teachers spontaneously mentioned the benefit of the interactive teaching approach in bringing members of the classroom together as a close, harmonious community, but they were quite emphatic about it. One S4 teacher had recently transferred to another school and had taken over a class which had had three relieving teachers in the previous two terms. She stated,

> *It saved my relationship with the second group of children, it really did! It just got us going together as a community and they sort of found out that doing things together really could be quite fun.*

5. The approach caters for children of varying abilities.

Four teachers specifically mentioned the versatility of the approach in that it accommodates children of different ability within one class. A S4 teacher said, "The variety of questions that were investigated meant that even the slower children found something worthwhile to investigate and get an answer to." A S3 teacher had the same view. "I found the bright children extended themselves almost limitlessly."

6. The teachers experienced positive feelings when they saw their children working enthusiastically with their own ideas.

This benefit was referred to by seven teachers and is illustrated by the comments of a S2-4 teacher and a S2 teacher respectively.

> *Intrinsically there is some sort of fascination with finding out kids' ideas. That's the first thing I think that really fires you, gets you going.*

I like to listen to them [children] talking. You get some good conversations and it's good just to tune in and listen. And when you hear several good conversations going on, the kids are really involved. That's the joy of teaching.

7. The approach can be used in other subject areas.

Eleven teachers commented on how they were now beginning to use elements of the interactive teaching approach in other subject areas. A S3-4 teacher said,

Really you can take it into every subject, even things like spelling and handwriting. You assume the children know this and that; then if you stop and have question sessions, it's incredible what comes back out of them.

A S2 teacher remarked on the benefit this way, "I'm incorporating this kind of approach wherever I can into other subjects. I don't know why we haven't been doing it years ago really."

Difficulties Encountered by the Teachers[24]

Twelve main difficulties were reported.

1. Some of the children's initial questions were superficial.

Eight teachers remarked that when they used the interactive teaching approach for the first time, a number of the questions asked by their children were ones that had been given little

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24. The teachers who were interviewed were also asked if they had experienced any difficulties in using the interactive teaching approach. Most recounted a number of difficulties which they had encountered and some mentioned ways in which they had tried to deal with them. The teachers on the one-day inservice course also related a number of difficulties they had experienced. There was a considerable variation in difficulties mentioned but perhaps this is not surprising given the diverse group of teachers who used the approach.

thought and/or did not lend themselves to realistic investigations. One of the science advisers, for example, had noted that with respect to children asking questions,

> *The more valuable questions often will be the ones which they crystallize out of the first set of questions, or things arising from what the first set of questions open up.*

Not infrequently, children's questions contain assumptions. These may be invalid and indicate that the children should be considering an as-yet unstated prior question before investigating the one asked. This was clearly recognised by a S2-4 teacher who said,

> *One of the things that has come out loud and clear is that kids ask questions for which there are three or four questions which should precede it, and I think you've got to go through that process with them of getting it back to the one that would be a good investigatory starting point.*

With a little experience the teachers began to realise how they might help their children do this. A S1 teacher, for example, began to **challenge the assumptions** that her children made.

> *The second time [topic] I did ask them what they meant by their question, and would say it back to them in a different way, and say, 'Did you mean...?' so that they would have to clarify what they were asking. And that made them think a little more.*

Another S1 teacher **modelled** questions for her children. She explained,

> *Every so often I'd say, 'Well, can I ask a question too?' and I would put a question on the list. Perhaps it was something I thought of could be worth investigating, or it was another way of introducing a different type of question.*

2. Thinking up investigations for some questions was not easy.

Four teachers reported having difficulty trying to help their children think up suitable investigations for some questions. A S3-4 teacher reflected, "For myself [a difficulty was] working out a research activity to suggest to them."

3. The diversity of questions being investigated by the children could cause teacher anxiety about control.

Three teachers remarked on the difficulty of 'keeping track' of what was happening in the classroom when different groups of children were engaged in a variety of investigations. The difficulty was also noted by one of the science advisers. In describing it he mentioned one of the measures that some teachers took to cope with it,

> *Getting the kids to plan out their work programme based on their questions has caused some of them [teachers] quite a few problems. It gets a bit out of control, or they feel it's going to. They've broken away from it at that stage and perhaps selected questions which provide activities which they can all do as a class.*

4. The reversal of teaching role that the approach requires of many teachers can be disconcerting at first.

Whereas primary school teachers in New Zealand are familiar with a teaching role in which **they** question children to lead them to the 'right answers', or alternatively they provide children with the answers, the teaching role embedded in the interactive teaching approach is one that requires teachers to receive and record their children's questions. Four teachers reported that they found this change of role very strange at first. They had to use considerable self-discipline to resist telling their children the answers to their questions. One J2-3 teacher summed up the difficulty for her this way, "With this approach you've got to be a good questioner, not an expert giver of information - and you've got to reverse your thinking!"

A number of teachers on the advanced studies course reported a similar experience which Eggleston (1984) summarised, "When trying this approach for the first time, some teachers find the reversal of roles rather disconcerting, that is, listening to the children's questions."

5. It is difficult to anticipate or get sufficient relevant resources for some topics.

In the experience of at least four teachers there is a problem with some topics of knowing in advance what resources are likely to be needed, or being able to get them if they can be anticipated. A S2-F2 teacher admitted,

> *I thought I was prepared and I thought I could do all these sorts of things [provide children with sufficient resources] but when it came to the crunch I could do it half the time, but not in the other half.*

6. It is intensive teaching and makes heavy demands.

The three teachers who reported this as a difficulty had obviously given it some thought. A J2-3 teacher said, "It's fascinating but it's very intense because the children are so fired and they're fascinated and they're wanting to ask and contribute and do things."

One S2-4 teacher explained the difficulty in more detail.

> *It puts a premium on classroom organisation which you have to do, not necessarily have to have thought out beforehand, but you've got to be prepared to do that on the spot at the time to suit the sorts of things that are*

> *cropping up with the kids' questions. You are likely to have a lot of children wanting to interact with you at the same time. If you have a number of things going that don't need you right at the moment and a group you can work with intensively it helps a lot, but it doesn't often work out that way.*

On the other hand, two teachers who had heard colleagues mention this difficulty of using the interactive approach expressed a contrary view. For example, one S2-4 teacher remarked,

> *I don't really find the pressures - you know, people [teachers] talk about the pressures of doing it [taking lessons] all the same way - I don't really feel that because I enjoy it.*

7. Teachers feel inhibited by external constraints and felt pressures in using the approach.

Six teachers related how they were keen to use the interactive teaching approach but since they felt that perhaps parents, principals or inspectors might not fully agree with what they were doing, they were experiencing some internal conflict. This was illustrated by the following conversation between the researcher and two teachers in Rotorua.

1st Teacher:	*It's still very difficult to get away from a written presentation of some form or other isn't it. I suppose we ourselves get stuck on it.*
2nd Teacher:	*I think it's the pressures of expectations from principals, other teachers, parents, inspectors who want to see what you've been doing.*
Researcher:	*Have you felt these pressures already in taking the topics you have taken?*
2nd Teacher:	*Well, nobody has put pressure on me, but they are still there in the back of my mind. Maybe if I was having an inspection or something I think I'd have to do something to show what I'd done, or if I have a parent-interview coming up. They would want to know what we'd done, and I'd have to have some-*

> *thing to show. I couldn't have a child there and question him to show that his thinking had improved [chuckles].*

One of the science advisers also noted that some teachers felt constrained in using the approach and were not necessarily able to implement it as they wished. Trying to put the difficulty as diplomatically as possible he said,

> *One or two of the younger ones [teachers] I think don't feel as though they are enough in control of their own autonomy; you know, they feel as though they've got a lot of, well I suppose 'help' from senior teachers, and principal and school organisation.*

8. Establishing evaluative criteria is not easy.

Although this point was mentioned by only one teacher, a S2-4 teacher who was also the school principal, it is a difficulty that warrants mentioning as it is related to the perceived constraint difficulty just described. This teacher explained,

> *What one uses, or a school uses, as a set of criteria is very, very difficult to frame. We've had about three different sets that we've tossed around this year. We've got one now that we think we're close to [being satisfied with] but I bet you it differs a lot from what other people might - in fact, even inspectors wanted to know why there weren't content-based tests at the end of each unit! [With this approach] you've got to have a different expectation of what you want in the end.*

9. Some children don't sustain interest in the topic.

The five teachers who mentioned this difficulty were generally those with large classes and it is interesting to note that they each estimated that perhaps one-fifth of their children fell into this category. For example, a S4 teacher said,

> *The lazy ones are keen at the beginning and get their question but they don't see it through, and I find that a bit disappointing. I don't really know how to keep them involved right to the end. And then they're a nuisance; they don't want to finish because they've lost interest, even though it's their own question, their own*

investigation. There would be five, maybe six, in my class that are like that.

In contrast to this teacher, who was at something of a loss to know how to overcome the difficulty, a S3 teacher with 36 children in her class had devised a practical solution. She explained,

I would say probably 80% [of the children] were exceedingly enthusiastic but you did get those ones who were not. And one of the things I had to do was get some worksheets that would direct them in the old-fashioned manner, because they weren't following up their line of investigation, and in no way was I going to let them sit and rest.

10. Many children did not have appropriate investigatory skills and had to be helped to develop these.

Six teachers remarked on how their children lacked various investigatory skills. The teachers did not view it so much as a difficulty as an 'eye-opener' to the low level of skills which the children actually possessed and therefore an indication of help needed. This is indicated by the comments of a S2 teacher and a S4 teacher respectively.

They [the children] had no idea how to go about investigating a question - no one had ever asked them to think for themselves before! And they haven't got a very developed idea of how to conduct a fair test.

The main problem I found was that some children have just got no idea as to what investigation to set up on their question.

11. Some children had difficulty taking responsibility for their own learning.

This is related to the previous difficulty in that a small number of children were observed by at least three teachers to be 'lost' when it came to devising and carrying out their own investigations. In this case, however, the teachers had generally worked out a strategy to overcome the difficulty. A S4 teacher kept some investigatory activities on 'standby'.

> *I think you've got to have a few little ideas tucked away for investigations if you've got some kid who really is stuck. I had activities to throw at the kids if they couldn't think of anything for themselves.*

12. The approach could be viewed in a narrow kind of way.

One teacher expressed concern that inexperienced teachers may see the approach based on children's questions as consisting of a single 'right' way of teaching, rather than consisting of potentially varied ways.

> *I think there is a difficulty for a teacher who has not been involved in it [the approach] thinking that there is* ***a*** *way of doing it. I think there are as many ways of doing it as there are teachers, within the basic framework of getting children's questions and working from them.*

SUMMARY AND CONCLUSION

In terms of the research questions which guided the investigation reported in this chapter (questions about the effect on teachers and children of experiencing a science teaching approach that has children's questions at it centre), the experiences reported by the children, teachers and science advisers showed considerable consistency.

Almost all of the teachers encountered some **difficulties** in using children's questions as a basis for the children's investigations. These included adopting new roles in the classroom, dealing with questions which were difficult to investigate, anticipating and acquiring sufficient relevant resources, knowing what to do with the few children who could not devise, or who did not sustain interest in, their investigations, and resisting pressures to conform to perceived external expectations.

However, the teachers stated that there were definite **benefits for the children** in adopting the approach. It promoted enthusiasm, purposefulness, co-operation and an increasing measure of open-mindedness among most of the children. The children themselves considered that it was a stimulating and meaningful way to learn.

The teachers also reported **benefits for themselves**. They felt greater confidence in teaching science because they recognised that they no longer had to be science 'experts', and did not have to ensure that their primary-age children adopted scientific viewpoints. This benefit accorded with a finding by Dooley (1977) that a group of Australian primary school teachers, who were 'talked into' trying Science - A Process Approach, gained in teaching confidence when they could become co-learners,

> *With the change in teaching strategy, teachers have lost the feeling that they should know all the answers. This gain in confidence is associated with the teachers' acceptance of learning along with the children.*
> *(Dooley, 1977, 31)*

The approach also gave the teachers direct access to their children's understanding, something they considered both fascinating and a necessary element in teaching.

Despite these reported benefits, it is necessary to include several words of **caution**. The teachers mentioned in this chapter reported their experiences to the researcher and other people whom they knew had been 'promoting' the interactive teaching approach and this may have influenced them to report more favourably than would be the case if they had described their experiences to people perceived to be neutral.

It should also be noted that most of the teachers had experienced a relatively lengthy and supportive introduction to interactive teaching. In all but one instance, the teachers had either participated in an inservice course of at least 25 hours duration or had worked in close consultation with members of the Learning in Science Project (Primary) team.

Further, the teachers were a special group who were not necessarily representative of primary teachers of science in New Zealand. Those who participated in the inservice course work had either been nominated to attend on the basis of their perceived ability to benefit from the course, or were sufficiently motivated to enrol in an advanced studies course to further their own professional development in science education.

CHAPTER 9

CONCLUSIONS

This final chapter contains two categories of conclusions:

(i) those which relate specifically to the research questions;

(ii) those which relate to other important issues that were considered or disclosed in the course of the investigations.

Questions which arise from the study that remain to be addressed are also recorded.

Relevant views and studies reported in the literature in the five years since the investigations documented here were completed are included for comparative purposes.

CONCLUSIONS RELATING TO THE RESEARCH QUESTIONS

Since the results of the investigations reported in Chapters 5-8 were considered in some depth at the end of each of those chapters, the conclusions are summarised here and, where applicable, compared with the conclusions of more recent studies.

Conclusions about Research Questions 1-3

These questions were concerned with whether it was possible to elicit questions about natural and technological phenomena from New Zealand primary school children, and if so then what might be the characteristics of such questions and what factors seem to influence the number and type of questions asked.

1. Children's questions could be elicited relatively easily.

On the basis of data obtained from children in 45 primary school classrooms, a major conclusion was that in most cases children's questions could be reasonably readily or very readily elicited, even by a stranger to the children. Despite the fact that the children were asked to adopt a role in school which had previously been almost entirely the preserve of the teacher (i.e. asker-of-questions), up to about half the children responded with questions the first time they were invited to do so.

2. Children's questions had potential value in teaching and learning.

Another important conclusion was the children's questioning suggested that a teaching approach which used their questions could have considerable value. Key features were as follows:

(i) the questions asked by the children provided the teachers with important insights into their children's thinking and intellectual ability;

(ii) a significant proportion of similar questions about a topic were asked by children from different classes;

(iii) a majority of questions were potentially investigable in some manner by the children, provided they had teacher guidance;

(iv) the children had ideas about possible answers to many of their questions;

(v) the children appreciated both the opportunity to ask about aspects that interested them and the challenge inherent in other children's questions.

3. Children's prior experiences and social context influence their question-asking.

A third major conclusion was that the number and type of questions asked by the children were influenced by several factors, the two most significant being the children's prior experiences of a topic, and the social context in which the question-asking occurred. It seemed that the more extensive and meaningful the prior experiences, and the more comfortable the social climate of the classroom, the greater the number of questions asked by the children.

Conclusion about Research Question 4

This question addressed the issue of whether a viable teaching approach could be devised using children's own questions as a central feature. A teaching model incorporating children's own questions was found to be viable, but the need for several modifications was indicated.

After constructing an approach that attempted to do justice to children's questions, the current view of science and constructivist ideas about learning, and after trying it with four classes of children (two by the children's own teachers and two by the author) on a topic which children had expressed little interest in, the conclusion reached was that with certain modifications the alternative teaching approach could be a valuable and flexible teaching model in primary school science. The modifications included greater elaboration of the approach (especially the roles required of the teacher), an example of how it could be used with a specific topic, more background information on the topic for the teacher, and suggestions about relevant support material for children's investigations. An important factor in the viability of the approach seemed to be the development of a non-judgemental, co-operative classroom social context.

The importance of the contribution of an interactive social context to the quality of pupil thinking, learning and questioning is supported by Ballard (1986), Hodson (1986) and White (1985). White, for example, cites a study by Baird of a sample of Australian Grade 9 and 11 students which indicated that the traditional social context of the classroom discouraged question-asking.

The idea of including books and other text material as important resources for the children is supported by Buckmann and Schwille (1984) who contend that book learning, that is, learning from vicarious experience, can help overcome some of the limitations of first-hand experience and 'common sense' by expanding the scope of one's thoughts and allowing one the freedom to dare to question various actions. It is important, however, to distinguish such material from the typical science textbooks mentioned by Elliott and Nagel (1987) which they consider teach pupils to think of science mainly as a collection of conclusions to be memorized.

Others who have recently, and apparently independently, considered pupils' own questions to be important in their learning, and who have devised or proposed similar learning approaches that incorporate the pupils' questions, include Cliatt and Shaw (1985), Fields (1987), Hawkins and Pea (1987), Hynes (1986) and O'Connor (1986). In addition, at least two science centres have recently encouraged children to send in questions that they would like to have answered. These are the Homi Bhabba Centre for Science Education in Bombay, and the Singapore Science Centre.

Conclusion about Research Question 5

Research Question 5 extended the curriculum development process to a consideration of whether teachers who were generally representative of New Zealand primary school teachers could adopt the innovation as intended by the developers.

