Fig 3.16:
William - age 9[6]

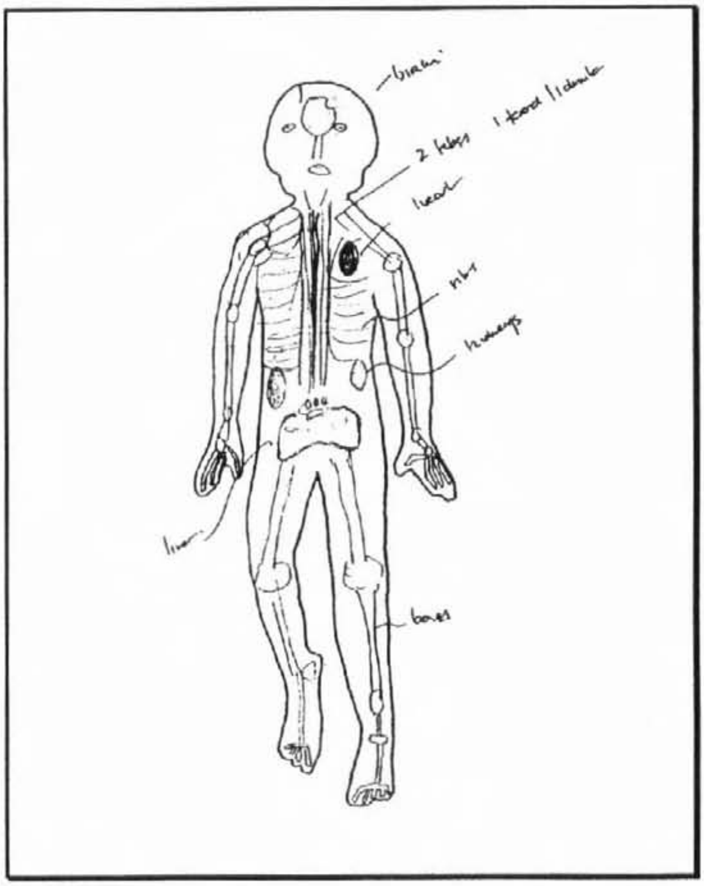
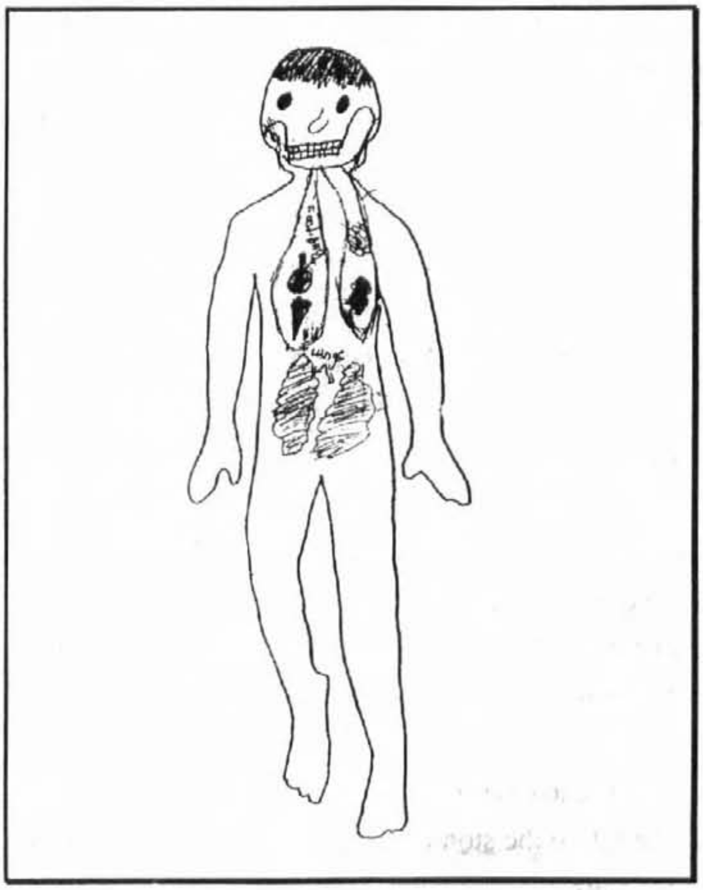


