8. CHANGES IN INDIVIDUAL CHILDREN

The other method for examining change is to look at what has happened to individuals. The networks provide a summary of the whole cohort, but are poor at providing insight into any of the changes that occurred for individual children. Such an analysis is important to obtain a picture of how the changes observed in the network arose. Consequently, it was necessary to develop a method of analysis that would provide some insight into any individual change.

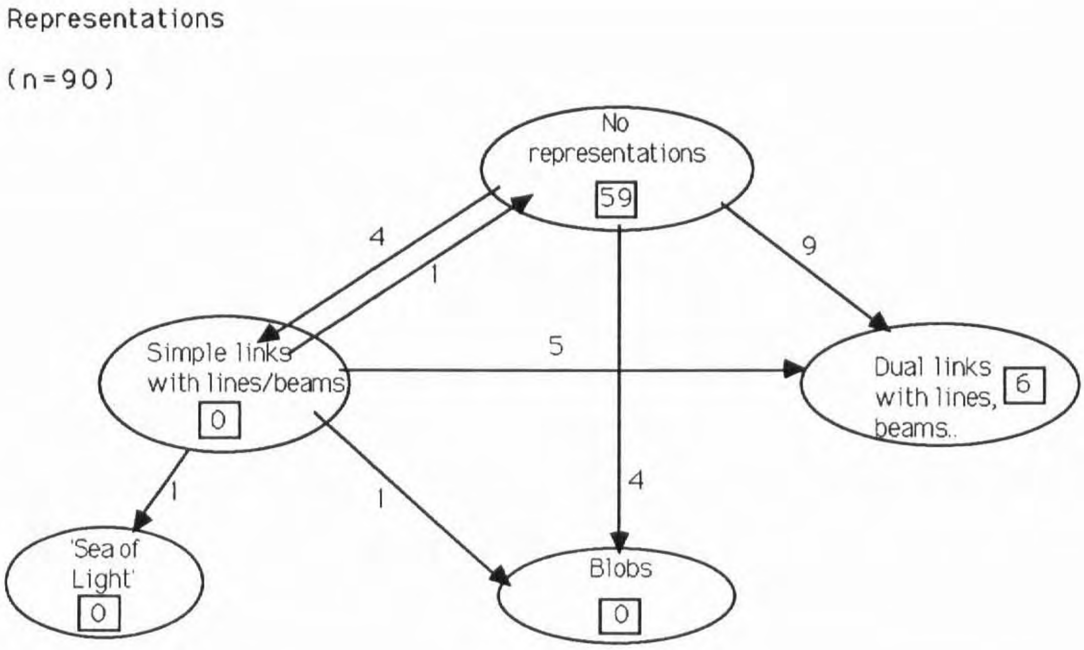
The chosen method was based on the fact that an examination of the data shows clearly definable features of children's understanding of light. A child's representations of light can be classified into groupings which can be said to be a) No representations, b) simple links with lines or beams, c) dual links and d) 'blobs'. Similarly an examination of the direction indicated for light and for vision, can be grouped into a) no direction, b) sense of direction indicated and c) accurate sense of direction. Data for changes in children's representations of light are shown in table 8.1 and 8.2 whilst table 8.3 and 8.4 show the data for changes in their ideas about vision. The large number of questions in each activity provided a large data sample for the size of the group.

In the tables, aspects of children's understanding are enclosed in ellipses and the tables show counts for the number of individuals who have changed their representation of light (Table 8.1 and 8.2) between the elicitation activities, pre- and post-intervention for the *same question.* The numbers in boxes within the ellipses, show the counts for those children who did not change the representation that they used.

The charts shown are summaries for three questions in the elicitation activities and tables for each question are provided later. The figures can be summarised by grouping into three categories; (i) those which show no change; (ii) those which show a change to a view which shows a more complex representation of light and explanation for vision; that is, one which is considered to have more of the features of a scientific representation; (iii) those which show a less sophisticated representation. It is clear from these charts that as well developing their understanding, some children go 'backwards' i.e away from a scientific view in their understanding.

(contd overleaf)

Table 8.1. Conceptual Map of Changes in Children's Representations of Light (Lower Juniors)



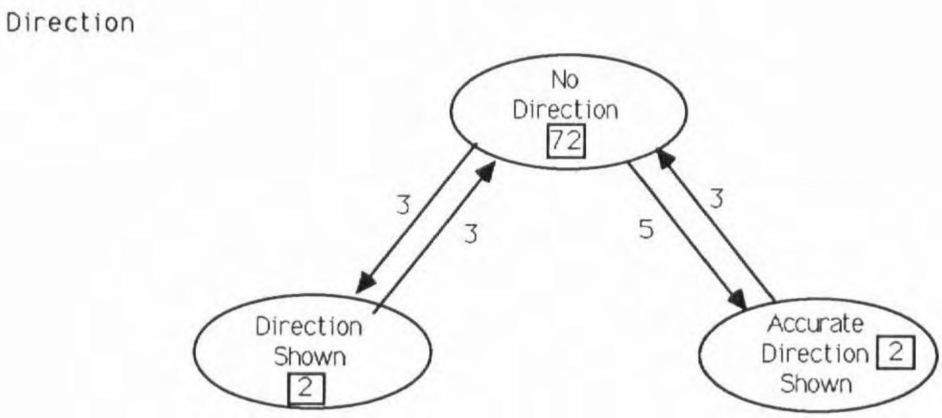
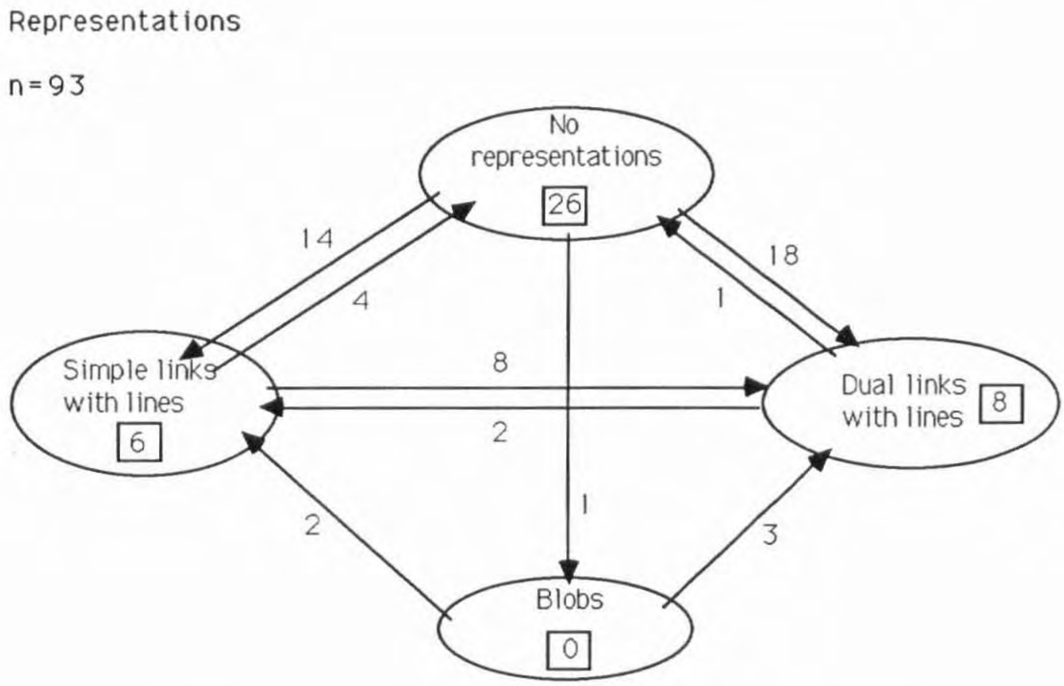


