5. CHILDREN'S IDEAS

5.1 An informal look at childrens' ideas

Examination of the data showed four areas of particular interest in the work produced by children. These were

a. Children's ideas about sources of light

b. Children's representations of light

c. Children's understanding of vision

d. The context dependence of the answers

5.2 Sources of Light

Children were asked to draw pictures of all the different things that they think can give off light. The following diagrams show typical drawings provided by children of differing ages.

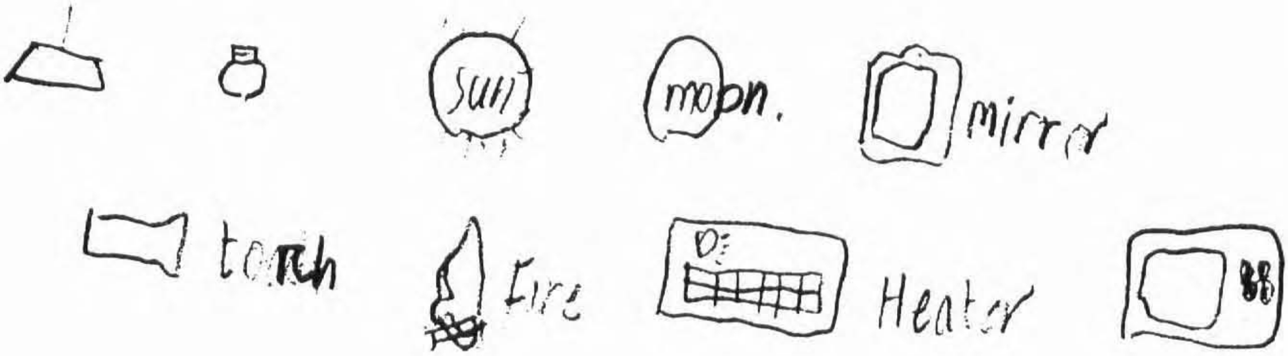

Fig 5.1 Age 8

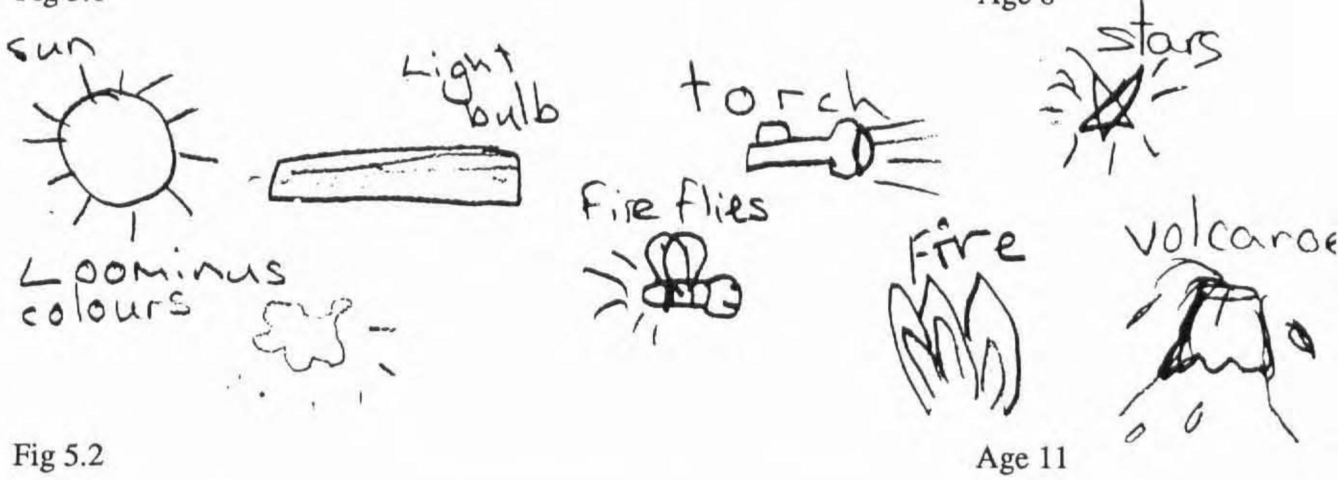

Fig 5.2 Age 11

The most interesting feature was the wide range of sources that children were easily able to think of and draw. This range showed little variation with age (Fig 5.1 & 5.2), though as these drawings show, these are predominantly primary sources. Some drawings did include reflectors and windows but these were much rarer. When children did mention secondary sources such as the ceiling, the window or sky, there was generally no further explanation of the nature of the source. A few children would add to their explanation by saying that 'the light is coming through the window from the sun.' thus demonstrating an awareness of the secondary nature of the source. It is possible that the use of the phrase 'give off' in the question, focuses children's thinking on primary sources.

Very few children showed less than three sources and many drew in excess of 6. The other feature was that there was no marked change with age as to the number of sources or the nature of the drawings. This data suggests that the idea of a source of light and an awareness of a wide variety of sources, is a well established concept by the age of 7/8, the youngest age which this study dealt with. Perhaps this is not surprising, because, if children's understandings are based in their perceptions, then everyday life provides a wealth of observations of a range of light sources.