1. Teachers' ability to read about and then adopt a teaching innovation aimed at facilitating pupil conceptual change depends on whether the teachers' prior ideas about learning, knowledge and teaching are consistent with the perspective advocated.

Study of a small sample of five teachers trying the teaching approach (as described in booklet form), suggested that whether such an innovation is adopted as intended depends on the match between the teachers' perspective on their own role in science education, the nature of science, and how children learn and that of the developers of the innovation. Two teachers whose beliefs about such matters were found to be at variance with those of the developers were unable to adopt the teaching approach, while the other three whose beliefs were compatible with those of the developers implemented the teaching approach consistently with the intent of the innovators.

2. Disseminating a radical teaching innovation through written materials alone is insufficient to guarantee its implementation on a wide scale.

A related conclusion was that a major curriculum innovation cannot be conveyed through written materials alone to teachers whose assumptions about teaching are at variance with the philosophy behind the innovation - despite the attractiveness of the possible cost-effectiveness of such a mode of communication.

Conclusions about Research Questions 6 and 7

These two research questions focussed on the reported effects on children and suitably-prepared teachers of a science teaching approach that had the children's own questions at its centre. Analysis of the responses of a sample of teachers and children resulted in three major conclusions.

1. Almost all the children found it a stimulating and meaningful way to learn.

2. Many of the teachers initially experienced difficulties, particularly in acquiring adequate relevant resources and in adopting the new roles required of them by the interactive teaching approach. Their change of teaching style was not made easier by perceived pressures to conform to external expectations.

3. The teachers found the approach to be a rewarding method of teaching in several respects:
(i) It gave them direct access to the fascinating world of their children's understanding.
(ii) It enabled the children to work with increasing purposefulness, enthusiasm, co-operation and open-mindedness.
(iii) It gave the teachers a greater sense of confidence in their ability to teach children in science. They did not feel the need to be 'experts' in science but rather people who helped their children make better sense of their world.

Initially, conclusions were advanced somewhat tentatively as it was felt that the teachers' responses may have been influenced by their knowledge that the author and others to whom their views were conveyed were promoting the use of the interactive teaching approach. However, there is support for the conclusions in the recent reports of several teachers (e.g. Dalzell, 1986; Harrison and Allport, 1987; Spyrou and Hattam, 1986) who have used the teaching innovation independently of the developers in both New Zealand and Australia. Their reports reflect difficulties and rewards similar to those identified in Chapter 8 of this report. For example,

(i) Dalzell (1986) wrote of the difficulty of adopting the new teaching roles required;

(ii) Dalzell (1986), and Spyrou and Hattam (1986) reported the positive effect on the self-concept of a number of their children, the sense of 'ownership' that their children had for the learning tasks, and the greater sense of confidence they themselves felt about teaching in science;

(iii) The three groups of teachers all commented on the insights it gave them into their children's understanding and learning, on how they had easily integrated other subjects into science using the approach, and on how they were able to use the approach with other subjects.

Spyrou and Hattam (1986) added that the girls were just as successful, inventive and eager to participate as the boys when the interactive teaching approach was adopted.

Each of the three groups of New Zealand and Australian teachers who used the interactive teaching innovation, developed in the course of the studies reported in this document, adapted it to suit their own teaching contexts. This flexibility of the approach would seem to be an important feature, especially in view of the observation of Jackson and Janes (1984) that any packaged programme can become boring for teachers and students if the same routine is followed year after year.

The conclusions of the reports of Cliatt and Shaw (1985), Hynes (1986) and O'Connor (1986), three groups of educators who also developed teaching approaches based on children's questions, indicate teaching and learning benefits similar to those outlined above.

CONCLUSIONS RELATING TO OTHER ISSUES DISCLOSED IN THE INVESTIGATIONS

This section proposes conclusions on three major issues disclosed in the research data collected during the investigations reported in Chapters 5-8. These relate to:

(i) children's learning and the value of children's own questions in that learning;

(ii) the teacher change process;

(iii) the process of curriculum development.

Conclusions Relating to Children's Learning

1. Children frequently constructed their own ideas.

As reported at the end of Chapter 6, observations of the children at work revealed many examples of children constructing their own knowledge from their current understandings, often in quite restricted ways. These support a constructivist or generative view of learning.

This constructivist view of learning has been supported by a number of science education researchers such as Driver (1987), Driver and Bell (1986), Driver and Oldham (1986), Erikson (1986), Hawkins and Pea (1987), Hodson (1986), Osborne and Wittrock (1985) Taylor and Fleming (1987), Watts and Bell (1984), Wittrock (1985). This suggests that the learning strategies of the children observed in the course of the studies reported here did not constitute idiosyncratic learning behaviour. As Osborne and Wittrock (1985) wrote, a constructivist orientation to learning is supported by research in such diverse fields as learning disability, mathematics education and reading, as well as science education.

2. Children's construction of ideas occurred in interactive learning contexts.

The data also revealed that much of the constructing of ideas by the children occurred in interactive learning contexts (Ballard, 1986; Hawkins and Pea, 1987; Simpson and Galbo, 1986) where children were given the responsibility and intellectual freedom (Hynes, 1986; Raywid, 1985; Wasserman, 1984; Wittrock, 1985) to engage in meaningful investigation, discussion and reflection (Hodson, 1986; Kohl, 1985; Watts and Bentley, 1986) of challenging questions or problems (Hawkins and Pea, 1987; Ross, Hills, Baird, Fensham, Gunstone and White, 1988). Such an interactive social context differs considerably from the social context of classrooms in which 'traditional', directed teaching and learning occur.

3. Children demonstrated an ability to co-operate with each other in their learning within an interactive learning context.

Whereas Benton's (1986) review of New Zealand classroom research indicates that co-operative approaches to learning have an ethnic dimension, Maori and Polynesian children having been found to co-operate in group work more easily than non-Polynesian children, the researcher and teachers involved in the studies reported in Chapters 6-8 commented favourably on the extent and effects of co-operation among pupils in their learning. This suggests that the potential of children to co-operate in learning should be investigated in classrooms designed to realise that potential, rather than in conventional classrooms which tend to inhibit the development of co-operation among pupils.

4. Children's ways of generating ideas seem best explained by a 'networking' or 'lattice' model of learning.

In the studies reported in Chapters 6 and 7, the way most children approached learning, together with many of the outcomes of their learning, suggest that a 'lattice' model of learning (Rowland, 1986) is a more accurate and useful metaphor of the learning process than the multiple, linear 'ladder' model with its levels or stages that has been promoted to teachers in New Zealand schools for a number of years (see, for example, Department of Education, 1988).

A lattice model stresses that the learning process is largely one of developing various intellectual strategies to generate links between prior ideas, and between prior ideas and new phenomena. The instances of children using analogy to make sense of the function of a skeleton illustrate this (p.88). The model also indicates the dynamic nature of conceptual development; children's concepts keep on expanding as new links are forged.

5. The teachers were better able to help their children develop appropriate learning strategies.

The data suggest that, within the context of interactive teaching, teachers found themselves much better placed to help their children develop appropriate intellectual strategies.

6. Boredom in learning was overcome.

The data also indicate that when children began to 'own' the learning, through the process of their own question-asking, the boredom associated with learning in science described in Chapter 1 dropped away almost entirely.

7. Question-asking seems to be a valuable intellectual strategy in children's learning in science.

The results of the investigations suggest that children's questioning is an important element in their learning in science. Other recent reports support the view that children's questioning is an extremely important intellectual process in their learning (Barratt, 1984; Donaldson, 1985; Haig, 1987; Harlen, 1985; Hawkins and Pea, 1987; Osborne and Wittrock, 1985; Tizard, 1985; Wasserman, 1984). Haig considers that

> *Posing problems is a crucial part of the inquiry process and it provides learners with highly appropriate opportunities to exercise their creative and critical intelligence.*
>
> *(Haig, 1987, 29)*

Osborne and Wittrock claim that

> *The generative learning model reinforces the view that the development of children's questioning skills should be of prime importance in science education at all levels... Learning science also requires learners to ask critical questions about their own ideas and the ideas of others.*
>
> *(Osborne and Wittrock, 1985, 27)*

Tizard's observation of young children learning also has considerable relevance for primary science education.

> *Simply by being around their parents, talking, arguing, and endlessly asking questions, children have opportunites to learn about a wide range of topics, in contexts of great meaning.*
>
> *(Tizard, 1985, 1)*

8. The meaning of children's questions can be readily clarified within an interactive approach.

If children's questions are accorded importance in their school learning then there is the difficulty, as Arzi and White (1986) noted, that the actual wording of questions may lead teachers to assume that the children mean one thing, whereas they could be asking something different. However, the studies reported here reveal that in supportive classroom contexts children's meanings for their questions can be clarified in a seemingly natural way.

9. The potential difficulty of parents objecting to their children being encouraged to ask questions can be forestalled.

A difficulty mentioned by Harlen (1985), is that some parents may be offended by their children being encouraged to ask questions. Although there was no evidence from the investigations reported here that any parent was offended, the possibility was considered by the developers of the interactive teaching approach who sought to forestall it by including in the monograph (Biddulph and Osborne, 1984) an open letter to parents and friends of the school outlining the reasons for the different approach to learning. This potential difficulty is not therefore insurmountable.

Conclusions Relating to Teacher Change

1. Teachers find it difficult to change their beliefs and practices.

Buchman (1987) contends that the assumptions held by teachers can be highly resistant to change. The data presented in Chapter 7 relating to Trials 1 and 2 supports Buchman's contention, at least when the efforts to effect teacher change are communicated through written materials alone.

2. Teacher actions are best explained by constructivist learning theory.

The data in this report support the view of Gunstone (1987), Gunstone, Baird, Fensham and White (1988), Oberg (1986), and Osborne and Wittrock (1985) that constructivist learning applies to teachers as well as children. The two teachers involved in Trials 1 and 2 (Chapter 7) interpreted the materials in ways which were consistent with their beliefs, rather than with the perspective of the developers.

3. Teachers may need on-going support to effect changes in belief and practice.

The way in which a number of the teachers involved in the development or testing of the interactive approach often sought to clarify aspects with the researcher or other observers suggests that there may be a need for teachers to have on-going support to effect a change in their teaching. This is also the view of APEID (1987), Hargreaves (1988), Harlen (1985), Parker (1985), Rowland (1986) and Wasserman (1984).

After listening to the implementation difficulties reportedly experienced by the teachers who participated in the inservice course mentioned in Chapter 8, the developers of the teaching innovation were convinced that support was needed. The most realistic form would be mutual support where two or more teachers in the same school attempted to implement the approach at the same time. This is akin to the collaborative and collegial problem solving recommended by Tisher (1985) as a means of enabling teachers to grapple with the complex enterprise of teaching, or the 'learning together' approach suggested by Dodd and Rosenbaum (1986).

4. Inservice education that models the teaching process it seeks to develop seems to facilitate teacher change.

Dr Roger Osborne and the author, the developers of the teaching innovation, devised an inservice course that included four special features which it was thought might facilitate teacher change. Other researchers have recently confirmed these as important components in teacher development courses. These were:

(i) Participants were helped to identify their present teaching beliefs (Confrey, 1987; Hewson and Hewson, 1987; White and White, 1985).

(ii) The alternative approach was modelled for the course members (Dodd and Rosenbaum, 1986; Wasserman, 1984).

(iii) Participants were provided with a learning experience that was congruent with the approach (Harlen, 1985).

(iv) Teachers were provided with time and encouragement to reflect on the issues (Erikson, 1986; Harlen, 1985; Oberg, 1986; Taylor and Fleming, 1987; White and White, 1985).

Although the focus of the investigation reported in Chapter 8 was not on teacher change as such, the data suggest that the inservice course was reasonably successful in helping the teachers move from being transmitters of knowledge to being promoters of inquiry.

The outcome also supports the view of Gunstone et al (1988) that a conscious endeavour be made by course designers to develop and conduct teacher education courses using constructivist principles.

5. Much remains to be done in identifying primary school teachers' beliefs about science education.

This study supports Confrey's (1987) view that the work of identifying teacher beliefs is as yet in its infancy, especially in terms of the metaphors and language (Lampert, 1984; Munby, 1986) which carry those beliefs, perhaps in a number of cases at the subconscious level.

6. There are grounds for optimism in using children's questions in primary science education.

On the basis of the data presented in this document, the pessimistic outlook of Dillon (1988) for the future of children's questions and inquiry in their school learning does not seem justified in the New Zealand school context. Dillon's research in the United States indicated that most teachers hold firmly to the belief that **they** should ask the questions to stimulate student thought. So ingrained is the habit in teachers' minds that even when a student does ask a question the typical response of teachers is to counter it with questions of their own. He concluded,

> *As student questioning has been inhibited - in greater part - by these systematic conditions since the onset of observational research around the turn of the century, and as no contempory factors can be perceived that might cause such change, no enhancement of student questioning in our lifetime will be observed. Schooling will be a process of knowledge transmission, and learning will not become a process of knowledge seeking.*
> *(Dillon, 1988, 208)*

The science education goal that teachers pursue, together with their views of how children learn, significantly influence their teaching practice. In New Zealand, despite perceived pressures to conform to alternative views and expectations, a number of teachers have demonstrated that they have the ability to learn to value pupil inquiry in primary science and to change their teaching practices to reflect constructivist principles to enhance such inquiry.

Conclusions Related to Curriculum Development

1. Curriculum should encompass social context as well as content.

The investigations in this report reveal:
(i) the learning environment was changed as teachers adopted alternative roles;
(ii) teachers found that the children's inquiries provided a meaningful guide to learning sessions;
(iii) valuable learning outcomes were identified which were entirely unanticipated.

In contrast to the implicit assumption within official education circles in New Zealand that the school curriculum consists of predetermined goals and content of instruction[25], the data reported here indicate that a prescriptive approach misses much of the reality of curriculum, and that a more realistic view would include the social context in which learning occurs as well as the actual outcomes of learning.

Several other researchers have reached a similar view about the nature of curriculum and the process of curriculum

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25. See, for example, the booklets "The Curriculum Review" (Department of Education, 1986), "Tomorrow's Schools" (Lange, 1988) and the draft "National Curriculum Statement" (Department of Education, 1988). On the other hand, the recent draft "F1-5 Science" (Department of Education, 1989) which draws upon the findings of the Learning in Science Projects avoids this assumption.

development. With respect to the nature of curriculum, Erikson (1986) contends that

> *Two related strands of curriculum are woven together in enactment. These two strands are the structure and content of subject matter and the structure and content of social relations by which the learners and teacher engage in the subject matter.*
>
> *(Erikson, 1986, 141)*

This interactive nature of the philosophical, psychological, epistemological and pedagogical components of curriculum has also been commented upon by Barratt (1984), Driver and Oldham (1986), Simpson and Galbo (1986), and Watts and Bentley (1986). The implication, as Driver and Oldham (1986, 10) pointed out, is the need for a "shift of status of the curriculum from that which is determined prior to teaching... to something with a problematic status."

2. Curriculum development requires disciplined research.

Driver and Oldham (1986) and Osborne and Wittrock (1985) recommend that a constructivist approach to curriculum development (which the data in this document point toward) be adopted. If this advice were followed then rigorous research would need to become an integral part of such development for these reasons:

(i) it would help to establish worthy goals (Tom, 1985) and check their feasibility in the reality of the classroom;

(ii) it would help to ensure that the teaching approach was congruent with the psychological principles of learning on which it was supposedly founded (Watts and Bentley, 1986);

(iii) it would assess the effectiveness of selected learning activities (Driver and Oldham, 1986);

(iv) it would establish what the actual learning outcomes were and under what conditions (Osborne and Wittrock, 1985) -

given that pupil responses are not necessarily predictable (Simpson and Galbo, 1986);

(v) it would identify a language to talk about curricula change that made sense to teachers (Lampert, 1984);

(vi) it could help generate evaluative criteria that are consistent with a constructivist view of learning and teaching. On this last point, Osborne and Wittrock (1985, 27) noted, "The implications of constructivist views for assessment are far reaching and have yet to be squarely faced."

3. A 'seeding' approach to curriculum dissemination may be required.

Communicating an innovative teaching approach to teachers in written form is no guarantee that it will be implemented as intended. This 'blanket' form of dissemination has been a feature of the curriculum change process in New Zealand for many years, but the experience of these investigations suggests that it should probably be replaced by a 'seeding' approach in which 'cells' of teachers who have participated in an inservice course of the kind described can try out the innovation and in turn introduce it to their colleagues, and support them through the required conceptual and teaching changes.

QUESTIONS RAISED BY THE RESULTS

Seven issues that require further research are outlined. In the final part of this section these are summarised as research questions.

Research issues

1. Longer term effects of the innovation need to be investigated.

The data reported in Chapters 5-8 involve children and teachers who have had experiences with children's questions in science at school that cover at most four months. The novelty effect could have biased the data to an unknown degree. Further research needs to address the longer term effects of the approach on children and teachers.

2. Children's foundation of understanding in science.

The data suggest that the interactive teaching approach may achieve a sounder foundation of understanding in science for primary pupils (White 1984) than is the case with traditional teaching. A longitudinal study of children's developing ideas, intellectual skills and enthusiasm for learning in science within the context of this teaching model would be valuable.

