3. METHODOLOGY

3.1 Sample

i) Schools

Five schools from the London area were chosen for this research, all in the Inner London Education Authority. The schools were all primary schools located south of the river. It was the intention to make full use of the whole age range in this study but the difficulties in obtaining a part-time researcher led to a limitation to the junior school age range, that is 7 to 11 year olds.

The selection of the schools was done by the researcher, Maureen Smith, who had already been working in the locality providing support to primary schools in the development of primary science work. Names of the participating teachers, their schools and head teachers are in Appendix 1.

ii) Teachers

The teachers invited to participate in the project were those known to the researcher from her previous work. This was advantageous in providing a pre-existing relationship and link between researcher and teachers which could be developed. Teachers were able to use this relationship to express their uncertainties about the work and ask for clarification. Unfortunately, the local authority was unable to release any of the teachers due to the difficulties experienced during this phase in obtaining any supply cover. This meant that all meetings had to take place during the teachers' own time, after school, and this had the effect of curtailing the extent of the teacher contribution to the research on this topic. The number of teachers involved in each school varied between one and three, though in most schools there were two teachers involved in the work. This was useful in that they were able to provide mutual support.

The teachers' normal style of working varied, between individuals who made sole use of classrooms based around groups teaching through topics and an 'integrated' day, and those who preferred to keep the class working together on a common theme. Teachers were encouraged to integrate the activities into their existing mode of working as there was a limitation to the amount of changes that could be expected of them. Many of the difficulties experienced and expressed by teachers were often to do with a lack of confidence in their own understanding of the topic.

iii) Children

Despite the limitation to a particular locale, the schools used reflect the wide variation seen in the London area between schools based in deprived areas and those with a substantial middle-class catchment area. Hence the children used in the sample represent children with a wide range of ability and ethnic background. All children in the classes of the participating teachers who were involved in the project to some extent were used for the pre- and post-intervention elicitation activities.

iv) Liaison

The part-time research co-ordinator also worked as a science advisory teacher and was able to use this role to provide enhanced support and guidance to the teachers involved in the project. In addition, it provided her with ready access to the schools to trial activities and materials being developed with the research team.

3.2 The Research Programme

Classroom work on the topic of 'light' took place over a relatively long period in the school year which can be summarised as follows.

Pilot Exploration	April-June 87
Pre-Intervention Data Collection	Sept-October 87
Intervention	Jan-Feb 88
Post-Intervention Data Collection	March 88

The pilot exploration phase was based on interviews with a small number of children. These used a wide range of questions to explore the nature of children's understandings of the topic of light and associated concepts. In addition, drawings and answers to written questions were employed to examine how valuable and reliable such sources were for eliciting children's meanings and understanding. Sample questions are shown in Appendix 2. The exploratory nature of this phase was necessitated by the lack of any substantial literatureappropriate to this age range providing a reference point for the level and depth of children's understanding. Many of the tools devised for probing children's ideas were modifications of methods that had been used with older children. At the end of this phase, the data was examined to determine which were the most valuable lines of approach for eliciting children's ideas about this topic. The other valuable feature of this phase, was that it provided time for developing a relationship with the teacher and the children so that they could become accustomed to the mode of working required.

Essentially, the classroom elicitation techniques were refined by the previous process and it provided an opportunity for teachers and researchers to develop familiarity with the material and each other. Data on children's ideas was then collected from children in classrooms using the selected activities. These questions and activities are shown in Appendix 3. The main methods of elicitation relied on written answers and children's drawings. These were also supplemented by interviews with a few children to provide further insight. No attempt was made to collect interview data systematically from a large number of children. This limitation was imposed by the exigencies of funding and restricted time available from the part-time researcher.

The intervention activities were designed in consultation with the teachers and from an examination of the data collected previously. The data suggested three areas of interest for possible conceptual development and a framework of activities was designed which

could be used by children to test their ideas on the behaviour of light. This was not presented as a prescriptive framework, but simply a range of exercises which could be used by children. Teachers and children were free to try other lines of investigation they wished to pursue. After the completion of the intervention phase, another set of elicitations was used with the children based on a similar questions to those used in the elicitation prior to the intervention.