Another notable aspect was the tendency of children to include simple lines on many of the sources, particularly the sun and light bulbs. The reasons for this representation were not clear. When asked why they had used such lines, some children commented that 'that is how you draw the sun'. However, Fig 5.2 is an example where this representation is extended to other light sources and for most children it shows the first representation of light as a line. A partial explanation may lie in the fact that the eye 'sees' lines coming off many point sources, particularly on wet nights or from bulbs with clear glass envelopes due to refraction of the light. In a later investigation with bulbs in the electricity topic, one child remarked 'Look, you can see the light coming off in lines.' This would suggest that the children are simply representing in their drawings an accurate representation of what they observe.

The source most commonly mentioned by children was the sun. The strength of this idea is supported by the exploration of the 'growth' topic where only two children mention a light source other than the sun as being necessary for growth. This is also confirmed by an exercise in which children were asked to write three sentences that included the word 'light'. A large number contained statements of the form 'Light comes from the sun.'

However, children had much more difficulty postulating a mechanism as to how light travels and arrives on earth to explain how light gets here. The most sophisticated would provide explanations of the form

'The sun beams light down onto the earth'

or show drawings of the form shown in Fig 5.3.

Fig 5.3 Age 7

Only a few showed clear evidence of a model of light which is travelling (Fig 5.4). Similarly in the research on sound, it was found that young children had no notion of sound travelling - they hear because they listen hard.

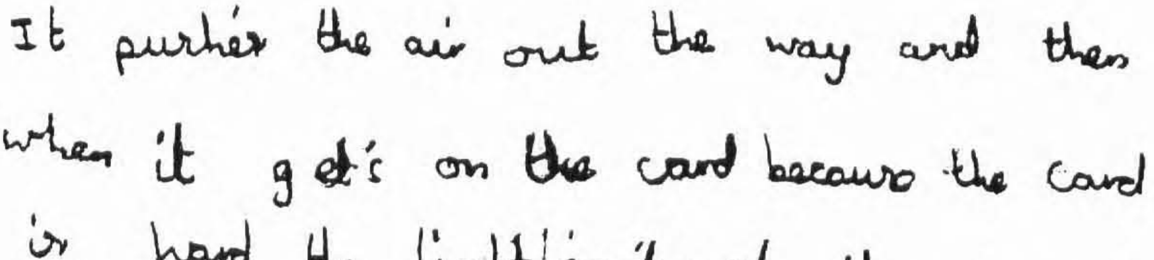
It purhes the air out the way and then when it get's on the card becauro the card is hard the light can't get through so it get's stuck so you can see some liglt

Fig 5.4 Age 9

Interestingly, this answer reveals that this child had not yet understood the more difficult concept that not all the light stops at the card.

However, answers of this sophistication were generally rare and it was much more common to provide answers of the form, 'the sun', 'by rays' or 'it beams down'. Many children had no explanation for how the light arrived. No children were found who elaborated on these answers and no evidence was found that the scientist's abstraction of light as a ray, which propagates rectilinearly, is part of children's vocabulary and understanding at this age.