Such a study could also investigate the dilemma involved in educating young children raised by Donaldson and Hughes (1984)

> *How do we retain the freshness and ease that characterise the pursuit of a spontaneous 'embedded' purpose, while achieving the restraint and rigour and control that characterise the tackling of a disembedded problem? How do we help young children to accept problems from others, accept constraints, become disciplined thinkers - and yet foster (or at least not kill) the heart's creative urge to bring forth its own thoughts: thoughts that may produce new solutions to the old problems - and in the end propose new problems?*
> (Donaldson and Hughes, 1984, 13)

3. Appropriateness of the interactive teaching approach for children from minority cultures.

There is some suggestion, although not disclosed in the data presented in this report, that the learning of Maori children is enhanced when they have an opportunity to study topics in an interactive learning mode. The effect on children from minority cultures of learning science in an interactive context is worthy of future investigation.

4. Children's attribution of their own learning.

The teachers' reports of their children working enthusiastically, and maintaining open minds suggest that the indoctrination practices (Raywid, 1985) of traditional classroom life had given way to education and that the children, in many instances, may have been replacing personal 'entity' theories of ability and intelligence with 'incremental' theories (Kwen, 1986).

Instead of the children conceiving of ability as something fixed, and consequently orienting themselves toward performance goals, 'looking smart', finding 'right' answers and avoiding risky or difficult tasks, they may have been changing to view ability as something that grows by one's own efforts, and to incline themselves towards genuine learning goals, the inquiry process and accepting uncertainty as a challenge.

The meta-learning perspective that children develop is critical to their future learning. This issue could well be addressed in future investigations.

5. Improving teacher education in primary science

Although the inservice course outlined in Chapter 8 seemed to be reasonably effective in introducing the teachers to the innovation, it must be acknowledged that the course was hurriedly designed and intuitively based. No systematic attempt was made to investigate its impact on course members due to lack of resources. Research is needed into teachers' adoption of an innovation (such as the interactive teaching approach) founded on beliefs which teachers do not currently hold. This research could address both the preservice and inservice dimensions of teacher education.

6. Degree of teacher understanding of science concepts

Although the evidence in Chapter 8 suggests that most teachers gained in confidence in their science teaching as they realised that within interactive teaching they themselves didn't have to be 'experts' in science content, data presented in earlier chapters relating to development and trials of the alternative approach involving the topics 'Metals' and 'Floating and Sinking' indicated that the teachers (including the author) felt somewhat 'lost' in their ability to help their children when they had insufficient understanding of the topic. The question arises, therefore, of how much background information a teacher needs on a topic to feel competent to play the roles suggested in interactive teaching.

7. Role of research in generative learning theory modification

The generative view of learning which is central to the interactive teaching approach puts an entirely different perspective on children's intellectual development from that inherent in traditional classroom teaching. It may therefore be possible for future research to build upon that described here to further theory development itself. As Child (1985, 16) acknowledged, "We have theories for describing intellectual development, but not theories for assisting intellectual development."

Future research questions

(i) Is the interactive teaching approach sufficiently flexible to avoid the boredom mentioned by Jackson and Janes (1984)? What are the longer term effects on children and teachers of using the approach?

(ii) Will children learning within an interactive approach develop a sounder understanding of natural and technological phenomena in their world, and sounder intellectual strategies, compared with those gained under a teacher-directed approach?

(iii) Is the learning of Maori and Polynesian children in primary science significantly enhanced by an interactive approach?

(iv) Are the personal and social benefits for children sustained? This question could be extended to address two problems identified by Alton-Lee (Benton, 1986). Does the interactive approach help children whose attitudes have been found to be highly resistant to change, and does it help primary children who have become debilitated by power exerted over them by some of their peers?

(v) Does the approach influence children to change their conception of their ability and intelligence (Kwen, 1986)?

(vi) What factors in both pre- and inservice teacher education courses, designed on constructivist principles, most influence teachers to change their beliefs and practices? What is the optimum length of such courses to enable an innovation such as the interactive teaching approach to be adopted by teachers in the manner intended by the developers?

(vii) What amount of background knowledge of a topic do teachers require to enable them to work effectively with their children using an interactive teaching approach?

(viii) In what ways might generative learning theory be modified by future research results?

SUMMARY OF CONCLUSIONS

The results of this study indicate clearly that when the children's own questions provide the focus of investigative work, they have considerable value for the children's learning in science. An interactive teaching approach, based on contructivist learning principles and taking into account the reality of primary school classrooms, was devised to promote the use of children's questions in this way. Primary teachers were found to need the guidance and support of both the alternative teaching model and appropriate inservice education to enable them to change their view of science and science education so that they could incorporate children's questions into their programmes. The major effects on teachers of making use of children's questions were a feeling of far greater confidence in teaching children in science, and a greater sense of awareness of the children's developing ideas and intellectual strategies.

The results also suggested that a 'lattice' model of learning is preferable to the traditional linear 'ladder' model in primary science education. Further, they showed that curriculum development, to be effective, requires a sound research base.

The longer term effects of the interactive teaching approach on teachers and children, particularly children from minority cultures, remain to be investigated.

APPENDIX 1

741 QUESTIONS ABOUT SEVEN DIFFERENT TOPICS OBTAINED FROM CHILDREN IN 45 PRIMARY SCHOOL CLASSROOMS

(including the stimuli used to elicit the questions)

(NOTE: The stimuli also involved a measure of non-directed class discussion in each case.)

TOPIC: FLOATING AND SINKING

PUKEHINA SCHOOL S4 (9 children only)

Stimulus: The children collected a number of items they thought would float (e.g. tennis ball, plastic lid, piece of pumice, branch, plastic ice-cream container, tin with lid off) and placed them in the school swimming pool.

Questions

1. How do poeople learn to float?
2. How do things float?
3. What kind of things float?
4. Can things float in water forever?
5. Why do things float?
6. Why do light things float?
7. Do heavy things float?
8. Can things float in the air?
9. What kind of things make you float?

OHAU SCHOOL S3/F1

Stimulus: The teacher read a short book to the class about the topic 'Floating and Sinking'.

Questions

1. When a bottle has got water in it, why does it sink?
2. If space was filled with water, would the world sink?
3. If you put water in a balloon does it sink?
4. Why don't you float in a bath?
5. Why do balloons float?
6. How come you sink when you've got jeans on?
7. Why don't eggs float?
8. Why do ships float?
9. Why does sand sink?
10. How come heavy things sink, but ships stay afloat? How come jeans sink?
11. Why do beer bottle tops sink?
12. How come paper boats don't sink straight away, and how come wood does not sink?
13. How do air balloons float?
14. How do boats float on water, and pegs, and insects?

15. Why do submarines both float and submerge, and how come spiders float?
16. Why do some things float and others sink?
17. Why don't ferries sink, because the cars and trucks are heavy?
18. Why does ice float?
19. How do icebergs float?
20. How do flies stay in the air?
21. Why do ping-pong balls float?
22. If you throw a stone over the river, it sometimes jumps. Why is that?
23. Why does string float?
24. Why do bumblebees float when they're dead?
25. Why do pins and needles float?
26. Why do stones sink?
27. Why is it, if you lie on your back in water, you'll float, but if you **stand** in the water you'll sink?
28. How do fish stay under water?
29. Do all stones sink, even if they're little?
30. Why do paper clips sink, when other heavier things can float?
31. Why do branches and big logs float?
32. Why do leaves float?
33. Why do clouds float?
34. Why do feathers float?
35. How does foam float?
36. Some species of birds store water in their feathers; how come they can still fly?
37. Why do we turn over on our fronts after we've been floating for a while?
38. How come some light things fall to the ground yet other heavier things stay up?
39. Why does a ring and a chain sink?
40. How come if you're in your undies and T-shirt we sink, but we don't if we're in togs?
41. How come if you hit a ball it keeps going and doesn't fall straight away?
42. How come you put a ball in the river or somewhere and you try to sink the ball and it still pops up?
43. How come jandals float and don't sink?

(Note: more questions could have been collected but the teacher decided to stop before the number became too unmanageable.)

TAMAHERE SCHOOL S3

Stimulus: The children saw a demonstration of what happens when a metal paper clip, apple, small piece of chalk, table tennis ball, and golf ball are placed in a container of water, and they were invited to consider the difference between the metal paper clip being placed in the water and big metal ships in the ocean.

Questions

1. Why do big ships float and why do little things like paper clips sink?
2. How do the boats stay up in the water?
3. Why do submarines go under the water and big ships float?
4. Why do people stay up in the water and then they sink sometimes?
5. Why do you sink when you dive in, and why do you kind of float up when you are holding your breath?
6. What makes or why do things float and sink?
7. Why do most plastics float?
8. Why do most metals sink?
9. How do things sink?
10. How do things float?
11. Why do little things sometimes sink and big things sometimes float?

TAMAHERE SCHOOL S4

Stimulus: Same as for Tamahere School S3.

Questions

1. How can a dry-dock float?
2. Why do we float most of the time and we're heavy, but a gold ball sinks?
3. How do ducks float?
4. How come submarines sink but battleships float, and yet they're made of the same material?
5. Is it because there is salt in sea water that ships float?
6. How come ducks don't go under water when they come in to land, but we go under when we jump in the water?

FIFTH AVENUE SCHOOL S2/3

Stimulus: As for Tamahere School S3.

Questions

1. Why does polystyrene float?
2. Why does salt water help you float?
3. Why do bubbles float?
4. How are bubbles formed to float?
5. How come if you blow a bubble through a square hole it comes out round?
6. Why do some people float and some people sink?

FIFTH AVENUE SCHOOL S4
Stimulus: As for Tamahere School S3.

Questions
1. How come dead things usually float?
2. How come when you take a breath and dive you float back up?
3. Why does most wood float because it feels really heavy on land?
4. Why do fish sink when they're dead?
5. Why do some things, when they die in water, float upside down?
6. Why do people float?
7. Why do fish float on their side when they are dead?
8. Why do light things sink and some heavy things float?
9. Why don't the tiny insects sink?
10. Why do some things float and then sink?
11. Why don't ducks sink?
12. Do fish sink when they're dead?

KNIGHTON SCHOOL S3
Stimulus: As for Tamahere School S3.

Questions
1. Why do babies float and big people sink?
2. Why do big ships float and other things sink?
3. When people fall in the water, how come their head is always facing down?
4. When people drown, how come they then float?

HILLCREST SCHOOL S4
Stimulus: As for Tamahere School S3.

Questions
1. When I'm on my back in the pool I'm kind of relaxed and I float but when I twist or turn or lower my legs a bit I go under; why is that?
2. If you're sailing in a big heavy boat and it's floating on the water, how can you tell if the water is heavier?
3. When people drown they usually drown under the water and a few days later they come up again; how come they float?
4. Why does oil float on the top of the surface; it seems like a liquid itself?
5. When you put water in the petrol tank, why does it float?
6. When you put a pin in the water it floats but when you give it a little tap it goes down; why does it do that?

GLENVIEW SCHOOL S4
Stimulus: Same as Tamahere School S3.

Questions
1. How do some things float and some sink?
2. Why do different types of plastic float?
3. What makes polystyrene float?
4. What makes buoys float?
5. Why does pumice float and other stones sink?
6. Why does some plasticine float and some sink?
7. What makes a piece of chalk sink?
8. Why does plasticine sink when you roll it up and still sink when you flatten it?
9. Why does a small piece of wood sink further than a large piece?
10. How come we sometimes float and yet sometimes sink?
11. How do tiny things like earrings sink and ships float?
12. Why do great big tankers float?
13. Why do big candles float?
14. How do galleons lean over and yet not fall over?

TOPIC: PLASTICS

TAMAHERE SCHOOL S3
Stimulus: Children viewed and handled various plastic and plastic-coated objects commonly used in the kitchen and around the home.

Questions
1. What is plastic made of?
2. How do they get the colour into it?
3. How do they get it into the shape?
4. What colour would it be without colouring?
5. Where does it come from?
6. Why does it melt?
7. How heavy is it before it is made into the shape?

EUREKA SCHOOL S2-4
Stimulus: As for Tamahere School S3.

Questions
1. What is plastic made out of?
2. How do they get the different thicknesses of plastic?
3. How do they put the colour into plastic?
4. How do they make plastic into different shapes?
5. How do they make different types of plastic?
6. How do they get plastic around things like wire?
7. How do they make plastic?

8. How do they get the writing onto plastic?
9. How do they make plastic bags?

HILLCREST SCHOOL S3-4
Stimulus: As for Tamahere School S3.

Questions
1. What is plastic made of?
2. How do they make it look like it's wood (like the egg cup)?
3. How do they make it hard or soft?
4. How would they print on the margarine container?
5. How do they shape all the things?
6. How do they make it so it doesn't look as though it has been joined?
7. How do they make the plastic bags so thin?
8. How do they make the bags so flexible?
9. How do they get the coating onto things?
10. How do they keep the plastic together on shoes?
11. Why can't plastic burn?
12. How do they get the colouring into plastic?

GLENVIEW SCHOOL S4
Stimulus: As for Tamahere School S3.

Questions
1. How do they make plastic?
2. What's it made of?
3. Why do we use plastic?
4. Who invented it?
5. What are some of its uses?
6. How do they colour it?
7. How do they make some of it see-through?
8. Why is it dangerous?
9. How is it shaped?
10. How do they make it hard?
11. What chemicals do they use?
12. Why is it flexible; what makes it flexible?
13. Where do they make it?
14. Why does it smoke a lot and smell when you burn it?
15. What makes it melt; why can it melt?
16. Why can't it be recycled?
17. Why is it so light?
18. How do they make it so thin?
19. Why do they use it on calculators and stuff instead of steel?

TOPIC: ROCK

HAUTAPU SCHOOL S3-4
Stimulus: The children handled various pieces of rock.

Questions

1. How come some rocks you can sort of draw with, like pumice?
2. Where did that glass kind of rock come from?
3. What is crystal kind of made of?
4. When you put one of the little grey rocks in the water it looks like a rainbow; why does it do that?
5. Why is the diamond the most valuable rock?
6. What are rocks made of?
7. Where do they come from?
8. Do they help the ground develop, or is there anything special about them?
9. How long does it take a rock to be made?
10. Did all rocks develop from volcanoes?
11. What types of rock are there?
12. Do rocks from other countries sometimes drift over here?
13. What types of shapes are the rocks in?
14. Would coral be the same as rock?
15. Do our rocks differ from other countries' rocks? If they do, is it because of the climate?
16. Would some rocks be used for cutting things?
17. How come some rocks can be made sharp?

WHATAWHATA SCHOOL S2-3
Stimulus: The children handled various pieces of rock.

Questions

1. How many different kinds of rock are there?
2. How many rocks in the world?
3. Where are rocks found?
4. Where did rocks come from in the beginning?
5. Why are rocks different colours?
6. How do rocks get their shape?
7. Can you get a special kind of rock?
8. Why do rocks have holes in them?
9. Can rocks be hollow?
10. Why are some rocks different weights than others?
11. Do they come from different places?
12. What are rocks made of?
13. Is gold a rock?
14. What are rocks used for?
15. Why are rocks sometimes smooth and flat?
16. Is mercury a rock or a metal?
17. Why does pumice float?

18. Do rocks change their shape?

KNIGHTON SCHOOL S3-4
Stimulus: The children handled various pieces of rock.

Questions
1. Where did the black rock come from?
2. If you cracked a rock in half, how come it has different colours in the middle?
3. Where did the clear rock come from?
4. How are rocks made?
5. Where do rocks get their colour?
6. How do they get so smooth?
7. Why are they hard?
8. How do they get their colour?

TITIRANGI SCHOOL S4
Stimulus: The children handled various pieces of rock.

Questions
1. How was the first rock formed?
2. Rock sort of changes into other rock; how does it do that?
3. How long does it take for a tree to go into coal?
4. How long does it take for a tree to turn into petrified wood?
5. Why are diamonds more valuable than most other rocks?
6. How many different types of rock does cooling lava make?
7. Why are diamonds harder than any other type of rock?
8. Why is lead heavier and yet it is so soft?
9. How are diamonds formed?
10. How many different sorts of things (ingredients) does rock take to be formed?
11. How many different types of rock are there?
12. When was the first bit of gold found?
13. Why did gold come so expensive?

ROBERTSON ROAD SCHOOL S4(a)
Stimulus: The children handled various pieces of rock.

Questions
1. How are they made?
2. Why is gold heavy?
3. Why do they have holes?
4. What makes their shapes?
5. How did they get their colour?
6. Why are they heavy?
7. How do you find them?
8. Why are some rusty?
9. How can you use them?
10. How come they break so easily when they are so heavy?

11. What are they made of?
12. Are there many different kinds?
13. How did they get where they are?

ROBERTSON ROAD SCHOOL S4(b)
Stimulus: The children handled various pieces of rock.

Questions
1. What makes them sink?
2. How are rocks made?
3. How do they get their holes?
4. What gives them their colour?
5. How come some are so heavy?
6. How long have they been there?
7. How do they get their different shapes?
8. Why are they so hard?
9 Why do we use rocks for concrete?
10. Are they solid?
11. Can air get into them?
12. Are they alive?