3.3 Defining 'Light'

Any attempt to develop a child's concepts needs to have a map of what a preferred understanding would be. The following list was compiled by the team to provide a map of ideas considered an *a priori* necessity for the development of the scientist's world view.

1. Light travels

2. Light normally travels in straight lines and can be represented by lines.

3. Light is produced by a range of sources and travels outward from the sources.

4. Many objects reflect or re-emit light as well as mirrors.

5. Primary sources of light emit light which travels long distances till it interacts with matter.

6. Vision occurs because light enters the eye from the object.

7. Shadows occur because the light is blocked by the object from travelling. A shadow should be seen as a lack of light rather than a 'reflection of' the object.

This list represents a basis or platform for the fuller understanding of the scientist. The child who thinks that vision occurs by rays emanating from the eye cannot understand the formation of an image in a mirror. Many secondary teachers take such notions for granted, assuming that there is a basic simplicity about these ideas which all children must appreciate. Consequently, this list acts as an ideal reference point; a collection of ideas that children *may* develop by age 11. One of the purposes of the research would be to examine to what extent such ideas do develop in children as a result of their experiences and activities.

These ideas also provide a framework for examining children's ideas allowing three questions to be addressed.

a) How disparate are the conceptions held by many children from such a framework?

b) What development is observable in children's ideas across the age range?

c) What potential does such an intervention have for the development of children's ideas towards this view?

This list was also used as a reference point for the development of the intervention. Given such a framework of ideas, the task was to develop activities which would assist the formation of a fuller understanding in children. The activities were devised using simple materials familiar to children. Their primary role was to provide a focus for discussion of children's thinking and to challenge their existing ideas. Other considerations in designing the activities were that the materials should be simple, easy to manipulate and safe to handle.

Further Research with Infants

Further research was undertaken with two classes of infant children in the summer of 1989. The study used similar methods to elicit these children's understanding of light and to explore the effects of the intervention strategies and materials. The results and data obtained from this study will be published as a supplementary report as part of this series of publications in due course.

4. PRE-INTERVENTION ELICITATION WORK

4.1 The Pilot Phase

This phase of the work was carried out by the research team. Ideally it would have been preferable to train the teachers involved to do more of this work. However, the lack of possible release provided little opportunity to do undertake such training. It was decided to use the available time for training the teachers for the main intervention work and for the preliminary exploration, to collaborate with teachers in the classroom .

Using the previously established framework, a set of activities was devised which would provide an opportunity to explore children's ideas about light and its behaviour. These were

a. Using the lights in the room

Children's attention was directed towards the lights and they were asked what the lights were for. The common response 'to see with' was used for further questioning to ask 'How the lights helped us to see' and whether children would describe light as rays that are travelling.

b. Shining a small torch at

- the eyes:

Since this has a physical effect on the eyes is to cause the iris to contract, it was felt that this may provide an experience that the cause was external i.e the torch and the effect was the consequence of too much light entering the eye.

- a piece of paper and moving the torch:

The torch was use to produce a pool of light on a sheet of paper. Moving the torch closer caused the pool to become brighter and vice-versa. This experience was used to explore children's reasoning and models about light.

- a mirror in front of the child with the torch held behind.