Another interesting feature was the range of children's astronomical ideas that were elicited in response to the question 'What happens to the light at night?'. There seems to be a distinction here between older children, who are developing an understanding that the world turns so that the sun shines on the other side, and younger children who provide other explanations. Typically older children would say

> *'The world turns so that the sun is on the other side.'*
> *'It comes from the sun and reflects from the moon'*

However, much more common were explanations that stated

> *'It goes off.'*
>
> *'The sun goes down and the moon takes its place.'*
>
> *'The clouds cover it.'*
>
> *'It moves to another part of the world because the sun moves.'*

Since these explanations did not reveal much about children's perceptions of light but rather their understanding of the world and the solar system, no attempt was made at any further analysis. However, they are revealing in that they show a range of astronomical models held by children and that there is some development across the age range.

5..3 Representations of Light

Examination of the drawings produced by children showed a wide variation in the representations of light produced by children from that of the mature scientist to none. It is impossible to see a 'light ray' although it can be made perceptible by scattering dust in its path. Hence any attempt at representation was seen as an effort by the child to make the imperceptible, perceptible, that is to concretise an abstraction. In such a situation it was of interest to examine what kind of representation would be used by children to show their thinking about light and its properties.[1]

In the elicitation activity there were five possible questions that required a drawing for an answer where children could have shown some representation of light. These were, showing how they saw the light from a torch placed behind their head in a mirror; how they saw a candle, a book and a clock and showing what happened to light as it travelled through a box with holes in. Clearly this exercise was difficult, particularly for lower junior children where the majority showed no representation. Those that did represent light, most commonly represented it as a line. Fig 5.5 shows a typical example.

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1 In analysing the data and discussing representations of light, links between the object and the eye were considered to show children's thinking about vision and sight rather than their thinking about light.

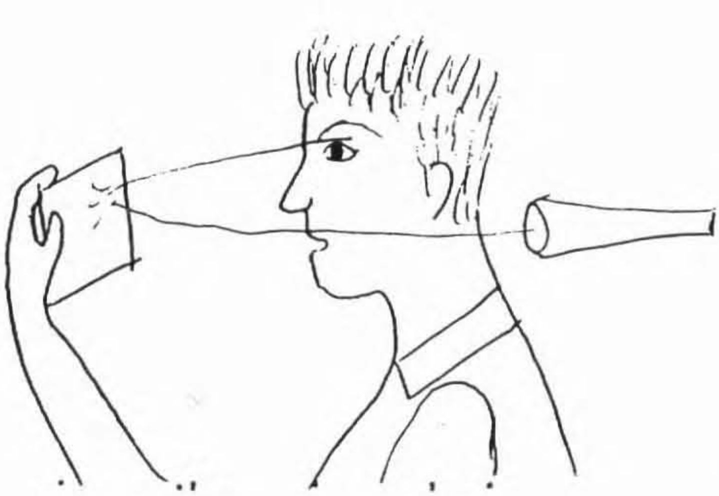


Fig 5.5 Age 9

Another common feature of the children's representations of light was the tendency to show a 'blob' of light on the mirror or torch. The term 'blob' was used by the research team to describe representations of light (on the mirror) such as that in Fig 5.5 and 5.6. Children would also tend to use a combination of 'beam' and 'blob' as in Fig 5.6 which was referred to as a 'dual' representation. The same child in a later question showed light represented as a line which was another example of the context dependence of the answer and dual representations.

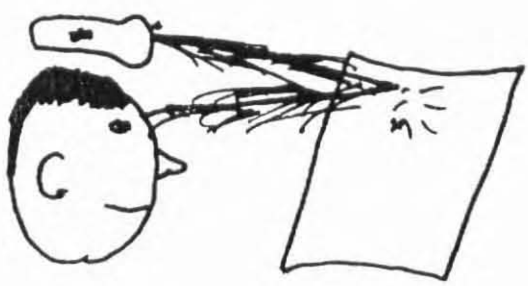


Fig 5.6 Age 8

The tendency to use lines may be an extension of the representation of light around sources such as the sun with short lines (Fig 5.1) which has been discussed. Nearly all children used this representation when drawing sources and very few individuals represented light as a line without showing the simple representation as well. If this was so, it could be seen as a pre-cursor or line of development to a more sophisticated model of light.