Table 8.2. Conceptual Map of Changes in Children's Representations of Light (Upper Juniors)



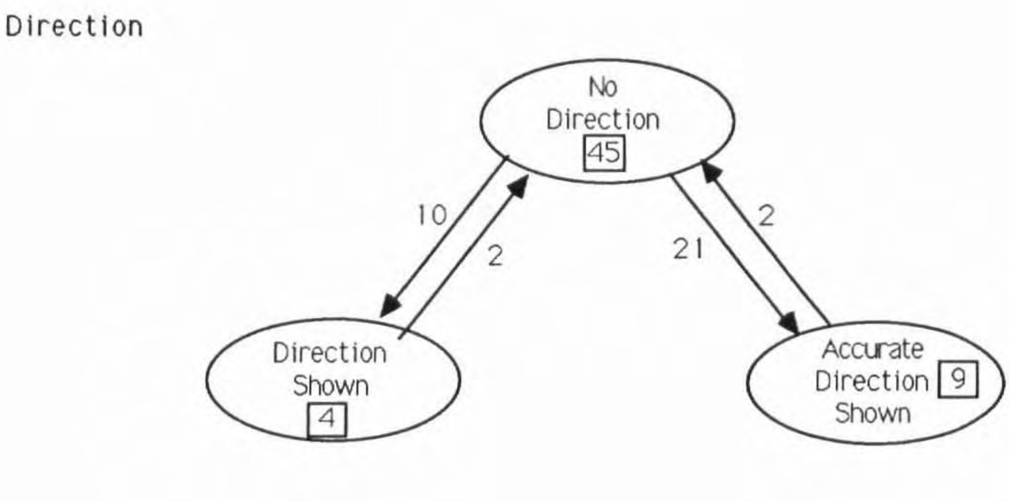
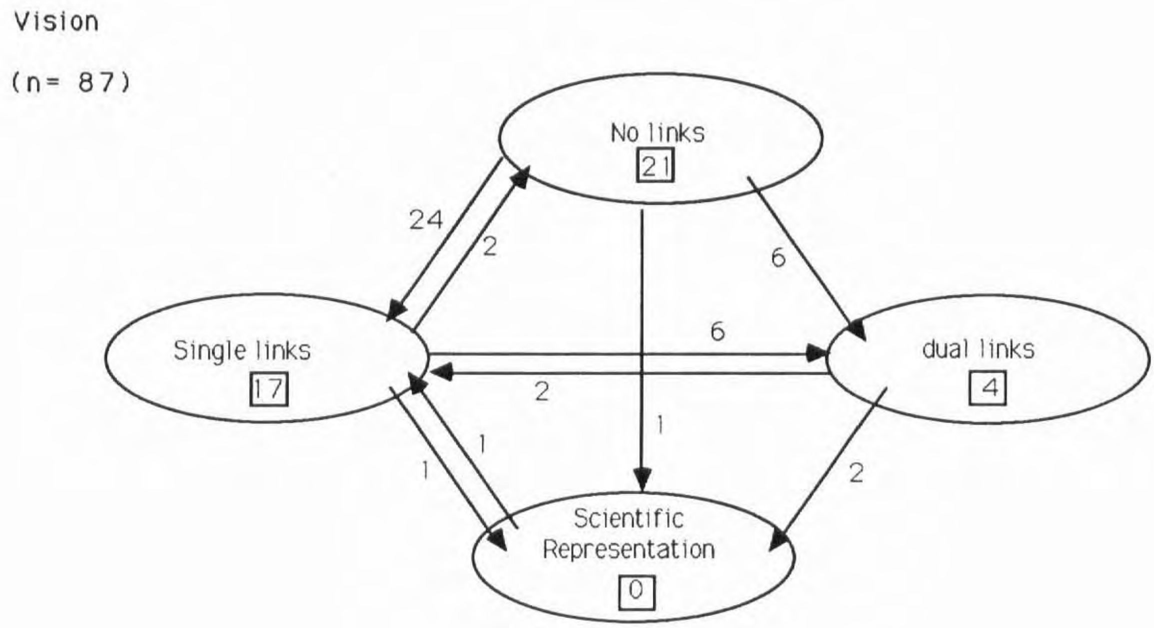


Table 8.3. Conceptual Map of Changes in Children's Response to Explain Vision (Lower Juniors)