WEYMOUTH SCHOOL S4(a)
Stimulus: The children handled various pieces of rock.

Questions
1. Why do they have different shapes?
2. Why are rocks different (hardness etc.)?
3. What are they made of?
4. Why do some have holes in them?
5. How are they made?
6. Where do they come from?
7. Why are there different coloured rocks?
8. Why do they feel different (smoothness etc)?
9. Why are they different sizes and weights?

WEYMOUTH SCHOOL S4(b)
Stimulus: The children handled various pieces of rock.

Questions
1. Why are some rocks rough and bumpy?
2. Why do some have holes?
3. How do they get colours?
4. Why do they have designs?
5. Do they grow; how?
6. Do they move; how?
7. Why is a gum rock clear?
8. How does a gum rock form?
9. Why are some smooth?
10. How do they make marble?

11. Why are some big and some small?
12. How does a pumice rock form?
13. Why are some shiny?
14. Where do most of the rocks come from?
15. Do rocks have the same inside as the outside?

TOORAK CENTRAL SCHOOL Gd.6
Stimulus: Five minutes unstructured observation of various pieces of rock.

Questions
1. Are all rocks hard?
2. What kind of rock is this?
3. Are all rocks rough?
4. Why are some surfaces rough and some smooth?
5. What are rocks made of?
6. Is chalk made out of rock?
7. Why does this rock look like plastic?
8. What gives rock its colour?
9. Why does this rock look like stale bread?
10. Why do some rocks look like wood?
11. Why do some rocks have holes in them?
12. Are all rocks heavy?
13. Are all rocks the same shape?
14. Has there been any gold found in rocks?
15. Are any of these rocks valuable?
16. Why do rocks sparkle?
17. How long do rocks last?

TOPIC: METAL

TAMAHERE SCHOOL S2
Stimulus: The children observed various common objects made of metal.

Questions
1. What's it (metal) made of?
2. How many sorts of metals can you get?
3. How many things can you make out of metal?
4. How do you make it?
5. What temperature does metal melt at?
6. How does it feel to hold it?
7. Can walls be made out of metal?

TAMAHERE SCHOOL S3
Stimulus: The children observed and discussed instances and non-instances of common metal objects.

Questions

1. How can we tell if they (objects) are really metal?
2. How many different kinds of metal are there?
3. Is spray paint used on metal?
4. What stops stainless steel going rusty?
5. What is metal?
6. Why do we use metal?
7. Is most metal grey?
8. Do we use metal more than steel?
9. How do you make metal?
10. What country is metal made in?
11. How do you colour metal?
12. Do we need metal?
13. How do you get metal into its shape?
14. Is steel a metal?
15. Is steel stronger than metal?
16. How many things are made from metal?
17. Why is aluminium light?
18. Was metal used in the olden days?
19. Are many boats made from metal?
20. What is metal made out of?
21. Who invented metal?
22. Which country was the first country to use metal?
23. In what year did metal come to New Zealand?
24. What is the biggest thing made out of metal?
25. How much metal is scrapped every year?
26. Are different kinds of metal found with the same colour?
27. Where do we get metal from?
28. Is a car engine mainly metal?
29. What machines do they use to make metal with?
30. What was the first thing made out of metal?
31. What's the smallest thing that you can make with metal?

TAMAHERE SCHOOL S4

Stimulus: The children handled various common objects made of metal.

Questions

1. Why do metals always seem to go the same way in patterns?
2. How do you get the different sorts of metals?
3. Why do some metals stick on the magnet and why don't others?
4. Why does lead bend easier than other metals?
5. How are metals formed?
6. Why are they different colours?
7. Why do metals turn into liquid when they are very hot, and why do they go hard when they are cold?
8. How hot does the furnace have to be?

9. Why is it that gold can be found in certain rocks but can't be found in others?
10. Where do most of the New Zealand metals come from?
11. Why are metals different weights?
12. Are some metals easier to turn to liquid than others?
13. What are metals made of?
14. What is New Zealand's main metal that they produce?
15. How does metal oxidize? [To which one child asked: What does 'oxidize' mean?]

MATANGI SCHOOL S3-4
Stimulus: The children handled various common objects made of metal.

Questions
1. What is metal made of?
2. Why do we use metals?
3. What is it mostly used for?
4. How is it made?
5. Where is it made?
6. What sort of machine makes it?
7. Which countries used it?
8. Does New Zealand export it?
9. Does New Zealand import it?
10. When is the time that they use it most?
11. How do they shape the metal?
12. Why does metal rust?

BISHOPDALE SCHOOL S3
Stimulus: The children observed and discussed in a class group various instances and non-instances of metal, as exemplified in common objects.

Questions
1. How do you make metal?
2. Is uranium a metal?
3. Is metal a liquid?
4. Can you get certain rocks that are metal?
5. Could you build a house of metal?
6. Are cars metal?
7. Is rust a metal?
8. Can any metals prevent rust?
9. Are heaters made of metal?
10. Are tiles made of metal?
11. Are electrons metal?
12. Are computers metal?
13. Are hydro-electric dams metal?
14. Are atoms metal?
15. Are chair legs made of metal?

GLENVIEW SCHOOL S4
Stimulus: The children handled various common metal objects.

Questions
1. What's metal made out of?
2. What's the first stage of metal?
3. How come metal can be used many times?
4. How is it reformed over again?
5. How come you can bend it?
6. How many degrees does it have to be before metal will melt?
7. How come when you heat it some metal will bend?
8. Where does metal come from?
9. What types of metal are there?
10. How is metal located?
11. How long has it been used for?
12. Who discovered metal?
13. What kind of metal is used in a magnet?
14. Why is metal used so much?
15. What were the first uses of metal?
16. Why is metal used in some objects and not in others?
17. Would we live without metals?
18. When was metal first used?
19. Why are there different kinds of metals?
20. Why are most metals so hard?

(Note: Blackboard space limitations meant that not all the children's questions were recorded.)

HILLCREST SCHOOL S4
Stimulus: The children observed various common objects made of metal.

Questions
1. What is metal made out of?
2. How is it made?
3. Who discovered metal?
4. What is the bendiest metal?
5. What temperature does it melt at?
6. Why is it that when you get a grinder, sparks fly out?
7. How is it welded?
8. Where do you find it?
9. How many different kinds of metal are there?
10. What is the hardest?
11. What is the lightest?
12. What is the heaviest?
13. What is the softest?
14. How do you shape it?

KNIGHTON SCHOOL S4
Stimulus: The children handled various common objects made of metal.

Questions
1. How do we get all the different kinds of metal?
2. How is metal made?
3. If gold is a metal, how come it can't be picked up by a magnet?
4. What would we do if we didn't have metal; what would we use?
5. Where do we get all the different metals from?
6. How much centigrade does it take for metal to melt?
7. How many different metals are there?
8. Why is metal hard?
9. Why is it that some metals are light and some are heavy?
10. How do they make the shape that they're in?
11. Why do we have metals?
12. Is metal the strongest substance?
13. What different things do we use?
14. Do we really need metal?
15. How does metal get different colours?
16. Are UFO's made of metal?
17. Why is metal made?
18. Is there any heavier metal than lead?
19. When was the first time metal was made?

TOPIC: SPIDERS

MATANGI SCHOOL S2-3
Stimulus: The children looked at pictures of spiders.

Questions
1. How many poisonous ones are there in New Zealand?
2. Where do they get their silk from?
3. Why do some spiders jump sideways?
4. What are the different kinds of spider?
5. Do all spiders have quite a few eyes?
6. Why do some spiders run after their prey instead of building a web?
7. Do all spiders have a kind of sting?
8. Are there any spiders in the world that can fly?
9. Do just about all spiders have poison that they bite their prey?
10. Is there any spider in the world that can kill someone?
11. Why does a spider's web look invisible to a fly?
12. How do spiders look after their babies?
13. What would be the most poisonous spider in the world?

14. Why do most spiders build their webs high inside the house?

WHATAWHATA SCHOOL S4
Stimulus: The children observed some pictures of spiders.

Questions
1. How do they stay on the web and not fall off?
2. How do they make the web stay on the tree?
3. How do they get all the stuff to make the web?
4. How do they get the poison into the insects and kill them and not us?
5. How do they produce poison?
6. How do you know which ones are poisonous to humans or not?
7. Why do they have so many eyes?
8. How do the eggs hatch?
9. Why do all the spiders have eight legs?
10. Why do the females die after they lay the egg sac?
11. How do they stay on the silk when they go down to the ground?
12. Why are some spiders black?
13. What patterns do their legs move when they walk?
14. Why do some spiders live under the ground?
15. Why do the poisonous ones have a red kind of dot on their backs?
16. Why do spiders live under water?
17. When the eggs hatch, why do the babies sort of fly away instead of spreading out from where they are?

HAREWOOD SCHOOL S4
Stimulus: The children observed some pictures of spiders, together with a real spider.

Questions
1. How come they kind of curl their legs up when they're dead?
2. How many venomous ones are there?
3. What do they eat?
4. Is it true if you squash a spider it will rain next day?
5. Why do spiders have so many legs?
6. With so many legs, how come spiders can run so fast?
7. How come spiders are often with a whole lot of others?
8. How do they make their webs?
9. How many different types of spider are there?
10. Why does the trapdoor spider live underground?
11. How do spiders grow new legs?
12. How many baby spiders can a spider have?
13. How do they get their name?

14. Why do the spiders make those big cocoon things in the thistles?
15. Why do some spiders eat their own kind?
16. How do spiders mate?
17. How come the spiders can hang on their webs, because they would be just as heavy as half your finger and your finger couldn't hang on there for a while?
18. How do they carry their babies around?
19. What do they do through their life?
20. Where does all the material for their webs come from?
21. How do spiders sort of hang from nowhere?

ARANUI SCHOOL NEW ENTRANT CHILDREN
Stimulus: The children looked at pictures of spiders, they observed real spiders which they found at home and at school, and they searched for other signs of spiders at school both indoors and out.

Questions
1. How do spiders find silk?
2. Do they live in spider webs?
3. How do they lay their eggs?
4. How do spiders catch things?
5. Where do spiders hide?
6. How do they make their webs?
7. Where do they lay their eggs?
8. How do they eat insects?
9. How do spiders get away?
10. Why do they come inside?
11. Why are some spider webs different to other spider webs?
12. How do they make the sticky part on their web?
13. Why are they all different?

ROYDVALE SCHOOL S1
Stimulus: The children observed pictures of spiders and some live spiders in small plastic containers.

Questions
1. What do spiders taste like?
2. What do spiders eat?
3. Where do red back spiders actually come from?
4. Why don't poisonous spiders make a web?
5. How do they make their web?
6. How come some are big and some are small?
7. Why do spiders make webs?
8. Where do they make them?
9. Do daddy longlegs make webs?
10. Why do they have eight legs?
11. How do they hang from their webs?

12. How come the webs are white?
13. Why do some spiders make nursery webs?
14. How do they make the web go sticky?
15. Why do spiders make webs on trees?
16. How come spiders don't lay eggs?
17. Why are spiders black?
18. How can you tell the difference between the male and the female ones?

FENDALTON SCHOOL S4

Stimulus: The children observed pictures of spiders and real spiders in small clear plastic containers.

Questions

1. How many poisonous kinds of spiders are there in the world?
2. Where do they live?
3. How many known species are there?
4. How big is the biggest one and how small is the smallest?
5. What do the eggs look like?
6. What do they eat?
7. Where does their thread come from; if it is in their bodies, how do they make it?
8. What is the most dangerous species?
9. Why do they have the bright colours?
10. How did they evolve?
11. How many different ways do they have of catching prey?
12. How do they eat their prey?
13. Do they camouflage with where they are living?
14. How do the poisonous ones keep the poison in their bodies without killing theirselves?
15. Why do they eat things that are nearly the same as them, like grasshopers and flies which are close to them?
16. What animals eats them, if there is an animal that does eat them?
17. What makes them not stick to their own web?
18. How do the young ones fly when they are born?
19. Why do they have eight eyes instead of two?
20. Why is it that when a bird eats a poisonous spider it doesn't get poisoned?
21. Do they have different sorts of thread that they use for their webs?
22. What dangers do spiders have?
23. Do any spiders eat other spiders?
24. Who are the spiders dangeroust enemies?
25. What is the biggest prey a spider can eat?

(Note: These children had studied spiders a month or two previously.)

ST ALBANS SCHOOL S4

Stimulus: The children observed pictures of spiders and some live spiders in clear plastic containers.

Questions

1. How does it stay on one place upside down?
2. Why has it got its skeleton on the outside?
3. Why is it that some of them have their legs joined on to their back instead of their front?
4. Why do some of them have poison, and not all of them?
5. Where does it get all its web-making silk from?
6. Why do they have eight eyes?
7. Why are some hairy and some not?
8. Why are some people scared of them?
9. Why do spiders eat their mate?
10. Why do they have eight legs instead of four?
11. How do they react when they have caught their prey?
12. How many eggs does a spider lay?
13. How do they not get caught in their web when other insects do?
14. Why do they lay so many eggs?
15. Why do the young spiders eat their mother?
16. Why do some live in webs and others not?
17. Why does a spider that lays a batch of eggs die?
18. Why do some spiders have different webs?
19. When they lay their eggs, why don't the eggs stay with their mother in a bunch instead of going away and leaving their family?
20. Why are daddy longlegs called daddy longlegs, and why do they have long legs?
21. Why do some spiders don't die in water?
22. What kind of food do they eat?
23. Why do spiders eat different types of food?
24. After the baby ones have been hatched, why don't they stay with their mother?
25. How do they get fed?
26. How can some spiders walk on water and some spiders not?
27. When all the baby eggs are not hatched, why is it called a nursery?
28. How long do they live for?
29. How many different kinds of spiders are there?
30. How come when the wind blows them off, the silk comes out of their tail and it sort of sticks?
31. When some of them are born, why do they make a parachute so they can sail away in the wind?
32. Where do they live?
33. How do the babies pick up how to catch their food like their parents do?
34. How many parts of the body does a spider have?

35. How come their legs are so easy to pull off?
(Note: Some of these children had studied spiders earlier in the year.)

TOPIC: SKELETON

HAREWOOD SCHOOL S3
Stimulus: The children observed pictures and a plastic model (about 60cm high) of a human skeleton.

Questions
1. How long would it take for all the flesh to mould away?
2. Did our skeleton once have a tail, and how would the bone disappear?
3. Why do creatures have skeletons?
4. Why do skeletons decay after they have been buried awhile?
5. How does a skeleton hold together?
6. I wonder if the ribs were at one time not joined?
7. When we die how come there are bigger holes where the eyes have been?
8. What are bones made out of?
9. How does your spine work?
10. Can your hands and legs move when you are a skeleton?
11. How come there are dents in the side of the head?
12. How do the legs bend?
13. Are the teeth part of the skull?
14. How come there are cracks in the skull?
15. Why do the jaws stick out?
16. When we are babies, why isn't the skull joined?
17. How come the legs are so long, because when you are alive it doesn't look so long?
18. How come the jaws don't fall off when you are dead?
19. How can some people tell your age from your skull?

MARSHLAND SCHOOL S3-4
Stimulus: Same as Harewood School S3.

Questions
1. How come there are cracks on the skull?
2. Which animal has the fewest amount of bones in its skeleton?
3. How many bones in a skeleton of a human being?
4. How long does it take the flesh to go off the skeleton?
5. Why doesn't the heel part, which sticks out, show up on your skin?
6. How can you tell if a skeleton is a girl or boy?
7. What happens to the eyes when a person dies?
8. How many bones are there in the spine?

9. How come there is no nose on the skeleton?
10. Which part of the body has the most small bones?
11. What happens to the skin?
12. How many bones are in the whole skeleton?
13. Does everybody have the same amount of bones?
14. Why are the bone bits sticking out on the spine?
15. What is the smallest bone in the body?
16. Do the teeth automatically fall out?
17. What's the biggest bone in the body?
18. Does the jaws still move when the skeleton is left?
19. What happens to all its hair?
20. Why is there such a bad stench when a person dies?
21. How come there's so many bones?
22. Why are there holes at the bottom part of the backbone where it joins on to the legs?
23. What happens to your heart; does it just rot?

FENDALTON SCHOOL S3
Stimulus: The children viewed pictures of skeletons of various animals, including the human skeleton.

Questions
1. How do they stay together when there is no blood and things?
2. How come the bones (of the dinosaur) haven't rotted?
3. Does bone marrow stay in or does it not when you are dead?
4. When they are old bones does the bone marrow go hard?
5. Are there any animals without bones?
6. If you fracture something, why does the bone move?
7. If you crush your leg, how do they get the bone out of the skin?
8. How come some animals, like turtles, have shells on their back and not skeletons inside?
9. Why do dogs like to eat bones?
10. How many bones are there in the human body?
11. How come adults' bones are more brittle than babies'?
12. How do the people know where to place the bones when they're putting them in the museum?
13. How come a cat has nine lives and we only have one?
14. How come birds' bones are hollow so they can fly?
15. Are there any bones in a cat's tail or a dog's tail?
16. How do bones grow?
17. Why is a certain bone in the chicken called a 'wish-bone'?
18. How do bones shape with your nose and things?
19. Are there any bones in snakes?
20. Do people have 'wish-bones' in their body?