Other models that were used to represent light were particles. Here the light was drawn as a series of dots, beams of light (Fig 5.7) and occasionally a sea of light which was sketched into the drawing (Fig 5.8).

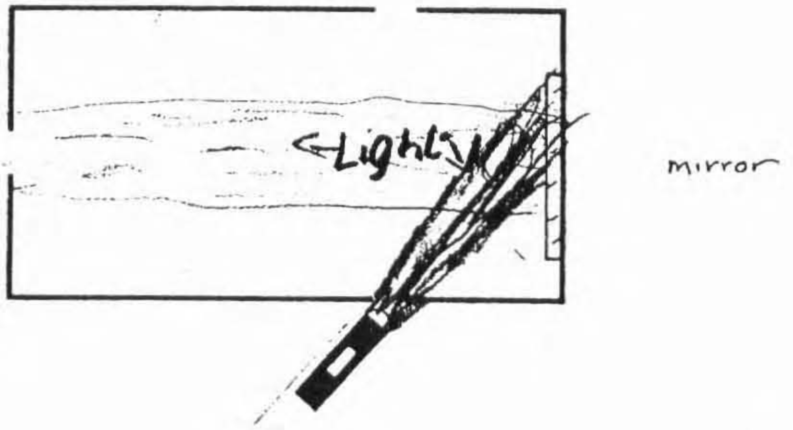


Fig 5.7 Age 11

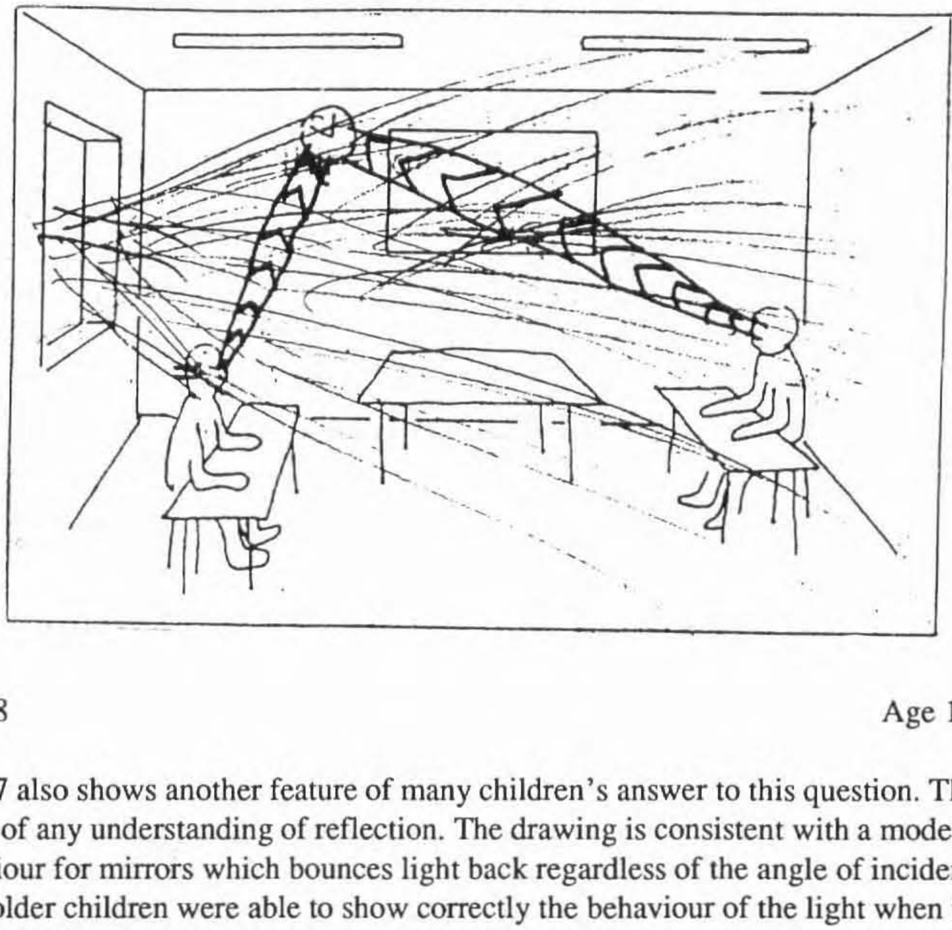


Fig 5.8 Age 11

Fig 5.7 also shows another feature of many children's answer to this question. This was a lack of any understanding of reflection. The drawing is consistent with a model of behaviour for mirrors which bounces light back regardless of the angle of incidence. Only older children were able to show correctly the behaviour of the light when incident on the mirror in this question. Fig 5.8 also indicates an understanding of vision which is discussed in section 7.1c.

Another important feature of the representations shown was the increasing number of children who indicated a specific direction of travel on the diagrams with increasing age (Fig 5.9). No direct request was made for such information and there is no evidence to explain why the direction was included.

However, such representations, typified by Fig 5.9, suggest that children are increasingly seeing light as something which travels and has a direction of travel which would indicate a development in their thinking. Obviously further questioning might reveal such a development and it is unfortunate that there was insufficient time to probe this progression further.

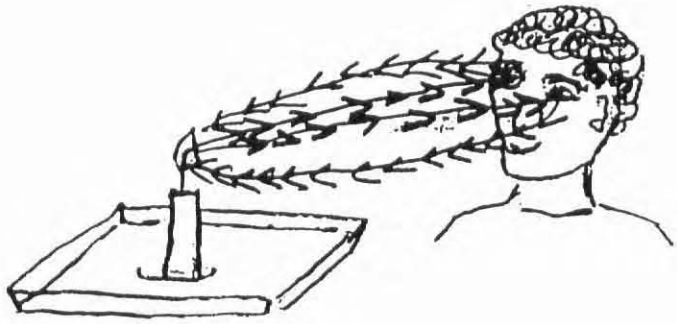


Fig 5.9 Age 11

In summary, a proportion of children were capable of showing a representation of light which was more than a simple representation (Fig 5.2) and the proportion increased with older children. The predominant representation was that of a straight line with several other methods shown, but representations could be context dependent. Older children could more readily indicate a direction of travel which may be an indication of a recognition that light travels.