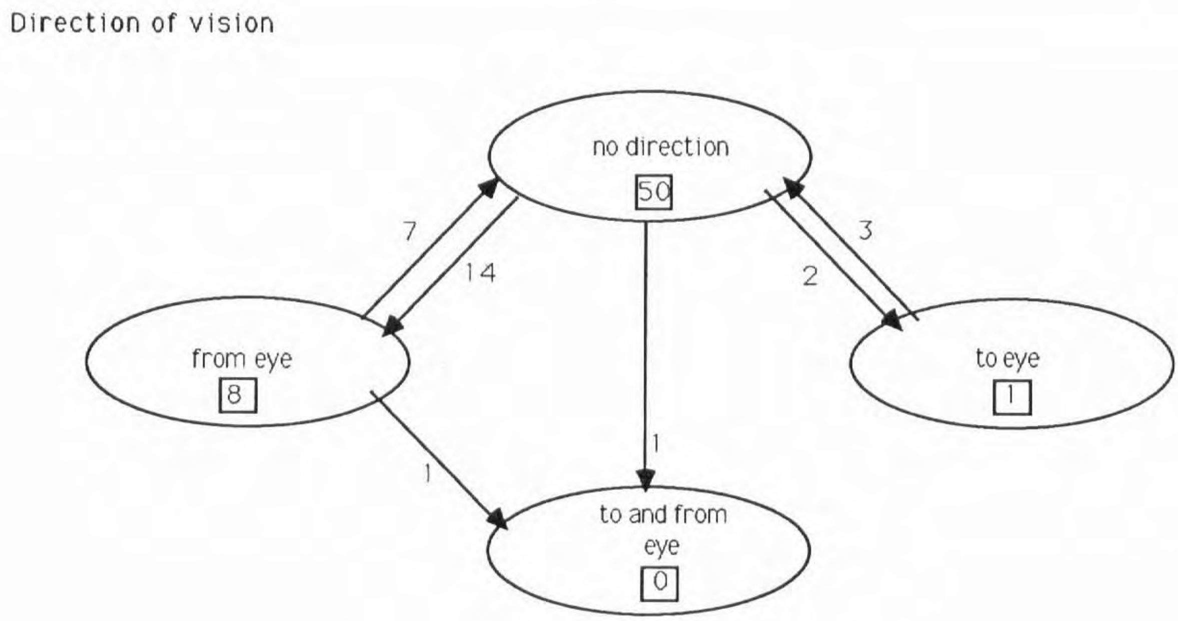
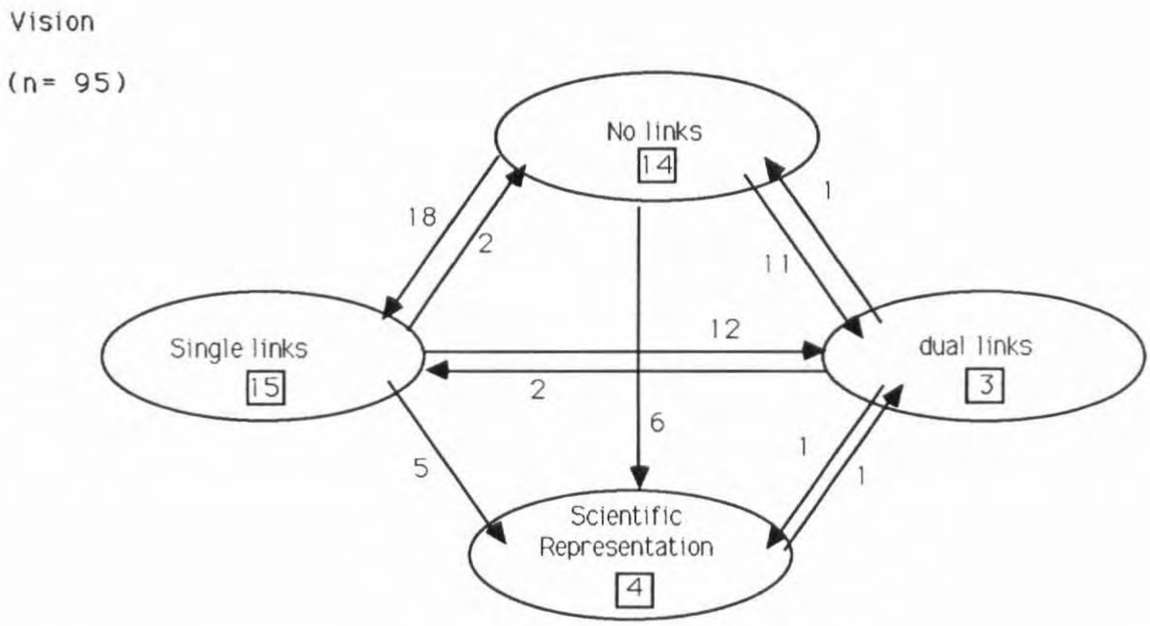
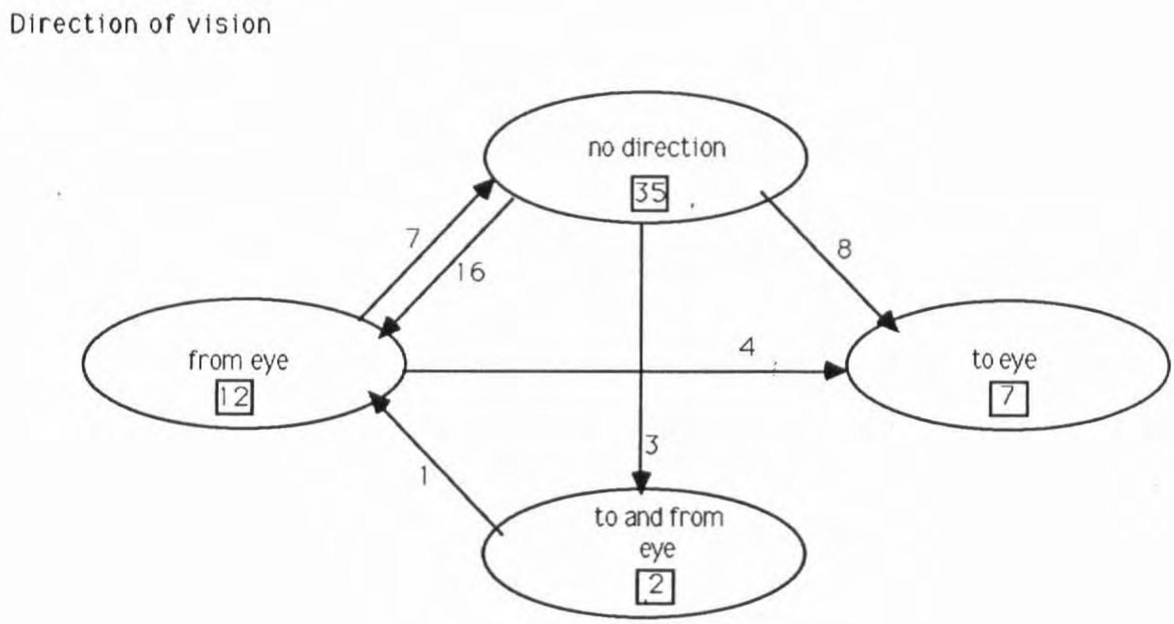


Table 8.4. Conceptual Map of Changes in Children's Response to Explain Vision (Upper Juniors)





The data in these charts can be summarised in tabular form

Table 8.5. Summary figures for changes in children's representations of light.

		No Change	Change to more features of a scientific model	Change to less features of a scientific model
UPPER				
JUNIORS	Representations	40	46	7
(n=93)	Direction	58	31	4
LOWER				
JUNIORS	Representations	65	22	3
(n=90)	Directions	76	8	6

A chi-squared test of the figures in Table 8.5 shows that there was a significant difference ($p<0.01$) for representations and directions between upper and lower juniors. This confirms the analysis of the networks which showed that more change was occurring for the upper juniors than the lower juniors. An analysis of the response for individual items shows that the main contribution to this difference was provided by responses to questions about seeing a book. This would support the notion that it was only upper junior children who are more likely to develop a model of light which is applicable to situations where the source of light is not evident.

The other feature of this analysis is that there were many more children showing no sense of direction i.e no arrows in their drawings of light, both before and after the intervention, compared to those that showed no representation of light. This merely shows that children are often prepared to draw links without indicating a sense of direction. In the case of beams or particle representations, directions were only very rarely indicated.

Table 8.6 shows similar figures for children's ideas about vision and the changes that occurred.

Table 8.6. Summary figures for changes in children's ideas of vision.

		No Change	Change to more features of a scientific model	Change to less features of of a scientific model
UPPER				
JUNIORS	Vision	36	53	6
(n=95)	Direction	56	31	8
LOWER				
JUNIORS	Vision	42	40	5
(n=87)	Directions	59	18	10

There was no significant difference between the upper and lower juniors in the changes that have taken place for their ideas of vision or the direction they showed in their explanations. This is perhaps surprising in that it implies that the intervention has had more effect for lower juniors than that indicated by the network analysis.