(Note: The children had studied skeletons the previous term.)

ST ALBANS SCHOOL S3

Stimulus: The children viewed pictures of skeletons of various animals, including the human skeleton.

Questions

1. How do you tell which sort of skeleton it is?
2. How are the bones in the skeleton formed?
3. How do you know how old the bones are?
4. When did the first skeleton get found?
5. What materials are the bones made of in a skeleton?
6. Where did animals and skeletons come from?
7. Why do we need a skeleton?
8. How can you tell if it's male or female?
9. Scientists say they have found bones of giant people; is it true?
10. How many bones are in a human's body?
11. Why is it that when someone is buried the bones don't rot away with the flesh?
12. Why is it that the bones don't decay?
13. How big would the biggest skeleton in the world be?
14. When a dinosaur skeleton is found, how do they know what type it is?
15. How do you know whose bones are whose if you find a heap of lots of bones?
16. If you find a bone and nobody knows what it comes from, what do you do?
17. Is there anything really moving around in a bone while it is in a human's body?
18. Why do bones have to be white?
19. How do bones grow when we grow?

BISHDALE SCHOOL S3-4

Stimulus: The children viewed pictures of various skeletons and also a plastic model (about 60cm high) of a human skeleton.

Questions

1. How many bones has a person got?
2. What mammals have back-bones?
3. What actually joins the bones together?
4. Are teeth bones?
5. Do bones live?
6. What is the strongest bone in your body?
7. What makes all your bones move?
8. How long is it until you are a skeleton when you are dead?
9. What is your brain made out of?
10. How does your brain work?
11. How long is it until your bones are fully developed?
12. What makes your bones grow?
13. What are bones made of?

14. How long does it take till your bones rot?
15. When you've got a broken leg, does your bone actually break and if it does, what makes it heal?
16. Why do we have bones?
17. How much teeth have you got?
18. What is the longest bone in your body?
19. What makes your mouth move?
20. What makes your hair grow?
21. What's the smallest bone?
22. How do you get them spots, chicken-pox?
23. How come babies when they're born, some have hair and some don't?
24. How come babies bones are soft when they've just been born?
25. How do you get warts?
26. How come when babies are born, if you drop them sometimes they'll get, their brain goes all funny when they grow up?
27. How come when you're a baby your head isn't divided into four quarters and it grows into it?
28. How do you get pins and needles?

TOPIC: Flowers and Seeds

TAUPIRI SCHOOL S3-4
Stimulus: The children viewed various instances and non-instances of fruit (e.g. banana, tomato, potato, pumpkin), instances of seeds, and instances of flowers. They were also invited to suggest to the researcher the order in which he should place three cards bearing the labels 'fruit', 'seed' and 'flower' - depending on whether they saw any links between these.

Questions
1. Can the seeds in each thing grow into the plant?
2. How do seeds grow?
3. How do the pips get in the fruit?
4. How do the seeds get into the plants?
5. Is there any seed inside the pip of a peach?
6. Do peas have seeds?
7. Does a radish have seeds?
8. Do bananas have seeds?
9. Where do we get seeds for food from?
10. Who created seeds, or where did they come from in the first place?
11. Why do plants have flowers?
12. Why do tomatoes have flowers on it?
13. How does a flower change into a pumpkin?

14. How does a flower turn into an apple?
15. Do blossoms have pips?
16. Does a pear tree grow flowers?
17. Do orange trees grow flowers?
18. Does a peach [tree] grow flowers?
19. Why do fruit have seeds?
20. How does an apple grow?
21. How do tomatoes grow?
22. How do peaches grow on the tree?
23. Is potato a fruit?
24. Is a strawberry a fruit?
25. Is rhubarb a fruit?

PAPANUI SCHOOL S2-3
Stimulus: As for Taupiri School S3-4 above.

Questions
1. Why do scientists call what we call vegetables, fruit?
2. Why is fruit called fruit, and vegetables called vegetables?
3. Why is the pumpkin called a fruit?
4. How come a tree grows roots down in the ground?
5. How do plants grow?
6. What's the texture of those plants and seeds and fruit; what do they feel like?
7. What's the fruit made of?
8. Does the fruit which falls onto the ground sort of become compost and help the seed inside to grow?
9. How come the pumpkin is soft in the middle and hard on the outside?
10. Why are fruit round?
11. How do you get the fruit's shape?
12. How come the fruit needs blossom before it can develop?
13. How does a seed produce a plant?
14. What's seeds made of?
15. How did the seeds get in the fruit?
16. How do little seeds turn into big fruit?
17. Why are there seeds in most fruit or vegetables?
18. How come the seed or flower only grows in dirt?
19. Why does the flower come and then the fruit?
20. Why is the flower from the pumpkin spiky?

GLENVIEW SCHOOL S3
Stimulus: The children examined a variety of seeds and then had an informal class discussion about them with their teacher.

Questions
1. Which came first, the seed or the tree?
2. Why does that one have prickles on it?
3. How are seeds made?

4. Why do little seeds grow into big trees?
5. Why are some seeds slippery?
6. Why are they all in different shapes?
7. Do all plants and trees contain seeds?
8. Where did the first tree or seed come from?
9. Why are seeds hard?
10. Do all seeds grow into vegetables?
11. Why are some seeds poisonous?
12. Why are seeds on trees?
13. Why have pine cones got those flat things sticking out?
14. Is there a popular tree in New Zealand?
15. Will trees and seeds ever run out?
16. What is the biggest tree in the world?
17. How would a tree become extinct?
18. How do seeds travel?
19. Why do seeds grow?
20. When would we ever be able to eat leaves on a tree?
21. What does a seed contain?
22. Will there ever be a money tree?
23. How do seeds die?
24. Where do seeds go when they're dead?
25. Does it help if you talk to your seeds to make them grow?
26. Why do seeds cost money?
27. Why do plants grow with money? - I saw on television if you put money in the ground a plant will grow up.
28. Why do ferns have seeds; where do they keep them?
29. Have seeds ever flown?
30. Where does oxygen come off a tree?
31. Will seeds ever grow on the moon?

APPENDIX 2

113 QUESTIONS OBTAINED FROM CHILDREN IN THREE PRIMARY SCHOOL CLASSES ABOUT THREE ADDITIONAL TOPICS (including the stimuli used to elicit the questions)

(NOTE: Non-directed, whole-class discussions by the children also preceded their questions.)

TOPIC: Slaters

EUREKA SCHOOL S1-2

Stimulus: The children observed live slaters in clear plastic containers.

Questions

1. When one climbs on top of the other, is that when they are mating?
2. How many legs have they got?
3. Why do they live under bark?
4. Why do they carry their babies under their chest?
5. What do they eat?
6. What do they do most of the time?

TOPIC: BIRDS

STOKE SCHOOL S3

Stimulus: The children observed stuffed birds on display, a live bird brought to the classroom by their teacher, and with their teacher looked at books about birds.

Questions

1. How do birds lay eggs?
2. How are eggs formed?
3. How does the chick live inside?
4. Why do different birds have different shapes?
5. How and where do birds go to sleep?
6. Why do birds fly in flocks?
7. Why do different birds have different beaks?
8. How do birds mate?
9. Why do birds migrate?
10. What do birds eat?
11. How long do birds live?
12. Why do birds live in nests?
13. Why do birds need tails?

14. How do birds fly?
15. Do birds have ears; why?
16. Which birds have big or small eggs?
17. What do chicks in the egg eat?
18. How are birds created?
19. Why do different birds have different feet?
20. Why do owls only come out at night?
21. Why do some birds nest on the ground?
22. Where did the first bird come from?
23. Why are eggs different colours?
24. Can birds see colour?
25. How many eggs can a bird lay?
26. How long does the baby bird stay in the nest before it can fly?
27. Why are fantails so small?
28. How long is the chick in the egg?
29. What did the moa eat?
30. Which birds are endangered of becoming extinct throughout the world?
31. How do birds sing?
32. How far can birds fly?
33. How do birds keep warm?
34. How do diving birds hold their breath under water?
35. Do birds enjoy music?
36. Do migrating birds lay their eggs in warm countries?
37. How does the kiwi breathe?
38. How many native birds does New Zealand have?
39. Why are there so many different species of birds?

TOPIC: TIME

OHAU SCHOOL S3-F1

Stimulus: The teacher read to the children a few short extracts from four books about time, seasons, before man, clocks and watches.

Questions

1. How did the dinosaurs actually die out?
2. How did the dinosaurs get on earth in the first place?
3. Which came first, Adam and Eve, or the apes?
4. Who was the first man to discover the year?
5. Would you ever be able to go back in time, or forwards?
6. Were the apes that used to be on earth like humans with regard to walking, fighting and eating?
7. Who invented the 12 month calendar, the one we use today?
8. Who invented maps?
9. Who found out about the seasons?

10. How did all the other animals form after the dinosaurs died out?
11. Who invented watches?
12. How long does it take the world to go round once?
13. What was the first living thing on earth?
14. What's going to be the last thing on earth?
15. In which year were clocks invented?
16. How do we know it's really the right time now?
17. What time will the world blow up?
18. Who knew how to name the seasons?
19. Who invented the clock?
20. Who was the first one to feel an earthquake?
21. How did the Grandfather clock get its name?
22. When will World War III begin?
23. When will the last volcano erupt?
24. Who invented meal times?
25. When will Antarctica melt?
26. Which will be the middle year, in all time?
27. Who was the first man on earth?
28. Who found out that 60 seconds make a minute?
29. If there was an ice age, how long ago do scientists reckon it was?
30. How come, if everyone died in the ice age, life still continued?
31. Who discovered the first dinosaur bone?
32. Who invented digital watches?
33. How did people know there were dinosaurs on land?
34. When did, what time of year did the world develop?
35. If there's another ice age will all the technology be ruined?
36. Is there going to be another ice age?
37. How did all the countries get their names?
38. Who invented the speedo in a car?
39. How long did it take mankind to find light?
40. If the ice age returns, will we be flooded out?
41. How did the seasons get their names?
42. How come the dinosaurs, if the cave men were present, why is it that the dinosaurs died out and we didn't?
43. Which is the middle century?
44. When was the first land farmed?
45. How did people know that there were cave people?
46. How did different races of people emerge when there were only cave men to start off with?
47. When was fire first caught and used by man?
48. Who made the first match?
49. How long ago did people start living in houses?
50. Who found out that the earth was round?
51. Who invented the numerals to go on clocks?
52. When will the world end?
53. When did the first fish appear in water?

54. When was the first dolphin found in the sea?
55. Who invented the alarm clock?
56. Who invented the time bomb?
57. When was the alphabet first used, and words and things?
58. How come the crocodile survived?
59. When was time invented?
60. How long ago was the world made?
61. If the world wasn't created by God and it formed from the big bang, how come there's all animals on it?
62. How come, why was the black hole formed?
63. Why do they say that in time we will be in the black hole without light?
64. How long have we been living in time, we people?
65. How long ago did the King invent rules?
66. When the big bang went off, how come there was **sea** as well as **land**?
67. How long does the average person sleep?
68. When was the first mummy dug up?

APPENDIX 3

RESOURCE BOOKLET ON 'METAL'
(written by the researcher)

METAL

WHAT IS METAL?

Is it iron? Is it hard, silvery stuff? It can be, but it is more than these. So far 82 different things have been found which we call metal. Some of these can be joined together to make new 'metals'. In the diagram you can see the names of some common metals. You can also see how some may be joined together to make new metals or alloys as they are called. (The diagram is on the next page.) You can see from the diagram that steel is made from iron (by adding carbon).

Did you know that the 'lead' in a pencil is not really lead. It is graphite which is a form of carbon, and this is not a metal. (Soot and diamonds are other forms of carbon.)

You may be interested to know that three of the metals are called precious metals. They are gold, silver and platinum.

HOW CAN YOU TELL IF SOMETHING IS MADE OUT OF METAL?

You can not always tell by the colour. Gold and copper are quite different in colour from, say, aluminium and lead. You can not tell by the weight of it because some pieces of metal are quite light, such as the foil that food is sometimes cooked in. You can not tell by whether or not it sticks to a magnet because only iron, or things that have iron in them, will stick to a magnet. You can not tell by whether or not it is hard because some things do not seem to feel hard, such as a Steelo pot cleaner. (If you tried to bite them with your teeth you would find that metals are quite hard though.) The best ways to tell if something is made out of metal are:
(i) if it is not already shiny, then scrape it with a file or sandpaper and see if it shines (it should),
(ii) see if electricity goes through it (it should),
(iii) bang it and see if it gives out a sound (most metals do).

WHERE DOES METAL COME FROM, AND HOW IS IT MADE?

Metals mostly come from different kinds of rock. They are mixed in with the rock. In fact there may be more than one metal in a piece of rock, and the metals themselves are often mixed together as alloys.

Sometimes the rock is on or near the surface (top) of the earth; sometimes it is underground. If it is near the surface then machines are used to scoop up the rock that contains the metal. When it is underground, mines have to be made to get it out.

SOME TYPES OF METALS

PRECIOUS METALS	
	gold
	silver
	platinum

SOME COMMON METALS		SOME ALLOYS
	mercury	
	aluminium	
	lead	solder
	tin	bronze
	copper	brass
	zinc	
	iron	steel
	chromium	stainless steel
	nickel	
	titanium	
	magnesium	
	manganese	
	uranium	

Sometimes the rock has already been broken or crushed up by nature and the metal (for example, iron or gold) is amongst the sand. If people want the metal and it is still in the rock then they have to crush up the rock and use special ways to get the metal out. They use different ways for different metals; sometimes they use chemicals and sometimes they make the mixture very, very hot so that the metal melts and runs out.

You may also be surprised to know that metals are also found at the bottom of the sea, and in the sea water itself, but they are hard to get from these places.

Nobody really invented metals. They are there in nature. Volcanoes seem to have brought them up from inside the earth. People have known about some metals for hundreds and hundreds of years. Long ago there was a Bronze Age and an Iron Age. The Greeks and Romans knew a number of common metals such as lead, tin, mercury, gold, silver, copper and iron.

How people first found out about metals is an interesting question. Perhaps by chance they lit a fire on some rock that had metal in it. If a wind made the fire so hot that the metal melted then the people could have found the shiny metal among the ashes. We can only guess about this because we don't really know.

What people have invented are ways to get the metal out of the rock in which it is found. They have also discovered ways to get it apart from other metal to which it may be stuck.

Metals are found in most countries, but not every country has every type of metal. New Zealand has some iron which comes from the ironsands along the west coast of the North Island. We also have some titanium and there is still a little gold and possibly a little copper left. There are small amounts of some other metals as well. Most of the metals that we use have to come from other countries.

WHAT ARE METALS USED FOR?

Metals are a bit different from each other in a number of ways and so they are used for different things. Some examples of what different metals are used for are shown in the chart.

METAL	USED FOR	REASON
gold	jewellery	a soft metal that is easy to shape
stainless steel	knives, forks, spoons	doesn't rust
aluminium	aeroplanes power lines	a light metal, doesn't rust, conducts electricity well
lead	fishing line sinkers	a heavy metal
copper	bottom of pots electric wires	conducts heat well conducts electricity well
steel	tools e.g. hammer buildings	a hard metal a strong metal
mercury	thermometer	it is a liquid
tin	coating thin steel cans	doesn't rust

APPENDIX 4

BOOKLET 1

FLOATING AND SINKING
Some teaching suggestions

Fred Biddulph
Peter Freyberg
Roger Osborne

Learning in Science Project (Primary)
Working Paper No.117a

PURPOSE OF THIS BOOKLET

This booklet is designed for teachers who may appreciate some extra guidance in <u>helping children develop their ideas</u> about floating and sinking. The booklet contains
(i) information about the ideas that we have found children hold on this topic,
(ii) information about the ideas that scientists hold on the topic,
(iii) suggested procedures to help move children gradually from intuitive explanations <u>towards</u> those which will ultimately be more useful to them.

We wish to stress that the procedures, investigations and projects outlined in the booklet are <u>suggestions</u>, nothing more. Use any that seem manageable. Try them in a different order if it seems more appropriate to do so. They may suggest to you other aspects that you would like to explore with your children. Feel free to do so. Indeed if you feel a little more adventurous then you might like to consider an alternative approach based on children's questions which we have set out in another booklet (Working Paper No.117b).

BASIS OF THE SUGGESTED APPROACH

The approach and teaching suggestions have been developed out of our work with the Learning in Science Project. We were aware of the following things:
(i) Children frequently bring to science lessons ideas which they have already formed from their everyday experiences.