5.4 Children's ideas of vision

Perhaps one of the most interesting features of this research was the wealth of data it exposed about the range of ideas that children hold about the nature of vision. Essentially, this can be divided into four areas.

i. No explanation
ii. Explanations without links
iii. Explanations with single links
iv. Explanations with dual links.

i. No explanation

For many children, particularly younger children, the process of vision appears to be non-problematic in that their drawings and explanations provide no indication of anything other than the simple act of looking. When asked to provide a drawing to show 'How you see a book?', there would be no information, other than the simple observable features (Fig 5.10).

Fig 5.10 Age 11

There was also evidence that some children's interpretation of the question was limited to a descriptive answer as their answers were literal drawings of what a book would look like. However, there were two other questions which were attempting to elicit the nature of the child's understanding of vision which compensated for such interpretations of the question. What was evident was that providing any explanation of viewing objects which are secondary sources of light e.g books, was particularly difficult. Many common-sense explanations and drawings of this form shown in Fig 5.11 were observed.

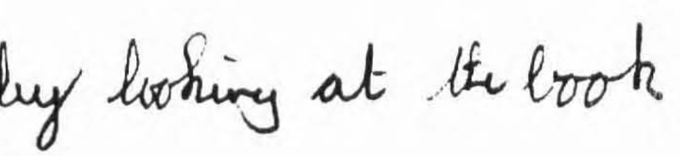


Fig 5.11 (a) Age 9 Fig 5.11 (b)

ii. Explanations without links

For some children, the explanation of how we see an object such as a book, candle or clock was not problematic. The explanation is a simple mechanistic type which recognises that your eyes are essential to vision (Fig 5.12).