More insight into the changes is provided by looking at the responses to particular questions using this method of analysis. The figures for the overall results are shown in Table 8.7 & 8.8

Table 8.7. Number of children who showed *NO CHANGE* on questions eliciting representations of light

Question	*Candle*	*Book*	*Clock*
UPPER JUNIORS	10(34)[1]	17(30)	13(29)
Direction indicated	16	22	20
LOWER JUNIORS	13(30)	29(30)	23(30)
Direction Indicated	21	29	26

1 Figures in brackets show the number of responses on this item.

These figures show that, for specific questions, there has been little change in the representation elicited from the pupils. This is particularly true of activities associated with secondary sources of light for lower junior pupils. This would suggest that the intervention has had little success in helping children of this age construct a model which represents the role played by light in seeing these objects. There is more success in viewing primary sources where the origin of the light is more tangible. This is confirmed by the figures in Table 8.8 which shows very few lower junior children have moved to a more sophisticated understanding of light for secondary sources.

(contd overleaf)

Table 8.8. Number of children who showed *change* to a more sophisticated representation of light.

Question	*Candle*	*Book*	*Clock*
UPPER JUNIORS	21(34)	13(30)	12(29)
Direction indicated	14	8	9
LOWER JUNIORS	16(30)	1(30)	5(30)
Direction Indicated	3	1	4

The figures show that the predominant shift has been for upper juniors and that the largest shift in the response provided, is to a representation showing more features of a scientific understanding for primary sources i.e the candle. This is further evidence that children find it difficult to interpret or explain the phenomena where there is no evident source of light.

A similar analysis of individual responses to elicitation questions about vision was also done.

Table 8.9 Number of children who showed *NO CHANGE* on questions eliciting ideas about vision.

Question	Candle	Book	Clock
UPPER JUNIORS	15(35)	12(31)	9(29)
Direction indicated	17	18	21
LOWER JUNIORS	11(29)	18(29)	13(29)
Direction Indicated	18	21	20

Table 8.10 Number of children who showed *change* on questions eliciting ideas about vision to a more sophisticated understanding.

Question	*Candle*	*Book*	*Clock*
UPPER JUNIORS	17(35)	18(31)	18(29)
Direction indicated	14	10	7
LOWER JUNIORS	15(29)	9(29)	16(29)
Direction Indicated	7	6	5

In comparison to the figures for children's representations of light, the data in Table 8.9 & 8.10 reflects that there has been more change in pupil's models of vision and the ideas that they are using as a result of the intervention. They are similar in that the change has been more substantial for upper juniors than for lower juniors.

In all cases the change that has happened has had more effect on the nature of the link than on any sense of direction indicated in the responses. An explanation for this is difficult to provide, other than that the work helped to establish a more concrete representation of the link between light, source and object. Children may not have considered the direction as being something of substantial significance. Many failed to show any sense of direction in their responses to explain vision or of their representation of light.

In conclusion, these data provide a more detailed picture of where changes in children's ideas have occurred. They support the analysis of the networks, in showing that there has been some change, and that has been most significant for upper juniors. It also shows the lack of stability of children's ideas since the picture presented by the data is one of greater overall change than observed in the network analysis. Not only are children developing, but clearly there are some children whose explanations and ideas are 'regressing'. This would support a model of development for children's ideas which is non-linear which may consist of five steps forward and one step back.

(contd overleaf)

Summary:

a. *An analysis of the changes in individual children shows that a few children provide dresponses which showed less features of a scientific understanding after the intervention. The overall effect of the intervention has been to develop the understanding of a large number of children whose responses showedmore features of a scientific understanding. However, substantial numbers showed no change in their responses.*

b. *The evidence from these data partially support the analysis provided by the networks, which is that the significant change in understanding has occurred for upper juniors.*

c. *There is noticeably less development in the representations and responses to explain phenomena associated with secondary sources such as a book and clocks. Very few children showed much development here. This would indicate that understanding how we see such objects is an area of conceptual difficulty for primary children.*

9. SUMMARY

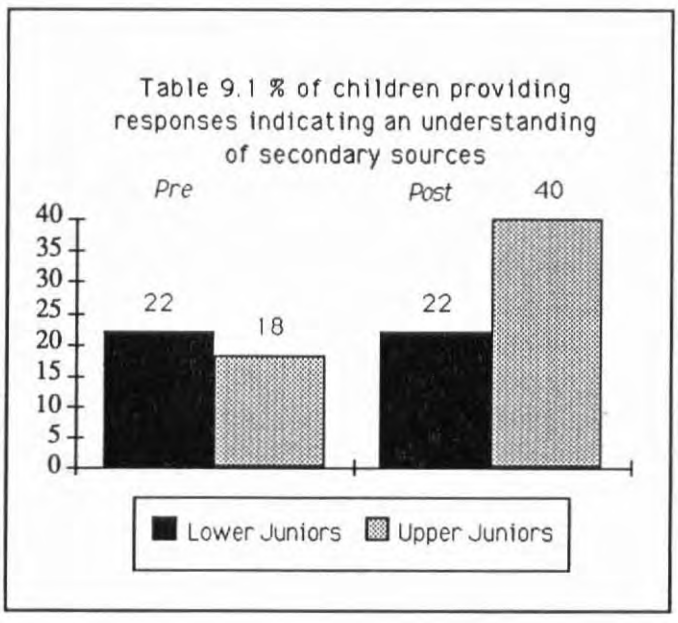
The following is a summary of the main findings described in section 7 and 8 and provides a resumé of the findings of this phase of the research. The data were obtained by an elicitation phase with children in the classroom from a set of practical experiences. This was known as the pre-intervention period. This was followed by an intervention phase when the children were allowed to try out activities and investigations related to the topic. Following this another set of data were obtained from the children using similar elicitation activities which is referred to here as the post-intervention phase.

The main areas of note were found to be:

9.1 Children's Understanding of Sources of Light.

All ages of children were able to show a knowledge of a wide range of sources and there was no evidence for any change as a result of the intervention or through development with age. However, it should be noted that children talked about primary sources nearly four times as often as they mentioned secondary sources of light.

The nature of children's understanding of secondary sources was probed in more detail but only a minority of children were able to offer any explanation that approximated to a 'scientific' understanding of these sources. The data shown in Table 9.1 indicates that upper junior children were developing a fuller understanding of secondary sources of light. This meant that they were able to provide an explanation which recognised the true source of the light. However an examination of the data by splitting it by age, regardless of whether it was collected pre-intervention or post-intervention, shows evidence that this change is possibly occurring by experiential development.