Fig 3.17:
David-age 8



6 The annotations to this diagram are those of the interviewer.

In one sense, such drawings are a clear demonstration of children's logic in trying to reconcile their ideas to their observations. Waste products emerge from two different points in the body as liquid and solids. Differentiation clearly takes place and these drawings show a sensible attempt by children to explain their perceptions. It is also worth noting that everyday language i.e.'it's gone down the wrong way' reinforces the concept of two tubes implying that there is more than one way for food or drink to pass through.

Progression towards a scientific understanding was shown by children whose answer only contained one tube. Fig 3.18 shows a good example. The stomach in such drawings was invariably placed in the centre of the abdomen and referred to generally as 'the belly' or 'tummy'.

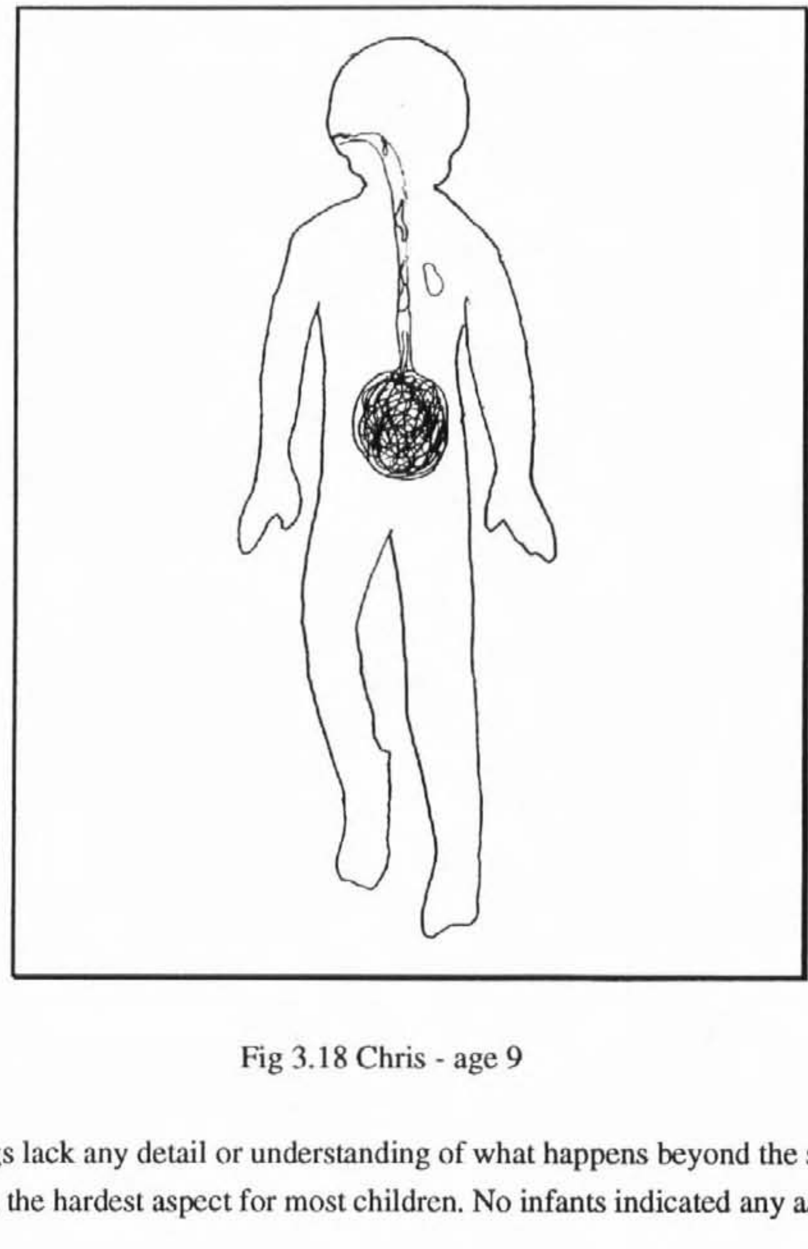


Fig 3.18 Chris - age 9

Such drawings lack any detail or understanding of what happens beyond the stomach. This is in fact the hardest aspect for most children. No infants indicated any aspect of the digestive tract beyond the stomach and only a minority of lower and upper juniors did so and an example is shown in Fig 3.19. This would indicate possibly that excretion is a relatively poorly understood process by children under 11. An alternative explanation is that eating and excretion are seen as two separate processes by children and not one continuous process.