(ii) Some of these ideas may be rather misleading.
(iii) It takes time and a variety of experiences to change children's misleading ideas towards a more scientific viewpoint. In this respect it is important that children's learning experiences be authentic. That is to say, there should be no hidden agenda which could convey the message to the children that they must reach the conclusion required by the teacher, rather than one based on their own observations and thinking. Such a hidden agenda tends to result in children learning (and readily repeating) their teacher's verbal explanation without changing their previous ideas. If they are to make better sense of their world then they must have time to think through their new experiences.
(iv) Scientists' ideas are generally quite abstract, but they are usually built from a number of less complex ideas which primary children can begin to understand.
(v) To help children begin to understand these less complex ideas it is necessary to know what are their existing ideas.
(vi) Children's development of understanding is bound up with their development of intellectual skills and attitudes. It is the making of better sense of the world that gives purpose to the development of intellectual skills. At the primary level we feel that adult common sense is sufficient to guide children in developing their intellectual skills and understandings in the course of investigations.

SCIENTISTS' AND CHILDREN'S VIEWS ABOUT FLOATING

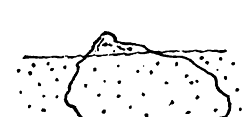
The purpose of this section is to outline
(i) what scientists mean by the term 'floating';
(ii) what children understand by it;
(iii) what ideas children hold about floating and sinking;
(iv) what children want to know about this topic;
(v) the most useful idea that primary children could develop.

Knowing these things may be useful in helping children with the suggested investigations and projects which follow.

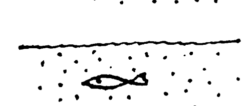
Scientists' meaning for 'floating'

Floating is a complex phenomenon. There are at least three types of floating.

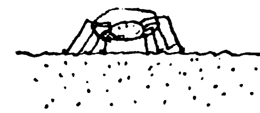
1. Floating on a liquid
   - partly submerged, e.g. iceberg



2. Floating within a liquid
   - wholly submerged, e.g. fish



3. Floating <u>on top of</u> a liquid
   - wholly supported by the surface tension, e.g. water spider



Our focus here will be on floating <u>on</u> a liquid.

Children's understanding of the term 'floating'

We have found that children not infrequently use the term 'floating' in a different way from adults in general and scientists in particular. For instance they may consider that:
(i) an object which is more than half submerged is not really floating (it is sinking, or partly-sinking and partly-floating); or
(ii) only stationary objects are floating (compare with swimming).

It is important for children to realise that the <u>science meaning</u> of floating includes both moving and nearly submerged objects.

What we have found about children's ideas on floating and sinking

Children quite often think that whether an object floats depends on:
1. the material it is made of (e.g. plastic would probably float but metal mostly sinks);
[We would want to explore and enrich this idea.]
2. if it has air in it;
3. its weight (e.g. heavy things float lower in the water or sink);
4. it having holes (e.g. holes may trap air and keep it afloat, or holes may let water in and make it sink);
5. its shape (e.g. if it is hollow or has 'edges' then it will float)
[We would want to qualify or modify these views.]
6. depth of water (e.g. objects will float lower in deeper water);
7. length of object (e.g. a longer object may sink);
8. it having a motor (e.g. that's why big metal ships float);
9. who or what made it (e.g. man-made products can float but most nature-made things sink, apart from wood).
[We would want to challenge these ideas.]

What children want to know about floating and sinking

We have found that children aged 9-12 years most often ask questions about:
1. Materials (e.g. Why do most metals sink?)
2. Objects (e.g. How do boats stay up in the water?)

3. People (e.g. When I'm on my back in the pool I'm kind of relaxed and I float, but when I twist or turn or lower my legs a bit I go under. Why is that?)
4. Other animals (e.g. How come insects float?)
5. Weight or size (e.g. Why do big ships float and why do little things like paper clips sink?)
6. A general rule (e.g. Why do some things float and some things sink?)

The most useful idea for primary children to develop

The most useful concept for children to develop at the primary level is that an object will float if it is <u>light for its size</u>. Certainly depth of water, length of object, having a motor, or who made it are not relevant. Some objects, like a candle, float but do not have air in them. Only if an object is heavy for its size will it sink. Holes do not make a material that floats sink (try putting holes in a candle and see if it sinks).

Special Note:

In the investigations and projects which follow, the scientists' view is given for your benefit only. Words such as 'density' and 'proportionately' are <u>not</u> ones to use with primary children. Let them express their conclusions in their own words.

SUGGESTED INVESTIGATIONS

The investigations proposed in this section are designed to allow children to
(i) test some of their ideas and thereby begin to gain some understanding of floating;
(ii) develop various skills of processing information (e.g. predicting, observing, reasoning;
(iii) acquire some scientific facts (e.g. which materials float and which do not).

Investigation 1: Which materials float?

This is an investigation of the floating of objects which are made entirely of <u>one material</u> without air spaces or without being shaped to float, e.g. a solid block of material.

COMMONLY HELD CHILDREN'S VIEWS

We have found that children can be strongly influenced by:
(a) the <u>size</u> of an object (big things will sink despite the

material);
(b) whether or not it is thought to have air inside it (some children say a candle floats because it has air inside it);
(c) the shape of the block (e.g. if a block is reshaped so it is flat with a large surface then it will float according to some children).

SCIENTISTS' VIEW

An object made of a single material will sink if it is heavier than an equal volume of water. (In children's terms, it will sink if it is heavy for its size.)

INVESTIGATION [Class, mini-group (2-3 children) or individual]

A range of materials can be investigated to find out whether or not they float - (e.g. wood, candle, rubber, polystyrene, aluminium, glass, plastic, pumice, steel clip).

RECORDING

(a) Mini-group or individual

Material	We expect it will (float/sink)	Why we think that	We find it (floats/sinks)

(b) Class (summary)

Materials	Why we think they floated/sank	What most scientists think
A. FLOATED		They are light for their size.*
B. SANK		They are heavy for their size.*

* To be added, possibly at the end of this investigation.

Investigation 2: Do holes in floating materials affect their floating?

COMMONLY-HELD CHILDREN'S VIEWS

Holes will let the water through and the material will sink.

SCIENTISTS' VIEW

If a material floats then holes in it will not cause it to sink.

INVESTIGATION [Class or mini-group]

Float various materials which float (e.g. disc of candle, piece of polystyrene, cork, apple) in water, predict the effect of making holes in them, and then test.

RECORDING [Class, mini-group, or individual]

Material that floats	We expect that with holes in it, it will sink/float.	We find it sinks/floats.

CONCLUSION (in own words)

SPECIAL NOTE:

A scientific idea is one that is capable of being tested. If it can't be refuted or rejected by testing then it will survive - at least until such time as it is refuted or, alternatively, is replaced by an even more useful explanation. This investigation, and the next two, are designed to enable children to challenge and refute ideas which they may hold. We are aware that it is a quite different approach to that normally used in schools (where children usually find out that something is the case, rather than that it is not the case), but are hopeful that you will be able to help the children in the manner suggested.

Investigation 3: Does depth of water affect floating?

COMMONLY-HELD CHILDREN'S VIEWS

The deeper the water, the lower/higher the object will float. In really deep water it may even sink, according to some children (possibly associated with swimming out of one's depth).

SCIENTISTS' VIEW

Depth of water does not affect the level at which an object floats.

OTHER POSSIBLE RESPONSES

Some children may see what they think they are going to see. If they already believe that an object will float lower in deeper water, then they may think they see it lower. Hence the need to mark the floatation level on the object, and to record observations.

INVESTIGATION [class or mini-group]

(a) Have containers with various depths of water. Teacher (or child) floats objects (such as a block of wood, toy boat, partly filled bottle or jar) in one container and then children predict how it will float in the others.

(b) Children mark flotation level on an object floating in shallow water and predict whether or not the level will change when it is put in a greater depth of water.

RECORDING [class, mini-group or individual]

Object	We expected it would float (lower/same/higher)	We find it floated (lower/same/higher)
Woodblock Bottle Boat		

CONCLUSION (in own words)

____

Investigation 4: Does length of an object affect its floating?

COMMONLY-HELD CHILDREN'S VIEWS

A long piece of candle will float lower than a short piece (because it is heavier). A long piece of wood will float lower than a shorter piece of the same kind. If you cut the top (visible) part off an iceberg the rest would sink because the floating part has gone.

SCIENTISTS' VIEW

The proportion of the object below the water's surface depends on the nature of the material, not how much of it there is. A long plank will float at the same level as a short plank of the same wood because the density is the same in both cases.

Different volumes of material will float proportionately as high in the water. (If a small volume floats at half its thickness, a large volume will also float at half its thickness.)

INVESTIGATION [class or minigroup]

Float a series of short objects (e.g. piece of candle, piece of wood, plastic block) on water. Show children longer pieces of the same materials, have them predict and then check these flotation levels.

RECORDING

As for Investigation 3.

CONCLUSION (in own words)

EXTENSION ACTIVITIES

Cut 2 pieces of different area from the same thickness of polystyrene. Children predict and then check the flotation level.

Cut 3 pieces of the same area from the same thickness of polystyrene. Join 2 pieces, one on top of the other, with a small piece of cellotape. Children predict how each piece will sink in the water.

EXPERIMENTAL PROJECTS

The main emphases with the experimental projects are on the children
(i) recognising that ideas in science must be testable;
(ii) having an opportunity to test some of their ideas about how non-floating materials may be made to float;
(iii) acquiring some scientific facts (e.g. which material is the best floater).

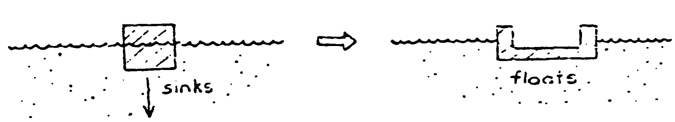
Project 1: How can we make non-floating materials float?

COMMONLY-HELD CHILDREN'S VIEWS

Some children have suggested that a small ball of plasticine may be made to float if it is shaped into a thin, flat sheet, or into a long, thin 'sausage'. We have also found that after children have seen a cube of plasticine sink, most have predicted that a hollowed-out, equivalent sized cube of plasticine would sink too. They have been quite surprised to find that it floated (provided that it was lowered gently into the water).

SCIENTISTS' VIEW

We can make non-floating materials float by increasing their effective size without increasing their weight, or by decreasing their weight without decreasing their effective size (e.g. by hollowing them out).



small effective size — reshaped to have a larger effective size

SOME SIMPLE EXPERIMENTS

Children can experiment with non-floating materials (such as lumps of plasticine, potato, carrot, thin sheet of copper or aluminium) to see if they can get them to float. One form of recording would be a chart showing pictures of the material/object in water before and when floating, accompanied by a short text explaining what was done to make it float. At the conclusion there could be a teacher-guided class discussion focussing on the chart to consider whether or not there was any common means by which the non-floaters were made to float.

EXTENSION ACTIVITY (shaping a non-floater to carry the greatest possible load)

If a number of children are each given an equivalent amount of plasticine they can experiment to see who can construct a floater to carry the greatest load. A fair test might involve the greatest number of marbles the floater could carry without sinking,

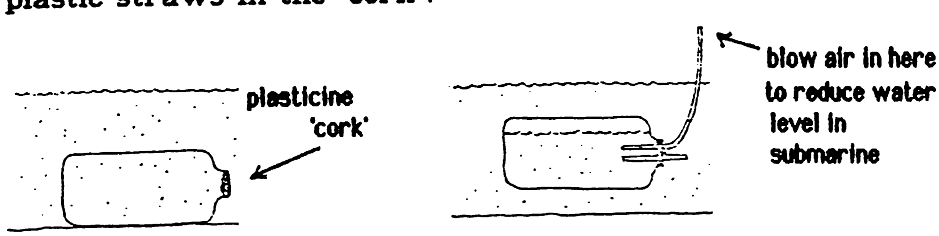
DRAWING CONCLUSIONS

Children should be encouraged to formulate in their own words the idea that for a given weight of material the greater the amount of water it can be made to displace (push aside) the greater will be the floating capacity of the object. Objects that are light for their effective size are the ones that float.

Project 2: How can we raise a sunken object to the surface?

Sometimes people want to raise sunken objects to the surface. Dredges raise materials such as oysters, shingle and gold, but we are concerned here with objects which have inadvertently sunk, such as boats (which once floated) and cars (which never floated).

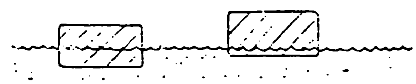
The children may be able to suggest, and experiment with, various means of raising model sunken objects. For example, a bottle filled with water could represent a sunken submarine. This could be raised by inserting two pieces of plastic tubing or plastic straws in the 'cork'.



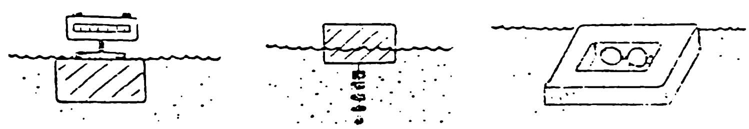
Project 3: Which material is the best floater?

If a boat is swamped then it is likely to sink. Which buoyant material should boat-builders place in the limited spaces on a boat if they wanted to prevent it sinking? Which material (e.g. balsa, willow, plastic, polystyrene) floats best and would give the most support? Children will probably need considerable help if they are to devise a fair test. The first requirement would be blocks of material of equivalent size.

Two possible ways of measuring floatability would be:
(a) the greater the amount of material above the water, the greater the floatability;



(b) the greater the force required to push the material under the water line, the greater the floatability.



kitchen scales upside down hanging weights marbles placed on nylon netting fixed to bottom

POSSIBLE EXTENSION ACTIVITIES

(a) Siting buoyancy material for stability
If it is found that polystyrene is the best floater then the children could try attaching pieces of the material to a plasticine 'canoe'. They could experiment with both amount and siting of the polystyrene to determine how much is required and where is the best place to attach it so the canoe remains floating and stable when filled with water.

(b) Testing life-jackets for buoyancy
During the summer months it may be possible to test in the school pool which life jackets are the best floaters. Perhaps the best way would be to attach equivalent weights until a life-jacket just sank.

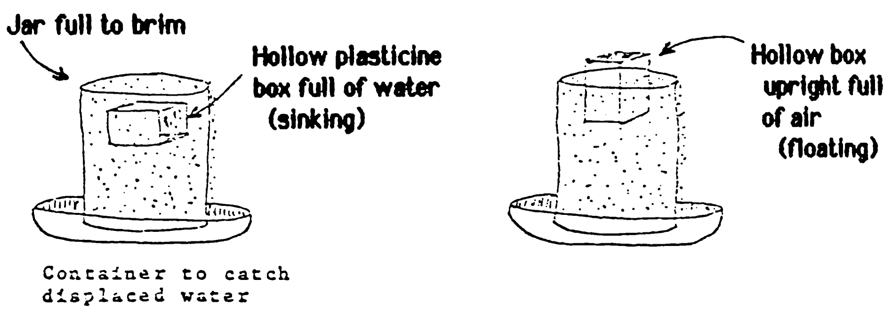
Project 4: How much water does an object push out of its way when it is floating, compared with when it is sunken?

NOTE: We feel that the following project is probably suitable only for fairly able 10-12 year olds.

Many children find it strange that when non-floating material (such as plasticine) is shaped into a floating object (such as a hollow box or 'canoe') it actually pushes out more water than when it is completely submerged. A reasonable simple way to investigate this is to fill a jar to the brim each time and catch the amount of water that is pushed out by the object when it is completely submerged and when it is floating. After they have seen the amount of water pushed out by the object when it is completely submerged, the children might like to predict whether the object when it is floating will push out more, less or the same amount of water. They check this.

If the water pushed out by the object when it is floating is collected in a small light container then children can compare the weight of the water with that of the object that pushed it out. A rough but adequate measure for this situation is to hold the object in one hand and the collected water in the other. This avoids the problem of scales that don't measure too accurately or other factors that can affect the amount of water pushed out. Children are sometimes surprised to find that they weigh about the same. (The weight of water pushed out by <u>any</u> floating object is the same as the weight of the object.)

OBSERVE ——→ PREDICT ——→ OBSERVE



SCIENCE AND SOCIETY: Non-experimental projects

Through studying the application of floating and sinking to our lives (past and present) children can
(a) gain some knowledge of social value, and
(b) recognise that science can help them make better sense of their world.

Three optional projects are proposed, to provide children with a choice. Their research is likely to take the form of consulting books and people. The teacher will probably need to offer guidance in setting out their main ideas and exemplifying them. Whether the children work individually or in mini-groups, and whether the results of their research are displayed in chart, booklet or other format is left to the teacher and/or the children to decide.

Project 1: What use are floaters?

Things that children might investigate in this project include:
(a) transport (e.g. shipping, floating logs to mills)

(b) recreation (e.g. duck decoys, boats, surfboards)
(c) support (e.g. floating dock, emergency floaters, life jackets)
(d) marking underwater objects (e.g. with buoys)
(e) indication of horizontal (e.g. spirit level)
(f) separation (e.g. fat from water)
(g) regeneration (e.g. coconut floating to another island, mangrove seeds)

Project 2: Can floaters be problems?

Aspects that could be investigated here include:
(a) pollution (e.g. oil)
(b) boating hazards (e.g. icebergs, logs, lost containers)
(c) mixtures that separate with one substance floating on top of the other and requiring to be shaken, stirred or remixed before use (e.g. paint, aerosol sprays, some medicines, lotions, peanut butter)

Project 3: What use are sinkers?