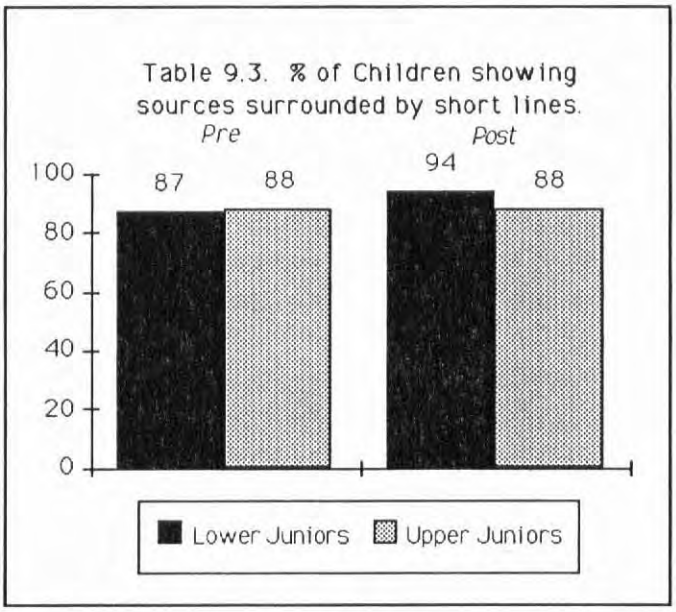
The most noticeable feature shown by the data is that there was very little change in children's understanding of sources of light as a result of this intervention. Table 9.2 shows the mean number of sources provided by children of both groups before and after the intervention.

Table 9.2. Mean Number of Primary Sources indicated

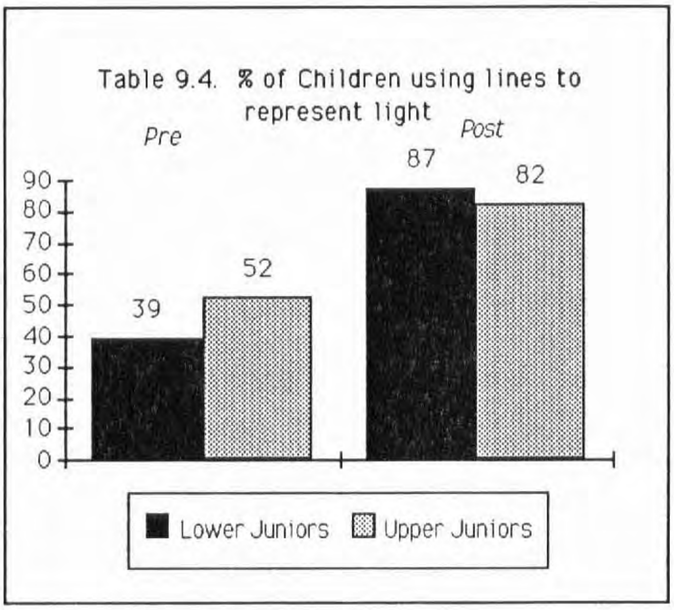
	Pre-Intervention		*Post-Intervention*	
	Lower Juniors	Upper Juniors	Lower Juniors	Upper Juniors
Mean number of primary sources shown per individual	3.5	4.0	3.6	4.0

9.2 Children's representations of light:

The representations used by children to show light were another prominent feature of children's work. Firstly, it was apparent that nearly all children's drawings would show light around sources represented by short lines (Table 9.3).



However the use of extensive lines e.g lines that linked source and the object or source and the eye, was limited prior to the intervention (Table 9.4). One notable effect of the intervention was the increase in the number of children who used this form of representation for light in their responses. Upper Junior children in particular made significantly greater use of lines with arrows to indicate a sense of direction.



Another notable feature of children's representations were that those used by the upper junior children became more varied and context dependent. Significantly more children used dual representations of light in an elicitation of their understanding after the intervention. These data are shown in Table 9.5. A closer examination of the data shows that part of this is accounted for by an increase in the use of beams to represent light.

Table 9.5. Percentage of children using more than one representation for light

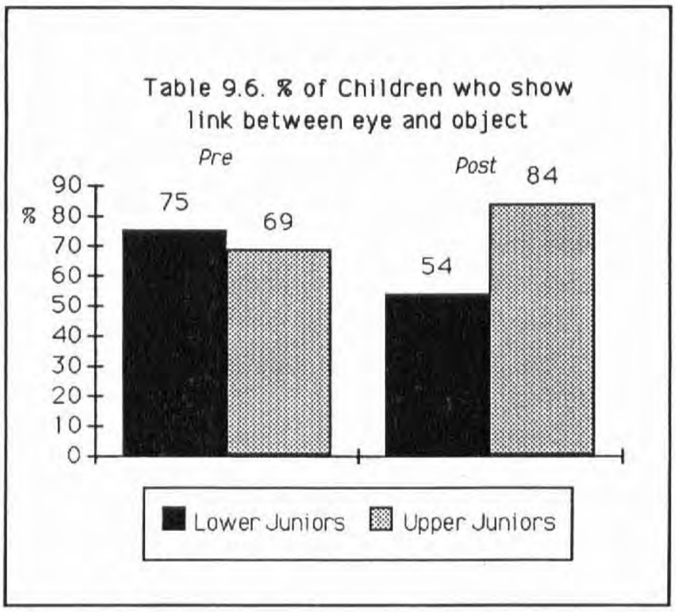
	Pre-Intervention		*Post-Intervention*	
	Lower Juniors	Upper Juniors	Lower Juniors	Upper Juniors
% of children providing dual representations	26	27	48	61

Finally, it is worth noting that very few children showed no representation of light. For many lower junior children though, this representation was limited to 'simple' lines surrounding sources.

9.3 Children's responses to explain vision:

Table 9.6 shows that many children were able to provide responses which indicated a link between eye and object. The majority of these responses incorporated a sense of direction to the link.

However, a sizeable proportion of lower junior children (35%) provided responses which showed no explanation for vision. A possible explanation is that vision is non-problematic for them and that 'we see with our eyes' was sufficient to account for the phenomena.



The most noticeable effect of the intervention on children's understanding was the increased use of dual links i.e eye-object and object-source by upper junior children (Table 9.7) coupled with a decreased use by lower junior children.

Table 9.7 Percentage of responses using dual links to explain vision

	Pre-Intervention		*Post-Intervention*	
	Lower Juniors	Upper Juniors	Lower Juniors	Upper Juniors
% of responses	30	7	18	45

However, this was accompanied by an increased use of dual models reflecting a greater context dependence of the response. The implication would be that whilst such work was developing children's understanding, their understanding was in a process of assimilation which is fluid. The children lacked any strong sense of coherence about their ideas which would allow a consistent interpretation of a range of experience. Another consequence would be that such work was possibly more appropriate to upper junior children as there was little evidence that the idea of dual links was assimilable by younger children

For lower junior children the two significant effects of the intervention were an increase in the number of responses showing single links between object and eye, and an associated decrease in those responses which provided no explanation of vision. From a developmental perspective, this could be regarded as a stage necessary for the development of a fuller understanding and a positive feature of this work. However there were no data obtained in this study which can confirm or refute this suggestion.