The response Fig 3.19 represents a relatively sophisticated response in that the drawing shows a unitary digestive tract and locates the stomach in an approximately correct position. Only older children produced such drawings and this, coupled with the evidence of their greater knowledge of internal organs, lends support to the thesis that children's biological knowledge develops between the ages of 5 and 10.

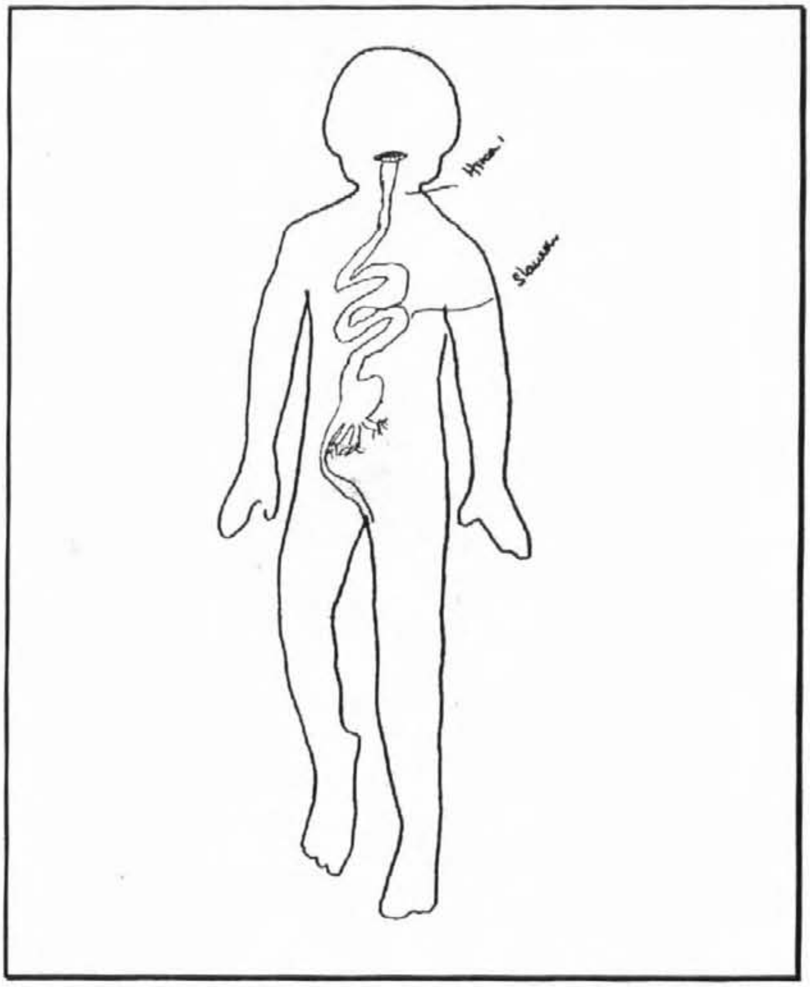


Fig 3.19: Edwin - age 9

What this data also supports is that the child's conception of the body is limited. For many children, it was restricted to that which is directly perceived or sensed. Knowledge that transcends such direct experience is only developed with difficulty over substantial periods of time and it is too easy for teachers to underestimate some of the difficulties children have in this domain.