This study could investigate such things as:
(a) mixtures, as above
(b) anchors (e.g. for boats and buoys, sinkers for fishing lines)
(c) for testing eggs (good eggs sink, bad eggs float)

ACKNOWLEDGEMENTS

We are grateful to David Symington, Ken Appleton and Eleanor Hawe for commenting on an earlier draft of this booklet.

APPENDIX 5

BOOKLET 2

CHILDREN'S QUESTIONS AND SCIENCE TEACHING: An Alternative Approach

Suggestions for teachers who feel comfortable about class control, with an appendix containing notes about 'Floating and Sinking'

Fred Biddulph
Roger Osborne

Learning in Science Project (Primary)
Working Paper No.117b

PURPOSE OF THIS BOOKLET

The purpose of this booklet is to outline an approach to science teaching that involves helping cildren with investigations based on their questions about a particular topic.

SPECIAL NOTE:
It is not suggested that this is the way to teach science; it is simply one alternative. Indeed if you feel less adventurous then you may wish to try our other booklet first (Working Paper No. 117a) and perhaps attempt this approach at a later time.

PERSPECTIVE UNDERLYING THE APPROACH

The approach is based on the major aim of primary science education in New Zealand, namely

"Developing an inquiring mind and the skills for exploring and interpreting the environment."
(Infant - S4 Syllabus & Guide, p.4)

Children's questions are central to the inquiry process. Furthermore experience has shown that their questions about a topic

(i) provide an indication of the ideas - both sensible and misleading - or lack of ideas that they have of it, and

(ii) can generate considerable interest among themselves in the topic and lead to highly meaningful investigations of it.

The approach also recognises that:
(iii) the point of developing skills is to enable chldren to gain understanding;
(iv) when children really want to make sense of something it provides them with a powerful incentive to improve their processing skills;
(v) each child has to construct meanings for her or himself;
(vi) the meanings which children generate result from an interaction of the ideas they bring to the setting, the phenomena they encounter there, and the skills (mostly intellectual) they use to process them;
(vii) children should occasionally have the opportunity to learn from their own mistakes.

THE TEACHING TASK

In general terms the task of the teacher is seen as providing children with opportunities and assistance to inquire about and investigate things and ideas which are meaningful to them so that they can make better sense of their natural and technological world. More specifically, it involves helping them in the following ways:

1. Knowledge - assisting them acquire scientific understandings and knowledge for themselves at their level;

2. Skills
(a) encouraging them to ask genuine questions about things they observe or ideas they come across;
(b) encouraging them to seek more information about particular events or phenomena;
(c) helping them to test out their present ideas and questions against available evidence;
(d) guiding them to construct reasoned explanations consistent with the evidence and logic;

3. Attitude - assisting them to appreciate that there is a tentativeness about all scientific explanations and that knowledge claims, if they are to be called scientific, must be capable of being tested.

NOTE:
This approach is different from the traditional one that many of us have used previously. That approach involved trying to transmit to children knowledge which we thought was suitable for them. In so doing we tended to stifle their own inquiry, as

some teachers have recognised.

> "I think it's the way you teach things it could even perhaps squash an inquiring mind."
>
> (J3-S2 teacher)

> "I think that as a race we [teachers] do inhibit kids asking questions because we talk too much ourselves."
>
> (Primary principal)

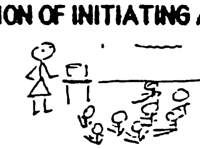
SUGGESTED TEACHING APPROACH

This is based on "Developing Interests and Attitudes" (NZ Infant - S4 Science Syllabus and Guide, Section 4)

The approach in outline

STEP 1 — PROVISION OF INITIATING ACTIVITIES

Provide your children with experiences that will enable them to ask questions. Record their questions.



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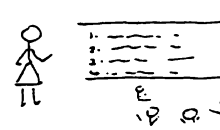
STEP 2 — DECISION RE QUESTIONS

Decide which questions are to be investigated.



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STEP 3 — GUIDANCE WITH PLANNING

Assist the children to plan their investigations.

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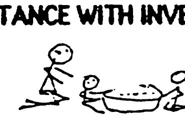
STEP 4 — ASSISTANCE WITH INVESTIGATIONS

Provide assistance to the children during their investigations.



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STEP 5 — HELP WITH FINDINGS

Assist the children to record, interpret and report their findings.

The approach in more detail

1. ELICITING AND RECORDING YOUR CHILDREN'S QUESTIONS
   - perhaps one lesson

With some topics children can probably draw on past experiences and knowledge to formulate questions, so that perhaps the only stimulus required is a picture or example of the thing to be studied. With other topics, however, the children may not know enough about them to have a basis on which to ask questions. In these cases more extensive initiating activities will be required. Possible activities include

* demonstrating something to the children (a discrepant event - one that you know is at odds with the ideas children usually have - is one possibility),
* showing them a film, filmstrip, slides,
* presenting them with instances (and non-instances) of some phenomenon or event and encouraging them to offer their views about these,
* reading them an article,
* letting them explore some apparatus or materials,
* letting them observe at some site.

The suggestions made in this section so far could result in children asking an extremely wide range of questions about a topic. This is not necessarily a bad thing; quite valuable learning could take place. You may feel, however, that since we seldom have unlimited time in the classroom for such studies that you would be happier if the children pursued questions related to ideas about the topic that seemed important to their further understanding of it at higher levels. To some extent it does seem possible to <u>focus</u> children's questions in such a direction by providing initiating activities that draw their attention to particular aspects of the topic. The activities already suggested can be used in this way.

You may find at first that the children cannot think of many questions. However, if they begin asking them publicly in a whole class group and you record them either on the board or on a chart one by one then it is likely to stimulate considerable interest in the topic by other children in the class and they will ask questions which then occur to them. Some teachers have found that after a while it is not a matter of eliciting questions but deciding when to stop them as the children keep on asking. (This problem may not be so great with later topics as the children learn to differentiate between questions which are investigable and questions which are not.)

There may be times, with older children especially, when you would like them to write their questions on paper either individually or working in mini-groups (up to 3 children).

NOTES:
* We are only interested in children asking genuine questions, that is, questions that they don't know the answers to already.
* One difficulty that a number of teachers have said they have had to overcome in obtaining children's questions is a strong urge to teach the children immediately a question is asked, especially if the question reveals that the child has a misleading idea.
* When you first attempt this approach you may find it convenient to end the lesson when the children's questions have been recorded so that you can think about the next step.

2. DECIDING WHICH QUESTION(S) MAY BE INVESTIGATED
   - this may take up to one lesson, depending on the means used

Children usually generate such a range of questions that some means has to be used to select one or more for study. Possible means of selection are:
(i) Let individual children or mini-groups choose a question that particularly interests them.
(ii) Let the children group the questions in a way that makes sense to them and and then have all of them (either individually or in mini-groups) choose a group of questions that interests them.
(iii) Classify the questions into those which are
* investigable by the children via practical activities;
* investigable by the children via consultation with people or books;
* investigable, but are beyond the topic;
* investigable, but would be too difficult for the children;
* not investigable using scientific methods.

Then choose, or allow the children to choose, one or more from the first two categories.
(iv) Select a question which seems a very basic one, that is, it could lead to ideas which are important to children's further understanding of the topic. Such a question will frequently encompass a number of others asked.

NOTES:
* You may be able to think of other useful ways of deciding which question(s) should be the focus of study.
* Sometimes it is possible to rephrase some of the children's questions so that they are more amenable to investigation but are still meaningful to the children.
* It is not always clear what children mean by some of their questions and it may be necessary to have them clarify them. Sometimes this can be done by having them suggest a possible answer.

3. ASSISTING CHILDREN TO PLAN THEIR INVESTIGATIONS
   - this may take one lesson or so

The children's investigations may be both practical and consultative (that is, consulting people and/or books). With both forms, however, the children will probably need considerable guidance in planning their investigations so that they will be able to, for example,

(i) use appropriate materials/apparatus,
(ii) carry out fair tests,
(iii) consult suitable people or books,
(iv) visit worthwhile sites,
(v) collect relevant and sufficient data,
(vi) have a realistic time-frame,
(vii) exercise concern for people and environment.

You may find that a 'science plan' or 'science investigation guide' (or whatever you like to call it) would provide a useful framework for children planning their investigations. At the S2-4 level they could perhaps make a written plan under headings such as:

1. NAME(S)
2. TOPIC
3. OUR QUESTION(S)
4. OUR INVESTIGATION
   (a) What we want to ask someone:
   (b) Who we could ask:
   (c) What we want to read about:
   (d) What we think we could do:

NOTE:
It will become obvious from the children's plans just what materials are likely to be needed. Some teachers have found that the approach can be fairly demanding in terms of the materials required by the children for their investigations and that it is therefore advisable to have suitable reference material (if any is available) on hand before the study begins so that during the study attention can be given to collecting the practical materials required.

4. PROVIDE ASSISTANCE TO THE CHILDREN DURING THEIR INVESTIGATIONS - the investigations may take one or several lessons

The children will be developing their skills at the same time as they will be developing their ideas, and they are likely to need considerable help with both. The help may include

(i) sympathetic challenging of their present ideas,
(ii) drawing their attention to aspects that they may be overlooking,

(iii) suggesting alternative methods, materials or other resources, if necessary,
(iv) acting as a resource person if you happen to have information that they request.

5. HELPING CHILDREN RECORD AND REPORT THEIR FINDINGS - this may take one or more lessons

The children will probably need guidance in, for example,
(i) what to record (e.g. repeated measures rather than a single measure),
(ii) how to record it (e.g. chart, table, graph, sentence),
(iii) what meaning can or cannot be taken from the data, and how this connects with what they already know; here the children may be encouraged to make use of analogy ("Oh, I see, that's a bit like..."), or to recall images, episodes or ideas from past experiences that may be related to their present investigation,
(iv) reporting the investigation and its results (e.g. booklet, chart, model, drawing, tape).

NOTE:
At the primary level, children tend not to be so interested in investigations relating to questions other than those they have been pursuing themselves so that having a group of children talk to the rest of the class about an investigation that they alone conducted would not necessarily go very well. Some teachers have found that having short reporting-back sessions by the children after steps 2, 3, 4 and 5 is better.

POSSIBLE VARIATIONS TO THE TEACHING APPROACH

1. Children could suggest likely explanations

A possible variation to the teaching sequence is to have the children themselves propose possible explanations to the questions they are about to investigate. After they have completed their investigations they could compare their conclusions with their proposed explanation.

2. Some questions may be simply explained

Some of the children's questions can be simply explained. At the end of the study you may wish to return to some of the unanswered questions that you know about and offer a simple explanation. We have found that children are usually still interested in their unanswered questions and appreciate explanations.

FINAL CONSIDERATIONS

1. The scientific method

There used to be (maybe still is) much talk about scientific method. However, scientists would say that when they are investigating they use their common sense and whatever method seems best to solve the problem at hand. We suggest that primary science education be approached in the same way, that we simply use our common sense to guide children in their investigations. For example, if we want to find out whether a system of pulleys makes it easier to lift a certain load then it is common sense to get a measure of the load without using the pulleys so that we have a basis of comparison. Children, even able 10 and 11-year-olds, don't necessarily think to do this.

We would also add that it is not really necessary to know all the answers to children's questions - some questions will turn out to be impossible to answer anyway - but it is importnat to join with the children in their search for answers or their search to find out whether their suggested explanations are sensible ones. In the process you will probably find that you learn many fascinating things yourself.

2. Will you survive?

The approach is not without its difficulties. For example, you may find that
(i) sufficient resources (suitable books, equipment, knowledgeable people, etc) are either not available or you haven't had time to locate them, and
(ii) children pursuing questions in different directions is something which is not easy to manage.

Do not feel guilty about postponing (or even cancelling) the lessons if you get into difficulty the first time. You will probably have learnt much about yourself and your children, and if you take up the challenge again later then you may find that you can handle the children's questions more easily or anticipate more accurately what resources are likely to be required.

APPENDIX

FLOATING AND SINKING

SCIENTISTS' AND CHILDREN'S EXPLANATIONS OF FLOATING AND SINKING

To assist children make better sense of their world it is helpful to know what ideas they already hold. We have found that they hold a range of ideas about floating and sinking, including in some cases the scientists' view. You may well find that some of your own pupils hold some of these.

1. What does 'floating' mean?

THE VIEW OF SCIENTISTS (and some children)

An object is considered to be floating if it is
(i) on top of the water, held there by the surface tension (e.g. a water spider),
(ii) at the surface and partly immersed (e.g. a ship),
(iii) fully submerged but freely suspended in the water (e.g. a fish).

SOME CHILDREN'S VIEWS

An object is considered to be floating if it is at the surface, partly submerged and stationary.

An object may be considered to be partly floating if it has a little bit above the water and a substantial amount under water (e.g. an iceberg).

2. Why do things float?

THE VIEW OF SCIENTISTS (and some children)

(i) In simple terms, they float because they are light for their size.
(ii) More technically, things that float do so because they push aside (displace) an amount of water equal to their own weight. For example, a fresh egg pushes aside a certain amount of water but this is not equal to its own weight so it sinks. When it goes bad, however, gases escape through the shell (i.e. it becomes lighter for its size), the amount of water it displaces is equal to its own weight so it floats.
(Note that this explanation is too difficult for almost all primary children to understand.)

SOME CHILDREN'S VIEWS - things float because

(i) They are light.
(ii) They have air in.
(iii) It's the material they're made of.
(iv) They're water resistant.

3. Does the length of material affect flotation?

THE VIEW OF SCIENTISTS (and some children)

If a material floats, then a longer or shorter piece of the same material will float at the same level (e.g. a full length candle will float at the same level as a shorter piece with the same dimensions).

SOME CHILDREN'S VIEWS

(i) A longer piece will sink because it is heavier.
(ii) A longer piece will float lower because it is heavier.
(iii) A longer piece will float higher because there is more of it being held up by the water.

4. Does the depth of water affect flotation?

THE VIEW OF SCIENTISTS (and some children)

(i) The depth of water underneath a floating object will not affect the level at which it floats.
(ii) The depth of water on top of floating material will not prevent it floating (e.g. a block of wood placed in very deep water will float up again).

SOME CHILDREN'S VIEWS

(i) A floating object will float lower in deeper water as it is sort of sucked down a bit.
(ii) It will float higher because there is more pressure of water under it.
(iii) Floating material placed in very deep water will stay down because of the pressure of water on it.

5. What effect does removing that part of floating material above water have on the material's flotation?

THE VIEW OF SCIENTISTS (and some children)

Removing that part of floating material which is above water will result in the material rising to have the same proportion above water. For example, if a floating block of wood was half out of the water, then removing the top would cause the wood to rise so that once again half would be floating above water.

SOME CHILDREN'S VIEWS

Removing the top part of floating material (e.g. of an iceberg) will cause the part below water level to
(i) sink,
(ii) stay just at water level,
(iii) roll over.

WHAT CHILDREN WANT TO KNOW ABOUT FLOATING AND SINKING

We have found that children aged 9-12 years most often ask questions about:

1. Materials (e.g. Why do most metals sink?)
2. Objects (e.g. How do boats stay up in the water?)
3. People (e.g. When I'm on my back in the pool I'm kind of relaxed and I float but when I twist or turn or lower my legs a bit I go under. Why is that?)
4. Other animals (e.g. How come insects float?)
5. Weight or size (e.g. Why do big ships float and why do little things like paper clips sink?)
6. A general rule (e.g. Why do some things float and some things sink?)

SUGGESTIONS FOR INITIATING ACTIVITIES TO FOCUS CHILDREN'S QUESTIONS

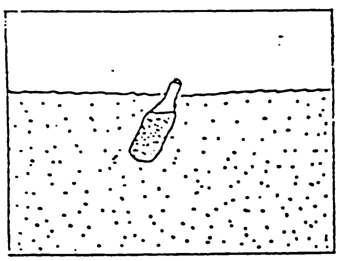
* If you want to focus on the meaning of 'floating' then you may show the children some foil on top of the water, a ball of plasticine under the water, a table tennis ball suspended in the water by some cotton tied to a weight on the bottom, a golf ball suspended in the water by some cotton tied to a stick at the top, and an apple immersed in the water at the surface. Examples of cards (OHP drawings) that could be used for the same purpose are show below and on the next page.

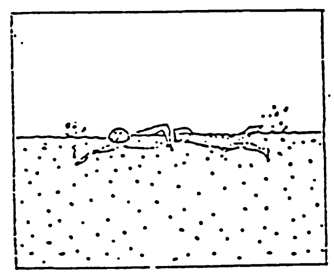
* If you wish to focus on floating and non-floating materials then you may demonstrate that some materials float (e.g. a plastic lid, large piece of wood, pumice) while some sink (e.g. rubber, small piece of chalk).

* If you would like to focus on the fact that some materials can be shaped to float then you may demonstrate that a paper clip sinks while a large ship floats, that a glass jar put in sideways sinks but put in vertically (with some ballast) floats.

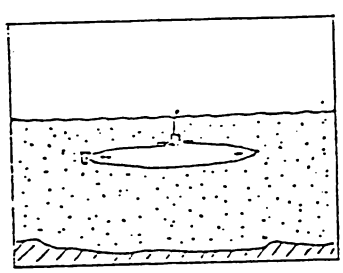
*   Similarly, other demonstrations using drawings or objects could focus on length of material, depth of water, and so on.