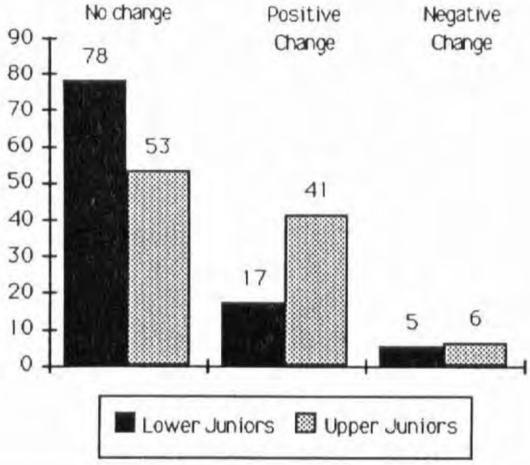
d. Context dependence:

A strong feature of the data obtained from the children was the context dependent nature of many of the responses within the same elicitation. The data to support this are shown in Table 7.15. There was insufficient time to probe whether the children perceived any conflict in their use of dual models to represent light or explain vision. For upper juniors, the effect of the intervention was to make such responses more common and there is little evidence to clarify what caused this change.

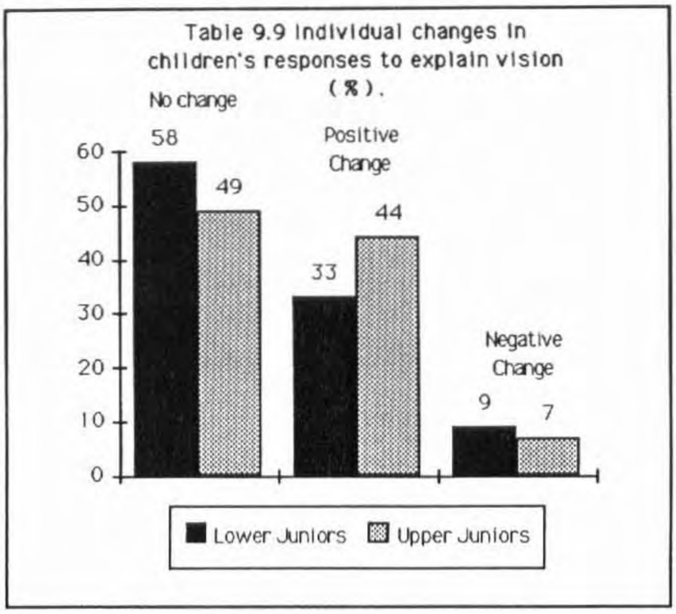
e. Change in Individual Children

The data were also analysed to examine the changes that had occurred in individual children. This was done by identifying common key features of children's responses e.g whether they used lines or blobs and whether they used single links or dual links. Similar questions were used before and after the intervention and the responses analysed to establish whether a move towards features of a more scientific understanding had occurred; whether the child's response showed features indicating regression or whether there had been no change in their response. These changes are represented by the concept development maps shown in Tables 8.1 to 8.4. Summary figures for individual changes in children's representation of light and their explanations for vision are shown in table 9.8 and 9.9.

Table 9.8 Individual changes in children's representations of light (%).



These show clearly that the predominant effect of the intervention has been positive in that children's responses show more features of a scientific understanding of light and that there was a greater change for upper junior children. However, the major feature is that for a large majority of children, there was no change in their response. This analysis supports that of the networks which show that the changes were predominantly for upper juniors who show more features of a scientific understanding.



A closer analysis of the data shows that there was less development in the representations and responses to explain phenomena associated with secondary sources such as a book and a clock (Table 8.8 and 8.9). Very few children showed a positive change here and this would indicate that understanding how we see objects which are not primary sources of light was an area of conceptual difficulty for primary children.