The question 'Why do we need to eat?' was also used to explore children's understanding of the process of digestion and the purpose of food. The predominant response at all ages showed that the process of eating food was seen simply in everyday terms of its outcomes - eating food keeps you alive, enables you to stay healthy, to grow or get stronger. Essentially, these can be described as macroscopic, holistic responses and examples were:

If you didn't eat you would be skin and bones and die.	Winston: Age 10
So you can grow up and get fit	Steve: Age 10
To keep us alive	Clare: Age 8
To keep you healthy	Jennifer: Age 7
So you get stronger	Tumseela: Age 5
That means you can play when you eat your dinner.	Afsham: Age 6

There was no indication that any specific foods were seen solely as providing energy or assisting growth. Only two children gave any indication that food supplied chemicals that are essential for life by saying that food provided vitamins. This outcome is possibly not surprising. Whilst many children recognised that food could be broken down into smaller pieces, to understand that food contains different components which are absorbed into the bloodstream and distributed around the body, requires a particulate view of matter which is conceptually difficult for children of this age.

As a consequence, one of the activities of the intervention provided an opportunity for children to investigate foods and their categorisation - attempting to introduce the notion that some foods were best for body building, some for energy giving, some for keeping you healthy and whilst others made you fat. The development of this understanding is the essential precursor to a further understanding of food, the process of digestion and its outcomes.

Respiration

The research also attempted to explore children's understanding of respiration by asking children 'What happens to the air we breathe?' Answers to this question essentially fell into three categories. Predominantly, responses given were of an everyday nature.

It comes out	Kelly: Age 9
The air what you breathe in goes down to your belly.	Felicia: Age 10
It goes inside your tummy	Ettorino: Age 6
Keeps us alive and well	Lekan: Age 10

Such responses were restricted to clearly observable aspects of respiration and the overall consequences of breathing by contrast to dead or inanimate objects.

The second category of response was one which revealed some greater knowledge of the organs involved in respiration or of the process itself. Such knowledge is not self-evident and shows an improved level of understanding

It goes through your lungs	Rachel: Age 9
Goes in your lungs-goes into your heart from the lungs	Leon: Age 8

The final category of response which was very rare was one which showed a knowledge of gaseous exchange.

Air comes down and carbon dioxide comes out	Joanna: Age 11

It was found that there was a high correlation (0.92) between those children who mentioned gaseous exchange in their responses and those who showed lungs on their drawings of what is inside the human body. This would imply that an understanding of respiration is dependent on the development of children's biological knowledge.

A full understanding of respiration requires a knowledge of the organs involved, the role of breathing in performing gasesous exchange and the processes that occur within the body at the microscopic level to release energy from food. None of these children showed this level of understanding but the latter examples showed that these children had a greater knowledge of aspects of the whole process.

Application of processes of life to discriminating living and non-living objects.

Children were asked to say whether a list of ten objects (a plastic box, a small piece of rock, a spoon, a plant, an animal, an insect, an apple, a toy car and a seed) were living, once living or had never lived. This area of research has been a focus of attention for over sixty years[7] and used as a means of studying children's causal reasoning. However, the main interest in this work was to use such a question as a means of eliciting children's biological knowledge and not as a means of exploring the causal reasoning of children.

The range and diversity of children's response to this question provides a fascinating insight to children's thinking. There is not space to exemplify the range of children's reasoning but three such responses are offered as examples.

Object	***Response***	***Reason***
Plastic box	*Never living*	*I don't know*
A small rock	*Once living*	*It was an animal once and it turned into a rock because my dad's friend has got thousands in the house.*
A spoon	*Never living*	*Cos metal is made*
A plant	*Living*	*Because it's growing*
An animal	*Living*	*It's made in an egg*
An insect	*Living*	*It's made just like other animals.*
An apple	*Once living*	*It was alive when it was growing on a tree*
A toy car	*Never living*	*Not sure*
A seed	*Once living*	*They came off another plant*

Leah - Age 9.5

This response shows the child's use of a number of criteria. Objects were distinguished by the fact that they can grow, reproduce, are man-made and that they originated from living material. A slightly different response is shown next.

7 See Piaget, J. (1929) The Child's Conception of the World.New York: Harcourt Brace for the first work undertaken in this area.