Fig 5.12 Age 11

No further explanation is needed and the impression given by the children was that the rationale is self-evident. Some responses of this form tie the explanation to the pupil of the eye which was seen as being involved in vision (Fig 5.13).

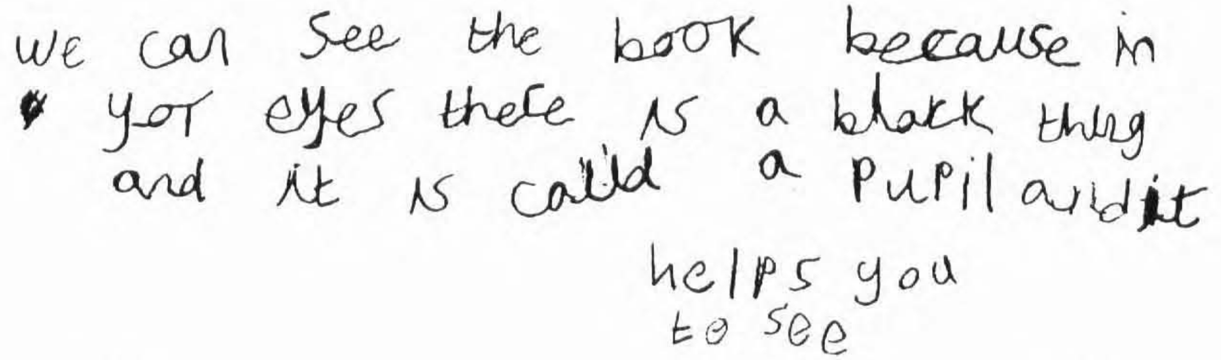


Fig 5.13 Age 8

The other aspect observed in these simple explanations was a recognition that light is needed for vision (Fig 5.14).

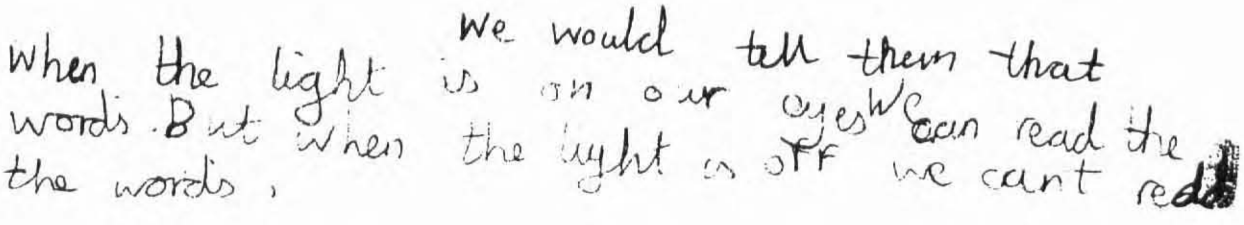


Fig 5.14 Age 10

Such an explanation acknowledges that light is a pre-requisite for vision but fails to provide further detail of the role played by light. In the post intervention elicitation, where children were asked to write three sentences about light, the statement that 'light is needed to see' was commonly expressed.

iii. Explanations in terms of simple links

Many children provided explanations or drawings that showed simple links between the eye and the object (Fig 5.15).

(contd overleaf)