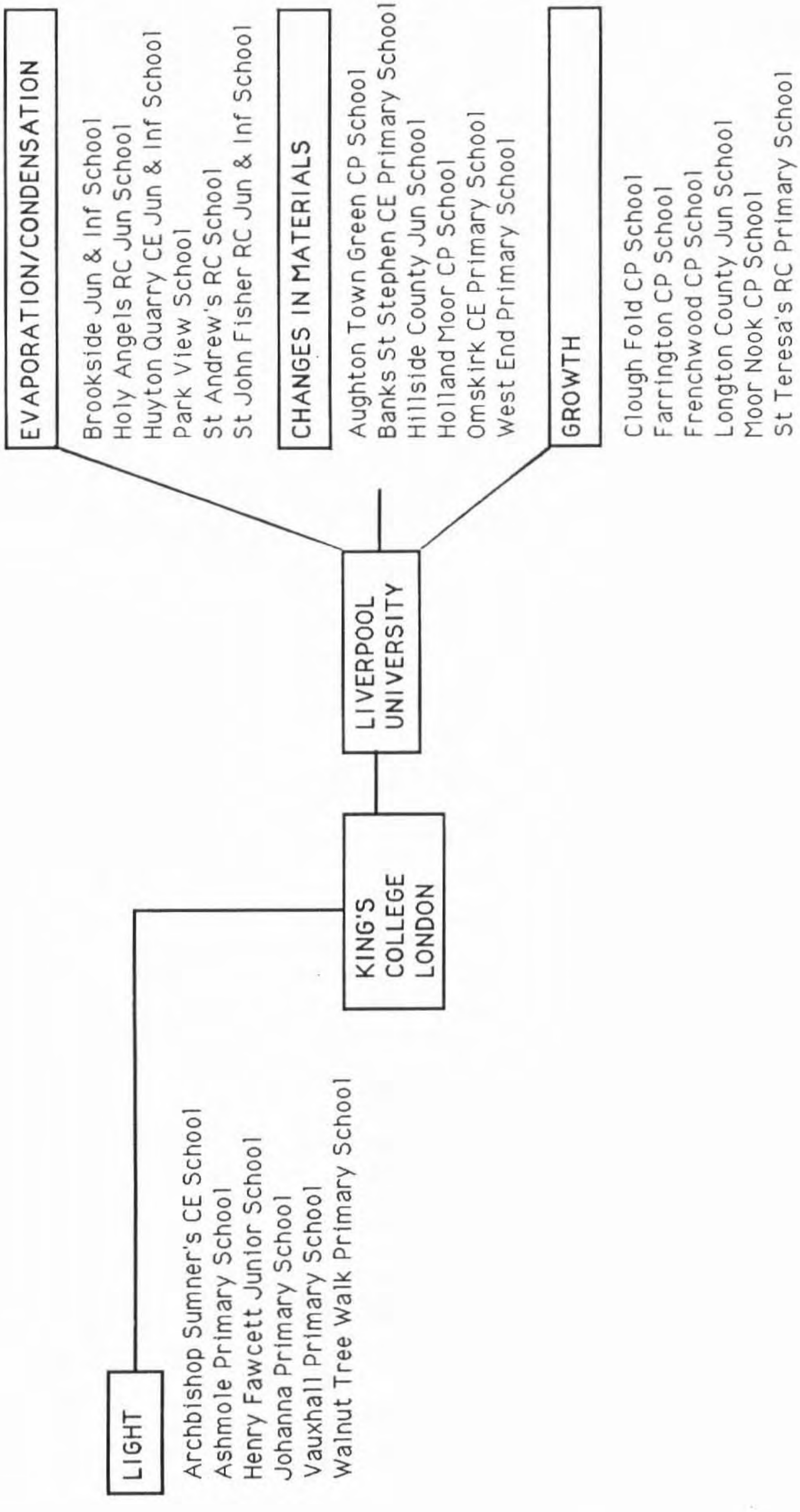
APPENDIX 1

Schools and teachers participating in the project

ILEA

Inspector for Science Education: John Wray

Schools	***Headteacher***	***Teachers***
Ashmole Primary	Ms P.Turnbull	Mrs M. Hutchinson
Henry Fawcett Junior	Mr F.S. Curle	Ms R. Newlove Mrs M. Robinson
Johanna Primary	Mr J.W. Hines	Mrs D. Carter Ms R.Hines Ms H. Ogbonna
Vauxhall Primary	Miss G. Brunt	Ms D. Gordon Mr V. Hayes
Walnut Tree Walk	Mrs V. Phahle	Mrs Wai-choo Tsang


EVAPORATION/CONDENSATION
Brookside Jun & Inf School
Holy Angels RC Jun School
Huyton Quarry CE Jun & Inf School
Park View School
St Andrew's RC School
St John Fisher RC Jun & Inf School
CHANGES IN MATERIALS
Aughton Town Green CP School
Banks St Stephen CE Primary School
Hillside County Jun School
Holland Moor CP School
Omskirk CE Primary School
West End Primary School
GROWTH
Clough Fold CP School
Farrington CP School
Frenchwood CP School
Longton County Jun School
Moor Nook CP School
St Teresa's RC Primary School
LIVERPOOL UNIVERSITY
KING'S COLLEGE LONDON
LIGHT
Archbishop Sumner's CE School
Ashmole Primary School
Henry Fawcett Junior School
Johanna Primary School
Vauxhall Primary School
Walnut Tree Walk Primary School

APPENDIX 2

Questions used in initial phase of research.

These questions were used in the first phase of the research to explore children's understanding of the topic and to evaluate which questions were of particular value in eliciting such understanding.

Light

1. Where is light coming from at the moment?
2. How does light get here?
3. What happens to light at night?
4. What is the darkest place that you can remember?
5. Why was it so dark?
6. How do light reflectors work?
7. How can we find out which is the best reflector?
8. Can cats see in the dark?
9. Where is the light in this room?
10. Where does the light come from at night when you are watching TV?
11. Write down as many places as possible where light comes from.
12. Very young children think they have disappeared if they cover their head. Why do they believe this?
13. Look at the candle. What has to happen for you to see it?
14. How would you explain seeing to a younger child? Do a drawing to show what you mean.

Mirrors and Torches

1. Where are all the different places that mirrors are used?
2. Can you use a mirror to see this torch behind you?

3. What did you have to do to see the torch?
4. What do you see when you look in a mirror?
5. Would you be able to use a mirror in the dark?
6. What is a mirror-image?

Colour and Light

1. Close your eyes. Now close your eyes and cover them with your hands. Does it look different? If so, can you describe the difference?
2. Which colours are easiest to see
   a) in daylight?
   b) at night?
3. How could you test your answers to (2)?
4. Would we get the same answer for everybody?

Seeing

1. Can you see the light I have placed over there?
2. Why can some people see the light but others cannot?
3. Draw how you think we see the light.

Light and Shadows

1. Why does it go dark just before a storm?
2. What are shadows?
3. Where do you find shadows?
4. What are shadow puppets?

APPENDIX 3

Activities A - F

A. Places where light comes from

EQUIPMENT REQUIRED Drawing Paper
Pencils

Questions

1. Where is light coming from at the moment?

2. How does light get here from the sun?

3. What happens to light at night?

4. Draw pictures of all the things that give off light.

B. Reflectors

EQUIPMENT REQUIRED Plastic Bicycle Reflector
Torch
Drawing paper and pencils
Tape recorder

1. Switch on the torch and shine it on the reflector.

   How do you think reflectors work?

2. Would the reflector work in absolute darkness?

   Why not?

3. Do a drawing to show how the reflector works when the torch is shone on it.

C. Torch and Mirror

EQUIPMENT Torch for each pair of children
Mirror
Drawing paper and pencils

1. Activity: One child holds the torch which is switched on behind the child's head. The second child is seated and given a plane mirror. He/she is asked to use the mirror to see the light from the torch.

2. Do a drawing to show how you used the mirror to see the light from the torch behind you.

3. Show on the drawing how you think the light travels.

4. Is any light coming towards you?

5. How would you explain what is happening?

D. Torch shining on paper

EQUIPMENT Torch
Piece of plain paper
Drawing paper and pencil

1. Switch the torch on and shine it at the piece of card.
   What do you see on the card?

2. How does light get to the card?

3. What happens to the light at the card?

4. Do a drawing to show what is happening when the torch is shone on the card.

E. Lighted Candle

EQUIPMENT NEEDED Candle standing in sand tray
Matches
Drawing papers and pencils

Activity: Teacher lights the candle

1. Do a drawing to show how you see the light from the candle?
2. How far does light from the candle travel?
3. Could you see the candle burning from the other side of a big room?

   Why is this? Explain your answer.
4. How do you think you see the light from the candle?

F. Seeing

EQUIPMENT NEEDED

Matches
Book
Drawing of 2 pupils looking at clock
Drawing paper & pencils

1 (a) Look at the book. How would you explain to you younger brother or sister how we see the book?

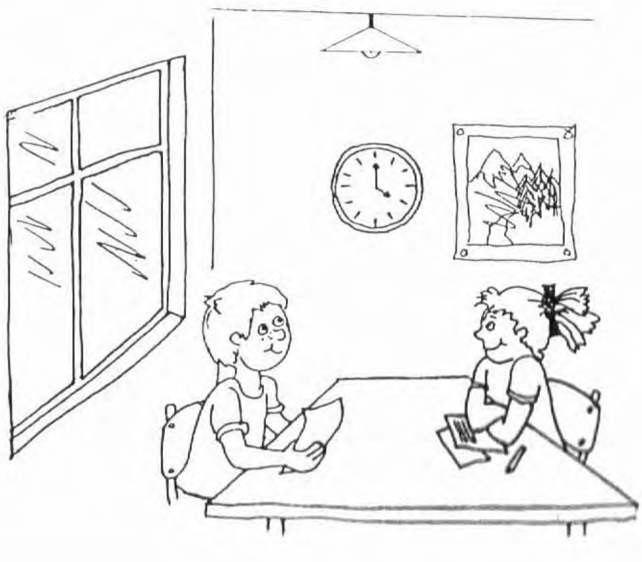
(b) Do a drawing to show how we see the book.