Object	***Response***	***Reason***
Plastic box	*Never living*	*It hasn't got a face*
A small rock	*Once living*	*Still got no face*
A spoon	*Never living*	*It's for putting food in your mouth*
A plant	*Living*	*It's growing and growing*
An animal	*Living*	*It's got a face*
An insect	*Living*	*They fly*
An apple	*Never living*	*You have to eat an apple*
A toy car	*Never living*	*It's got no face*
A seed	*Once living*	*You have to make a hole in it*

Jermaine - age 5

Here the child's reasoning centrates on the external features and shows the repeated use of the criteria of whether it has a face or not. Other responses show the use of the criterion of movement and purpose. Finally the third example shows a response which was typical of many infant children.

Object	***Response***	***Reason***
Plastic box	*Living*	*It's round and it's got a hole*
A small rock	*Never living*	*Because it hasn't got any holes.*
A spoon	*Never living*	*Because its only got a hole*
A plant	*Living*	*It's round and big.*
An animal	*Never Living*	*It's round and hasn't got any holes*
An insect	*Never Living*	*They haven't got any holes*
An apple	*Never Living*	*It hasn't got any holes*
A toy car	*Never living*	*Because you can't open the doors*
A seed	*Never Living*	*No holes in them*

Arridet - age 6

This response show the child focusing on a single external feature and repeatedly using this criteria. The simplest explanation of this response would be that the child only recognises visible external features and attempts to use these as a criterion in responding. There is also the possibility that such a response represents the child's attempt to articulate an explanation for a concept that has only been intuitively recognised. Once the child has managed to state an answer for the first time, they continue with the consistent application of the same criterion and do not recognise the need for more thought about the response.

Clearly a scientific response would demand the application of a consistent set of criteria - that is whether the object showed any of the features of the process of life (movement, growth, reproduction, digestion, respiration, sensitivity and excretion). The extent to which these responses were used is shown in Fig 3.20

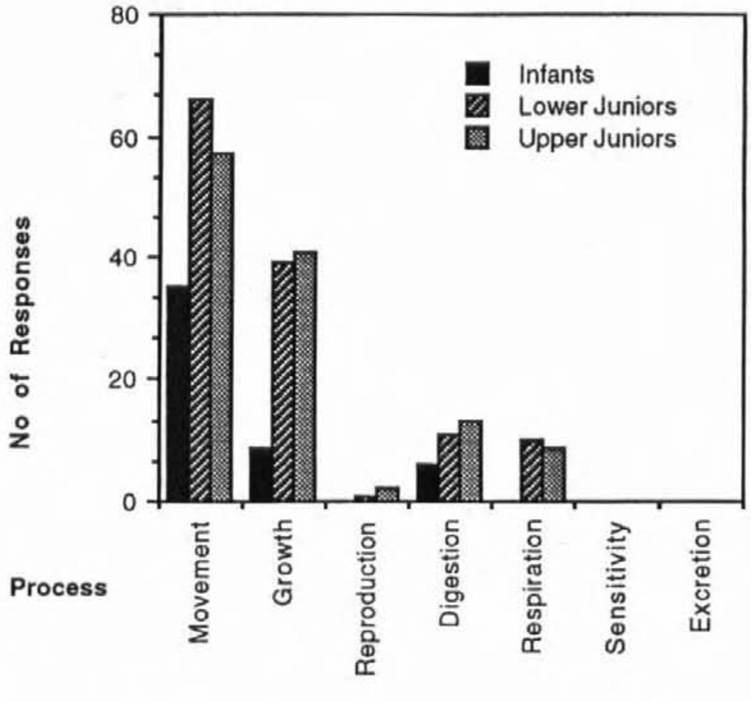


Fig 3.20: Chart showing the number of responses from each age grouping which mention specific processes of life.

The data show that the predominant process of life used as a criterion by children was that of movement and growth, and that such criteria were more extensively used by lower and upper junior children. Other processes of life were used as criterion in a very small number of instances out of a total possibility of 675 opportunities to apply criteria. The data does show that both lower and upper juniors mentioned reproduction, digestion and respiration more often than infants but even then, only in a very small number of instances. The fact that the question reveals that some lower and upper junior children knew of these processes would support the hypothesis that there is a natural development in children's biological knowledge during these years.