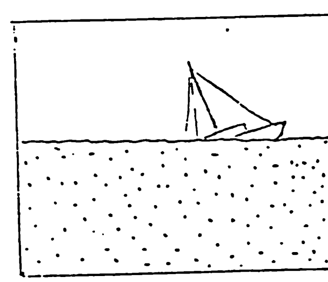
EXAMPLES OF DRAWINGS, PICTURES OR OBJECTS THAT COULD BE USED TO PROVIDE INITIAL EXPERIENCES

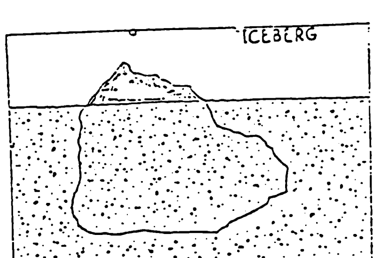




With these and the next two cards, you could say to the children: **"In the way you think about floating, would you say the... is floating? Why do you say that?"**

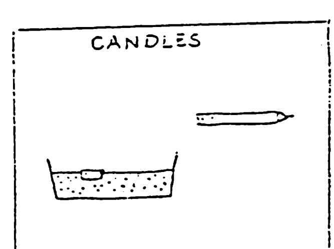




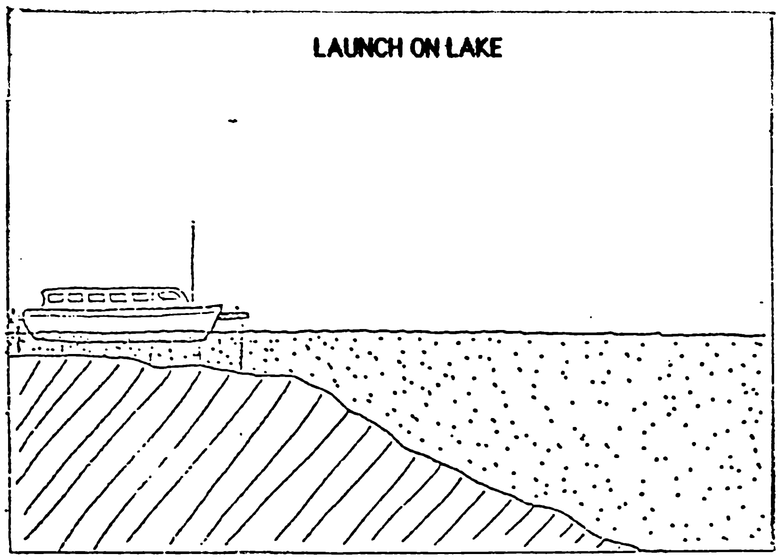


"If we cut the top part off the iceberg what do you think would happen to the bottom part under the water?"

"Why do you think that?"



"If we put the big candle into the water will it sink, float lower, the same or higher than the little candle?"
"Why do you think that?"



"When the launch goes over into the deeper water will it float lower down, the same level or higher up?" "Why do you say that?"

APPENDIX 6

EXAMPLES OF SPECIAL MATERIALS USED BY THE TEACHERS UNDERTAKING TRIALS 3 AND 4

1. Survey used by the Newstead School teachers

FLOATING AND SINKING SURVEY

NAME: .... SCHOOL: ....
DATE: .... CLASS: ...... ROOM: .....

---

1. WHY DO SOME THINGS FLOAT?

---

2. WHY DO SOME THINGS SINK?

---

3. WHEN YOU FILL A FLOATING MATERIAL WITH WATER IT WILL:
   - Sink
   - Float lower
   - Float same
   - Float higher

---

4. WHEN FLOATING MATERIAL HAS A HOLE IN IT, IT WILL:
   - Sink
   - Float lower
   - Float same
   - Float higher

---

5. WHEN AN OBJECT IS MUCH LONGER IT WILL:
   - Sink
   - Float lower
   - Float same
   - Float higher

---

6. WHEN THE WATER IS MUCH DEEPER THE OBJECT WILL:
   - Sink
   - Float lower
   - Float same
   - Float higher

---

2. Example of a card written by the Newstead School teachers to assist children with an investigation of one of their questions.

CAN LIQUIDS FLOAT ON OR IN OTHER LIQUIDS?

To find out:

(a) Get some water in a clear glass test tube, beaker, bottle or jar.

(b) Add some cooking oil.

(c) See what happens.

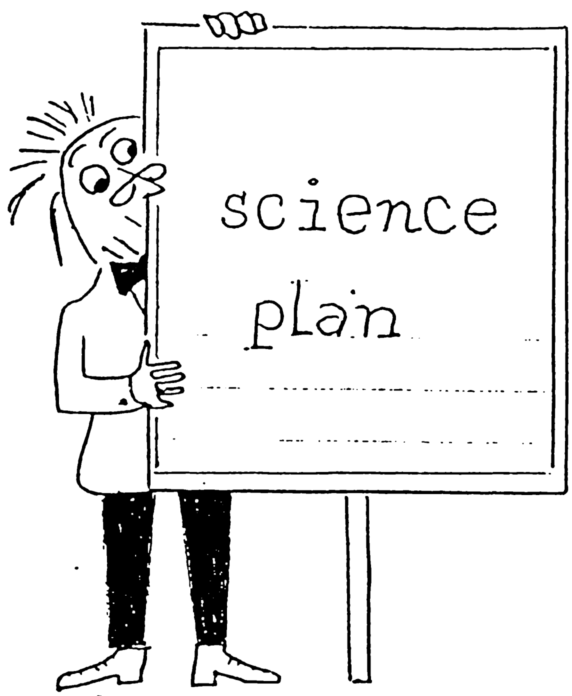
(d) Add some other liquids to water e.g. dyes, milk, vinegar, cooking.

(e) Try vinegar and cooking oil.

(f) Try shaking these mixtures for one minute, and then look at them again.

(g) Record what happens. Write 2 or 3 sentences, or draw diagrams to explain your ideas.

3. Teacher-prepared worksheet to help children plan an investigation



1. Write down your name and who you will be working with.

2. Write down the question you are investigating.

3. Write down all the ways you could find an answer to your question.

4. Write down how Mrs Roger can help you with your investigation.

5. Write down how you will record your investigations.

4. Additional teacher-prepared worksheet to help children plan their investigations

science

plan

your investigations

Today we begin our investigations.
The first thing we need to decide is:
What we want to find out.
The second thing we need to decide is:
What we are going to do to find this out.

REMEMBER!!

It may take you more than this one lesson to do your investigation so just concentrate on *one important thing* you are going to investigate *today*. It is probably best to do *one* activity a day and then *record* it.

Fill in this for today

1. ***The important thing we want to do today is...***

2. ***To find this out we are going to...***

5. Teacher-prepared worksheet to help children record investigation results

recording

Record <u>EVERYTHING</u> you do.
<u>All</u> investigations are valuable.

<u>STEPS TO RECORDING</u>

1. While you are doing your investigations write notes about everything you do. Do diagrams as well.

2. When you have finished your day's investigation write your notes up in full.

3. Work on your final presentation e.g. do headings, frames, diagrams etc.

FINAL PRESENTATION

Your final presentation must contain the following:

A. A bold heading: probably your question.
B. A record of all your investigations with diagrams etc.
C. A conclusion: an answer to your questions and your reasons for this answer.

6. Example of an observer-prepared checklist for helping children conduct an investigation

<u>DOES THE SHAPE OF AN OBJECT MAKE A DIFFERENCE TO WHETHER IT FLOATS OR SINKS?</u>

IN YOUR PLAN FOR YOUR INVESTIGATION

Have you decided what sort of material to try which you can make into different shapes easily?

Have you decided what shapes to try?
Hint: Don't forget to try different shapes made from the <u>same</u> material.

Have you decided how to check whether each shape floats higher or lower?

You may like to try this again with some other material. Just because something happens with one material doesn't mean it will happen with them all.

APPENDIX 7

46 QUESTIONS ABOUT 'FLOATING AND SINKING' ASKED BY NEWSTEAD S2-4 CHILDREN WHILE STUDYING THIS TOPIC

(Source: Biddulph, Appleton, Faire, Duncan and Roger, 1984)

Questions seeking clarification of meaning of 'floating'

1. Are parachutes floating in air?
2. If something is on the top surface of the water, is that called floating?
3. If something is not touching the bottom and yet is not at the top of the water, is it floating?
4. If something is in the water with only its top surface level with the top surface of the water, is that called floating?
5. When any animals dives or jumps into the water, are they floating or sinking?

Questions seeking information

6. Do things float better in shallower water than in deep water?
7. Can liquids float on or in other liquids?
8. Can things float in something that is not water e.g. air, oil, gas, petrol, lava, milk?
9. Does a thing have to have air in it to float?
10. If a true fish stops moving does it rise to the surface? Is it the movement that keeps it under?
11. Does the shape of an object make any difference to whether it floats or not?
12. Do some shapes help things that wouldn't float to float?
13. Does all wood float?
14. Do boats have to be moving to be floating?
15. Does all fat sink?
16. Do the chemicals things are made of help them float?

Questions seeking explanations

(a) WHY VARIOUS OBJECTS/MATERIALS FLOAT

17. How come a cork floats?
18. Why does wood float, 'cause wood is really heavy?
19. How come fire can float on water?
20. Why does oil and petrol float on water?
21. Balsa wood glue makes a sort of cover on the water, and some paints do the same. Why is that?
22. Why does a fish or a whale float?

23. How do icebergs float in the water?
24. How do life-jackets float?
25. How do dead fish float?
26. How do cargo ships float?
27. How come when the cargo holds are full a boat still floats?
28. Why do little boats with huge outboard motors stay afloat?
29. How come big things like water melons can float?
30. Why is it that human beings can float even though they are not full of air or polystyrene?
31. Why does cotton wool hit the bottom, then float on top again?
32. Why do empty plastic bottle pop out of the water and empty glass jars sit half-way in the water?

(b) WHY VARIOUS OBJECTS/MATERIALS SINK

33. A piece of plastic sank. Why did it sink?
34. Why do light things like wire gauze sink rather than float?
35. Why does soap stick to the bottom of the bath?

(c) WHY VARIOUS OBJECTS/MATERIALS FLOAT/SINK

36. Why do some people float and some people sink?
37. How come some balls float and some balls sink?
38. Why does water-logged pumice sink, and unwater-logged pumice float?
39. Why does dry cotton wool float while soaked cotton wool sinks?
40. Play-dough when it's rolled into a ball goes right to the bottom, but when it's a boat shape it stays floating. Why is that?
41. Why does a little pebble sink and a larger object float?
42. Why do some things float when they are one way up and sink the other way?
43. How come if you fill a container with water it sinks but when you blow air in, it floats?
44. How come that something like a log that is floating can be made to sink when a person get on it?
45. Why do some things float and other things sink?

(d) WHY VARIOUS OBJECTS BEHAVE AS THEY DO

46. Why do empty containers tip over when we put them into water?

28 QUESTIONS ASKED BY GLENVIEW S4 CHILDREN ABOUT 'FLOATING AND SINKING' WHILE STUDYING THIS TOPIC

(Source: Biddulph, Appleton, Faire, Duncan and Roger, 1984)

Questions seeking information

1. Does the shape of an object make any difference to whether an object floats or sinks?
2. Can things float in other liquids?
3. Will an egg yolk sink or float?

Questions seeking information about floating

4. Why do some things hollowed out float?
5. Why do large metal objects float?
6. Why do some large heavy things float?
7. Why does an onion go down and then come up again and float?
8. Why do heavy logs we can't lift, float?
9. Why does a hollowed-out object float face up, but when you put face down, half-floats?
10. Why do flat things float?
11. Why do fat people float better than thin people?

Questions seeking explanations about sinking

12. Why does a button move from side to side as it sinks?
13. Why does some wood sink?
14. Why small pieces of wood sink after being in water?
15. Why did an egg make things in a bag sink?

Questions seeking explanations about floating and sinking

16. Why do things float and sink?
17. Why does the inside of an acorn sink when the outside (shell) doesn't?
18. Why do some stones sink and some stones float?
19. Why does a raw egg sink and a boiled egg float?
20. Why does a potato sink and an apple float?
21. Why do humans float but some animals don't?
22. Why does a wooden button sink and a plastic one float?
23. Why do ants sink and then come up to the top?
24. Why do some insects float and some don't?
25. Why does cotton sink, and wood float?
26. Why does an empty yoghurt container float but a full one sinks?

Questions seeking explanations about other phenomena

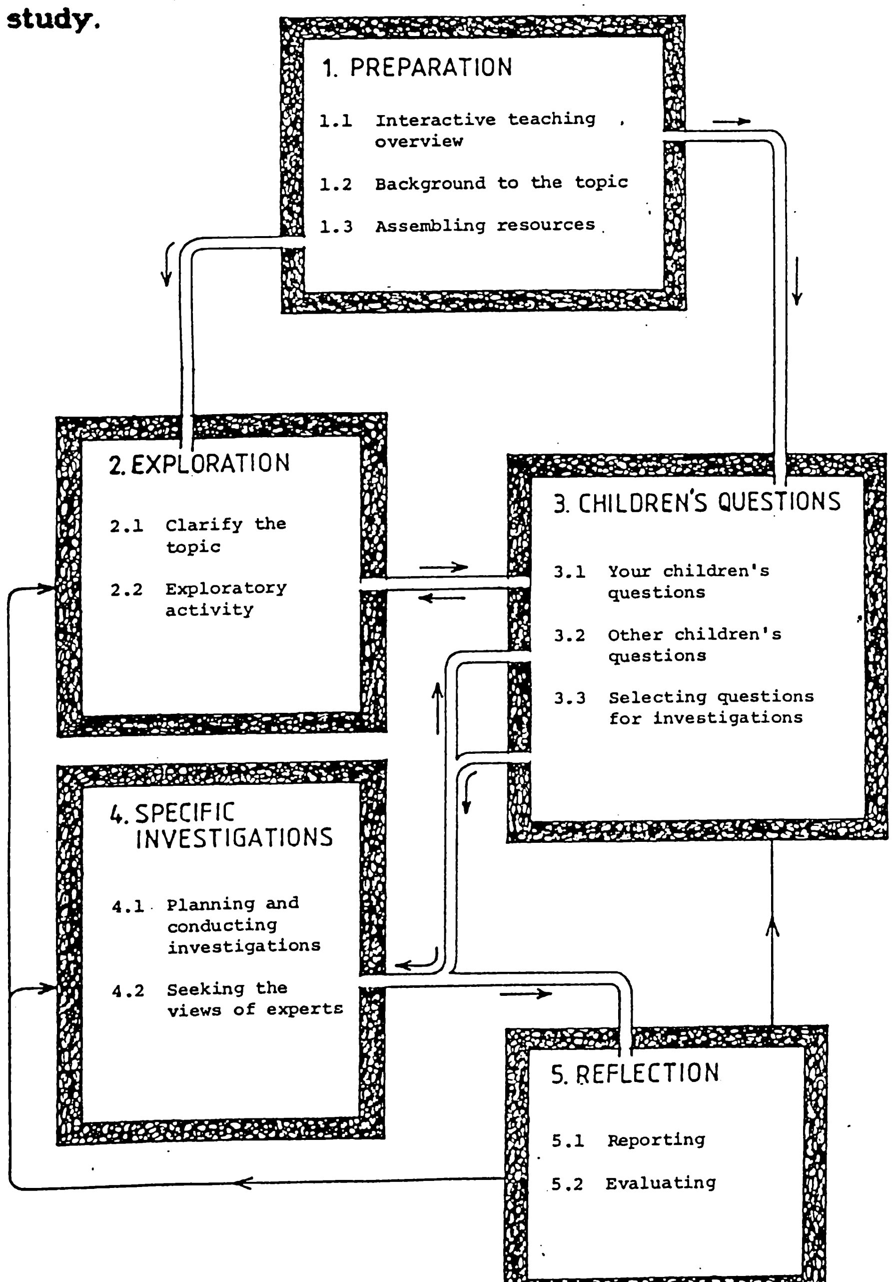
27. Why does a heavy thing become lighter in water?
28. Why does your leg get heavy in the bath?

APPENDIX 8

MAJOR COMPONENTS AND TEACHING ROLES OF THE INTERACTIVE TEACHING APPROACH

1. Key components of the Interactive Teaching Approach

The arrows are intended to indicate that the approach is not necessarily a linear one; components can interact, and some 'earlier' components could well be included in the later stages of a study.



2. Suggested roles for the teacher in interactive teaching

FACILITATOR OF LEARNING - in which the teacher tries to provide children with access to relevant resources together.

RESOURCE PERSON - in which a teacher who possesses information that a child may be seeking, provides it to the child.

NAIVE FELLOW-INVESTIGATOR - in which the teacher either genuinely expresses ignorance about some phenomena or role plays it, and at the same time conveys a willingness to find out alongside the child as a kind of senior researcher.

CHALLENGER OF IDEAS - in which the teacher deliberately but sensitively challenges those ideas expressed by a child which contain false assumptions, are inconsistent with evidence, not useful, not clear, and so on.

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