The children were asked to use the mirror to see the torch behind them. This did not cause them particular difficulty. They were then asked to draw how it was possible to see the light coming from behind them to see what representations of light they would use.

c. Looking with their eyes covered

The purpose of this was to use a simple activity commonly used by children in games as a means of exploring their ideas about perception. Why did covering their eyes make it difficult to see? Did very young children have notions of the existence of external space being dependent on their vision of it?

d. Making shadows with a torch and simple objects

A range of simple objects e.g books, pencils and hands, were used to produce shadows on paper with a small torch. Children were asked what caused the shadows and provided a range of explanations varying from those saw the shadow as a copy of the object to those that involved an understanding of rays and rectilinear propagation.

e. Looking at cameras and photographs

Photographs are something which children see and use from a young age. Children were asked how it was possible to capture the picture forever to see what understanding of light they used in their explanations.

f. Investigating a range of mirrors

Again, mirrors are part of common everyday experience and the light from a torch was reflected into another part of the room and children asked how this was possible. Plastic mirrors were used which cause distortion and children were asked why this happened. Generally, children provided explanations that talked of the light 'bouncing off' the mirror but their explanations of distorted images tended to focus on the bending of the mirror rather than light itself.

g. Examining the effect of spectacles

Many children wear spectacles and such children, or alternatively the researcher, were used as a focus to ask how spectacles assisted people to see. Answers tended to focus on the defects of sight. Typically, children would mention that without glasses everything was fuzzy and glasses made vision clearer rather than show any understanding of the effect of the lens on light.

h. Investigating sources of light e.g torches, candles, the sun

These sources were shown to the children and children asked to talk about the differences and similarities between them. Much of their discussion was about the strength of the sources with an implicit recognition of an overall similarity.

These activities all represented experiences which provided simple concrete experiences which could act as a focus for discussion about light by the children. For instance, the lights in the room would be turned off so that the room became noticeably darker and the children would be asked where the light was coming from now. This provided

insight into whether they simply saw the room as bathed in a pool of light which had diminished or whether they were aware that the room was lit by sunlight, even though the sun was not visible at the time.

One important difference between this topic area and others such as 'growth' is that the phenomena are instantaneous. Either the effect is observable or it is not and there is no long term property or effect. For instance, with the phenomenon of growth, an individual can test a belief that 'water is necessary to make it grow' fairly readily. A child can devise a simple experiment with two similar plants where the amount of water supplied to each plant is controlled. Consequently, it is possible to make causal inferences about the phenomenon as a result of perceptible effects. However, it is not so easy to test out the concept that' light stops when it hits a piece of paper.' Light appears to travel instantaneously from one location to another, its path is invisible and difficult to make perceptible. Consequently children often restrict themselves to simple phenomenological descriptions of the observable which makes it much hard to develop the scientist's notion of a 'ray'. Turning on a torch[1] produces light on the paper simultaneously, which is not observed to travel further. In many children's thinking, such events simply 'happen' and did not appear to require an explanation.

4.2 Results from Preliminary Explorations

Data were collected in the preliminary investigation by the researchers using a mixture of interviews and drawings. However, these were not a prescribed set of questions and additional questions were used to probe areas of interest for further clarification. Interviews were normally conducted with small groups of two or three children, mainly for the sake of expediency given the limited amount of time available. However, they also proved valuable in generating discussion between children on the issue when there was disagreement between them. A video recording was also made of one or two of the interviews at this stage for training purposes with teachers.

The early findings at this stage were summarised by simple counts of statements made by pupils. Essentially, pupils' views were:-

a. Light was localised with a particular source which may be the sun, a bulb or a lamp. Light does not travel very far from the source. Secondary sources of light were identified with an object such as a window, glass door or a ceiling. There was little recognition of the primary source of light in such instances.

b. Many saw the moon as a source of light rather than a reflector of the sun's light.

c. Cats can see in the dark because their eyes are bright and they shine. Cat's eyes are special eyes.