4: The Intervention Phase

The previous chapter provides some insight into the range of ideas about the processes of life held by young children. Whilst this qualitative picture is valuable in providing an insight into children's biological knowledge and understanding, the aim of this research was to attempt to extend previous work by devising a set of intervention activities which could be used by teachers to develop children's thinking and biological knowledge.

The rationale that underpinned the design of the intervention was that the teaching and learning would begin with a phase in which children would be provided with an opportunity to articulate and explore their own thinking in this domain. This was done by providing children with a range of activities that elicited their thinking through drawing, writing and discussion. A qualitative review of much of the data has been presented in Chapter 3. The data obtained from the elicitation was used informally to provide the teachers with a familiarity and understanding of their children's thinking about the processes of life. A set of structured activities was then provided which would provide an opportunity for children to develop their understanding and knowledge.

This intervention was designed to use a range of activities which would provide an opportunity for children to represent and clarify their thinking in more detail. This was generally done through drawings or group discussion. The criterion for selection of these activities was that they should require the *active processing* of information. These experiences were also designed to broaden children's schematic knowledge, extend their vocabulary and where appropriate, generate a conflict between their thinking and experience which would lead to a re-evaluation of their ideas.

The selection and design of the activities for the intervention was influenced by three factors

(a) A preliminary analysis of the data

(b) A set of ideas defined by the 'scientific' understanding (Chapter 2 - 'Defining the Processes of Life') which would assist a child in developing an understanding of the scientific world view.

(c) The teacher's contributions and ideas.

The elicitation gave a broad picture of the level of children's knowledge and understanding in this domain. Essentially, many children's knowledge of the body and of its processes was limited to external features and there was therefore a need to provide opportunities to develop their understanding of the internal components and their function. Unlike some other aspects of science e.g. electricity and light, such knowledge cannot be shown or developed through empirical investigations which are a feature of much physical science. Hence, the intervention used a range of broad strategies which were available for teachers to use whenever they judged appropriate. These can be described as a) sorting activities b) discussion activities c) modelling/making activities and d) investigations.

Sorting activities.

These activities require the active processing of information by children. Typically they would be provided with a number of cards. Each card would have a food on it and the children were asked to sort the foods into groups. Invariably, to start with children often sorted them into 'foods they liked' and 'foods they did not like'. The role of the teacher was then to encourage children to devise other ways of grouping the foods. One suggested activity for older children, was that food labels were cut off packets and then the labels sorted by the categories of information on the labels to encourage children to explore the meanings of the data presented in food labelling. However, teachers were always asked to provide children with ample opportunity to explore their own approaches to categorisation.

Another use of sorting was to provide children with a set of cards, each with a part of the body the written on it e.g. ear, mouth, lungs and another set of cards with the function on e.g. for hearing, for chewing food, for taking in oxygen. Children were then asked to match the names on the cards with their functions as a group activity.

A third approach was based around the use of simple classification activities. Sets of objects were provided and children asked to sort them into living and non-living. Children used their own criteria to start with but each time they used one criterion, they were then asked to think of another. Older children were encouraged to use more complex forms of classification to derive a wider range of groups e.g. Does it move? Does it live in water? and they were encouraged to use a variety of computer programs which enable such classification.

Discussion Activities

Many of the sorting activities discussed previously were undertaken by groups and hence required discussion and communication between peers which encouraged both articulation of their own thinking and the exchange of ideas. Wherever possible, activities were used that encouraged the use of this technique.

For instance, children were asked to discuss in groups such questions as 'How do healthy people look?' 'What do healthy people do?' and to produce a message for not so healthy people. In another activity, children were asked to draw a picture of what they thought was inside the body and then discuss each others' pictures and produce a group picture which they felt was most nearly correct. Further details of such activities can be found in Appendix 3.

Modelling/Making Activities.