2. Explain what happens to our sight if there is no light. ?

3. How does light help us to see?

4. Look at the drawing beneath which shows two children in a classroom

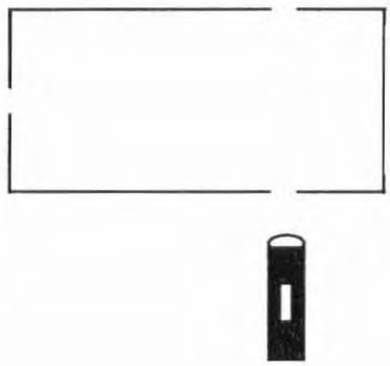
   Add to the drawing to show how you think the children see the clock.



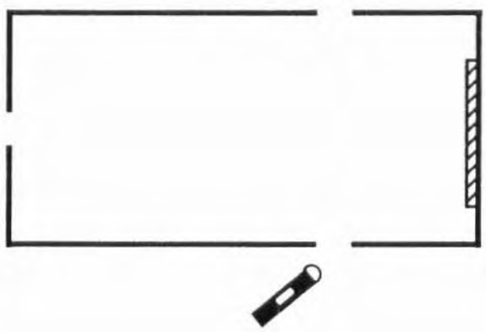
Additional Questions

The following are two additional questions that were added to the activities to be used in the elicitation after the intervention.

1. Look at this diagram. It shows a box from on top with two holes, a mirror and a torch. Add to the picture to show where the light goes.



Now add to this picture to show where the light is here.



2. Light is all around us. Write three sentences about light. Try and include the word 'light' in your sentence.

APPENDIX 4

Experiences with Light

Teachers' Notes

Bouncing light around a Table

Equipment Needed

Torch (Fairly bright, powerful torch needed)
4 Plastic Mirrors
Piece of white card
Plasticene

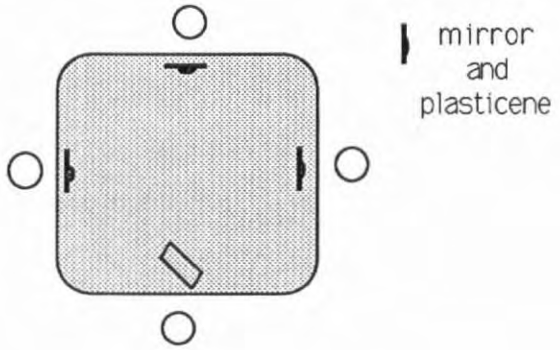
Aims

a) To introduce children to the idea that light can be reflected off shiny objects.

b) To develop the idea that light is travelling from one object to another.

c) To develop a model of representing light in drawings and diagrams.

This exercise should be posed as a simple game with light for children. The object is to send light from the torch by bouncing from one mirror to another till it is returned to the eye of the first person. The diagram shows the normal arrangement for doing this. Children in groups of four, should be introduced to this as a problem/game which they are asked to hypothesise an answer to first i.e



How could we bounce the light from this torch around the four sides of the table?

The activity can be structured by dividing it into four tasks:

Activity 1: Draw a diagram to show how you think light from the torch could be sent around the four sides of a table.

Activity 2: Using the mirrors, see if you can do this as a group.

Activity 3: Draw a diagram to show how you managed to do this task.

Activity 4: Imagine that you are a scientist, trying to find out a bit more about light. What would this activity have told you about light?

Investigating Shadows

EQUIPMENT NEEDED		
	Torch	Plasticene
	Small Stick	Pencil
	Ruler	Card
	Scissors	Paper
	Shoe Box	Sellotape
	Cocktail Sticks	

Aims:

a) To develop the idea that light is travelling from one object to another

b) To develop a model of representing light in drawings and diagrams

c) To provide an opportunity to examine the idea that shadows are formed by blockages of light.

d) To develop the idea that sharp shadows form because light travels in straight lines.

The shadow activities can be presented as prediction exercises. The children can be asked to guess or predict where different sized shadows form and then test their predictions. This allows them to challenge their own ideas and develop them. Children can work in pairs or groups for these activities .

Before the activity, the children can be involved in group discussion provoked by such questions as

What produces a shadow?
When do we get shadows?
Are shadows sharp or fuzzy?
Why are shadows sharp?

Children should have an opportunity to discuss these questions and record their ideas.

Discussion can be followed by the following tasks.

Activity 1: Draw where you think a shadow will form when a torch is shone on a pencil.

Activity 2: Try out this activity. Record your result.

Activity 3: Draw where you think a torch should be held to obtain

a) A shadow which is larger than a pencil.
b) A shadow which is smaller than a pencil.

Activity 4: Try out this activity. Record what you found out as drawing.

Activity 5: Where can you place a torch so that it shines on a stick and produces no shadow?

The Light Boxes Activity

EQUIPMENT NEEDED

1 Shoe Box
Mirror
Torch

Aims·

a) To provide children an opportunity to explore how light travels.

b) To develop a model that light travels and travels in straight lines.

c) To see that light can be bounced off mirrors.

d) To observe that light cannot be seen travelling from one place to another.

The light box has two small holes on opposite sides, a viewing slot and a small mirror taped to the inside back wall.

First ask the children to guess what they think will happen to the light when the torch is shone into one of the small holes. A worksheet is provided with suggestions for activities which can be used here.

The activity can then be done with the children working in pairs - one child looks through the viewing slot, preferably in a dark or shaded room. Another child shines the torch into one of the holes, first directly across the box, then at an angle onto the mirror. The children then swop roles and can be asked to discuss what they saw, where they thought the light was in the box and whether they had changed their minds from their original guesses. They can repeat this activity, looking into different holes until they are ready to complete the second activity. In this they are asked to complete drawings of the inside of the boxes showing where the light is, and whether they have changed their minds now that they have used the boxes with the torches.

Centre for Research in
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University of Liverpool

Centre for Educational Studies
King's College London

Primary SPACE Project

Science Processes and Concept Exploration

Research Reports

This Research Report is one of a series produced by the Primary SPACE Project under the direction of Professor Wynne Harlen (Department of Education, University of Liverpool) and Professor Paul Black (Centre for Educational Studies, King's College London). The reports describe collaborative research conducted with teachers aimed at understanding the development of young children's scientific ideas. The work has been funded by the Nuffield Foundation. Titles in the Research Report Series include:

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Forces	Earth in Space
Sound	Human Influence on the Earth
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Nuffield Primary SPACE Science Course

Materials for pupils and teachers to be published by Nuffield-Chelsea Curriculum Trust and Unwin Hyman

In the next stage of its work, the SPACE project is working with the Nuffield-Chelsea Curriculum Trust and the publishers Unwin Hyman.

The research results are being developed into materials for teachers and pupils, and are being tested in schools. The publications will cover the provisions of the National Curriculum for Science in Key Stages 1 and 2, and will include:

- A Teachers' Guide
- 12 Teachers' Theme Guides for Key Stage 2
- 3 Teachers' Theme Guides for Key Stage 1
- Complementary Pupils' Booklets
- An In-service Training Package for Schools or Groups of Schools

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