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1 The torches used in these investigations were of the small 'Duracell' type. These have the advantage of providing a bright but small light source which provides sharp rather than diffuse shadows. The mirrors used were of aluminised plastic. Whilst they do not provide such a good image as an ordinary mirror, they are comparatively safe.

d. There was very little notion of light travelling or understanding of how light gets here. Objects were seen to shine and there were mentions of light coming through the wires by electricity.

e. Sight was explained in terms of seeing with the eyes or some observable mechanism such as the pupil. The pupils gets bigger in dim light to help you to see. There was no understanding of the part played by light in vision other than that 'you need light to see with'.

f. Few children were clear what happens to the sun at night.. Explanations were often anthropomorphic or mechanistic. The sun 'gets tired' or is 'turned off' at night.

g. Mirrors 'bounce' or 'reflect' light but there was little understanding of how bicycle reflectors work. They were described as 'glowing'.

h. Pupil drawings of torches and experiments with light showed the objects but representations of light were often restricted to blobs. Very few drawings showed the light entering the eye.

i. Glasses help you to see better or, if there is nothing wrong with your vision, they make everything blurry. There was no understanding shown of the effect of the glass on the light.

Examples of this are shown in the following extracts from interviews.

Interviewer. How does light get here?

Sam. *By the light bulb and from the wires.*

Interviewer. From the wires?

Sam. *Yes it comes up through the electricity in the wires.*

Interviewer. What happens to the sun at night?

Sam. *It changes into the moon.*

Anne. *The sun goes out*

The results from this preliminary work were used as a basis for refining and clarifying the elicitation questions and activities. Those activities which clearly failed to produce from children anything about their picture of light were discarded and a limited subset of questions and activities produced. For instance, questions about seeing in the dark and about glasses had failed to produce anything other than purely operational answers of the kind 'you can't see in the dark' or 'glasses help you to see'. Such answers were not revealing and these activities were omitted. The richest source of data was found to

be children's drawings which provided a wealth of detail about the models they were using to explain the observed phenomena.

After a preliminary analysis of these findings, a new set of questions and activities was then used by the teachers and the researchers for the first phase of data collection in Sept/October 87. Data from the elicitation phase were then used as a basis for the designing and planning the framework of the intervention.

4.3 Elicitation

This phase of the work was carried out in collaboration with the teachers in the schools from September to October 87. Children seemed to enjoy the opportunity to partake in this work and they produced a large body of data for examination and analysis. Whilst it is inevitable that some cross-fertilisation of ideas would occur, the occasions on which this happened were relatively minimal as children valued the opportunity to express their own ideas in a non-judgemental situation where they were encouraged to express their thinking.

The activities for the initial elicitation were revised in the light of the experiences gained from the pilot phase by the elimination of those activities which had not proved fruitful in providing data about children's understanding of light. Since the pilot phase had shown that children's drawings were a particularly valuable insight into their thinking, the activities designed for the elicitation made extensive use of children's drawing.

Six activities were designed for use with children to explore phenomena associated with light. These were

a. Investigating where light comes from
b. How do bicycle reflectors work?
c. Investigations with a torch and a mirror.
d. Investigations with a torch and paper.
e. Looking at candles.
f. How do we see?

The activities were complemented with a list of activities and questions to be used by teachers and researchers, full details of which are shown in Appendix 3. The list was not prescriptive and children were allowed to explore and follow up their own line of thinking. During this phase, data were collected by the use of:

Drawings

Children were asked to use drawings to show what was happening to the light in their investigation and were encouraged to use such drawings as a recording tool. With some activities, to simplify the task, drawings were provided and children asked to add to the drawing to show what was happening e.g a girl looking at a candle.

Written Material

Children were encouraged to provide written responses to some questions which provided data that were used by the researchers. Typical questions that children wrote about without difficulty were:

> How does light get here from the sun?
> What happens to light at night?

However, not all children, particularly younger children were happy about writing and generally this was not such a useful method of obtaining an insight into the thinking of children.

Organisation

Much of the work in the elicitation phase was done by the researchers working with the teachers. This provided a valuable opportunity for developing the methodology of the project with the teachers. It also provided valuable insights of the children's thinking about the topic for the teachers which a useful preparation for the intervention phase. Some teachers expressed concern about the demands posed in terms of time and how to integrate the work into their existing range of activities. However, this phase of the work allowed time for these issues to be resolved and for the teachers to prepare and contribute to the intervention.