Models provide a tangible and concrete experience of objects which are not readily open to inspection such as the inside of the body. In one activity, children were asked to feel all their bones and then compare their experience with the representation shown on a cut out model of a skeleton. For older children, another cut-out was used where children were asked to place parts of the body on a large cut-out. Making posters of 'things that make us feel good' and 'things that make us feel bad' or large posters of 'energy foods' and 'body building foods' was also encouraged as a active means of enabling children to share and discuss their thinking.

Investigations

The general principle underpinning the SPACE programme was that children should be provided with an opportunity to design their own investigations with whatever equipment was easily available. In this domain, the range and scope for investigations is limited. However, appropriate investigations were suggested to teachers in the event of the children failing to devise an appropriate investigation or to supplement the activities devised by the children. Simple stethoscopes were made with plastic cups and rubber tubes. Pulses were felt and timed and children were asked to investigate the location of muscles in their own body.

Teachers were provided with a list of a possible activities (Appendix 3). These were seen as essentially a resource which could be used with children, as and when it was appropriate to the knowledge and understanding. The intention was not to provide a prescriptive set of experiences but simply a set of activities that were available for use. Teachers were encouraged to invite children to devise their own methods of testing their thinking. This was not always possible and, to broaden the experience of children, some of the activities suggested were used by most teachers.

General Issues

Although the data collection was undertaken by the researchers, the intervention work was undertaken by the teachers. During this phase, the researchers made regular visits to the schools to support the teachers and to share with them the data collected after the preliminary elicitation. Teachers who undertook to work on this project were given briefings about the nature of the approach and the need to elicit children's understandings of the particular concept of interest before commencing teaching. Moreover, it was emphasised to the teachers that the nature of the individual child's understanding should be the basis for determining the intervention work. That is, that they should attempt to ascertain what the child already knew before determining the strategy for teaching and learning. Sharing the data gathered from the elicitation with the individual teachers was one way of enabling this process and was undertaken in all instances. In addition, teachers were encouraged to undertake similar activities in the classroom to provide more insight for themselves.

No attempt was made to ensure consistency of experience between one classroom and the other. Variation is inevitable and a reflection of the normal classroom realities. Teachers were briefed about the general approach to the intervention and the strategies to adopt and asked to offer children a wide variety of experiences and opportunities to investigate topics of interest. The briefing document which was the basis for discussion with the meetings with teachers stated:

> ' We suggest that you carry out at least one activity from each section[1] and then as many others as you are able to. We would like you to keep a log of all the activities which you try, noting how successful you felt they were, how the children responded and how you were able to build on the activities. It would

1 See Appendix 3

also be helpful if you could record interesting comments made by the children and save copies of interesting/typical work.

It is important that most of the investigations stem from the children's ideas and are not presented to them in isolation. They may need to talk, write about or draw their ideas before embarking on an activity. Wherever possible, the activities should be initiated by the children in response to open-ended questions e.g. "How could we find out about....." or "How could we find if that it is true?"

Although children may wish to consult secondary sources for further information, this should be done in conjunction with practical activities, not "Let's look it up in a book!" first. Equipment available in the classroom for children to plan their own investigations should be a useful starting point for many of the activities.

Exploration

A table or corner could be set up in the classroom with the following equipment available:- a stethoscope (possibly homemade), a model skeleton, a forehead thermometer, balloons, bones, hand lenses, mirrors, string, timers, books about the body etc. Children could be given specific times to use the equipment so that they are able to devise their own investigations. They should also be given the opportunity to share their ideas with the rest of the class.

An area could be set up with some of the questions which the children were asked during the elicitation phase e.g. a collection of objects could be available to them to classify. They could be asked to sort them into three sets: - one for living (green), one for never living (red) and one for once-living things (blue). When they had sorted them they could enter their result onto a graph using the same colours to colour each square. They could use this data base for discussion and deciding which criteria they would use to decide if an object was alive or not.'

Consequently, the data obtained from this study cannot be used to judge the validity of any one activity but merely provide an analysis of the potential developments in children's thinking from exposure to a range of experiences which embody the broad strategies outlined here.