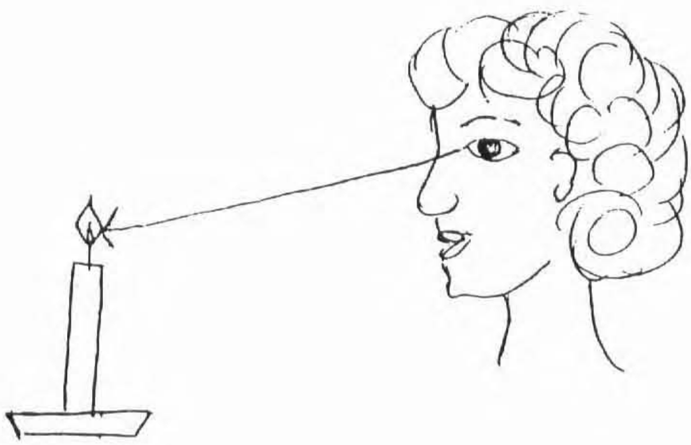


Fig 5.15 Age 10

The large number of such responses show that these children saw vision as an active process. This is not surprising and has been reported elsewhere in the literature. To look at an object, there is an action required of an individual to either move their head or eyes. The vocabulary and the metaphors of the language also imply action so that you 'give looks' i.e 'she gave me a look like daggers' or 'his eyes shone like pearls '. However, though many answers did show a direction, there were also answers which merely recognised the link and did not show any direction (Fig 5.16).

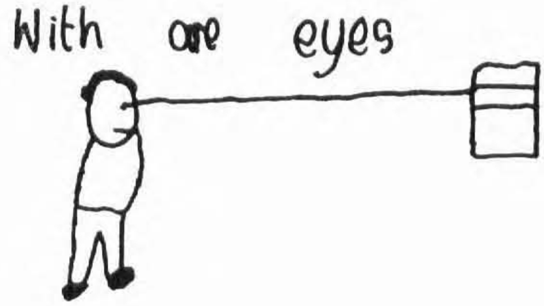


Fig 5.16 Age 8

The majority of such answers showed a representation for vision using lines. However, a few indicated the link in terms of particles (Fig 5.17). There was no evidence that this reflects a view of light but it did show a different conception of the link between eye and object consistent with a particle interpretation.

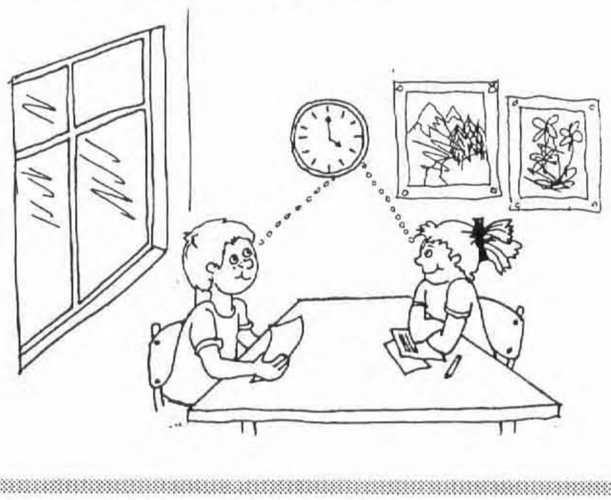


Fig 5.17 Age 10

Single links directed towards the eye are comparatively rare (Fig 5.18) which reflects the fact that only a very small minority of children had a model of vision which corresponds with the scientist's view.

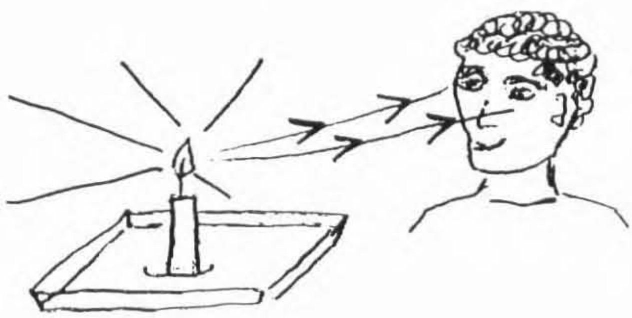


Fig 5.18 Age 10

iv. Dual links

A small but significant number of children recognised the need to show a source-object and object-eye link to explain vision. Identifying that 'light is necessary to see' and that 'we need our eyes to see with', they showed these two factors in a variety of forms. The simplest was that which shows the dual link with no direction (Fig 5.19).

The interesting feature of Fig 5.19 is that it also shows an attempt to reconcile these two ideas with a process of active vision. Light goes (presumably) to the eye and then to the mirror. However, nearly all dual representations showed a direction as well.

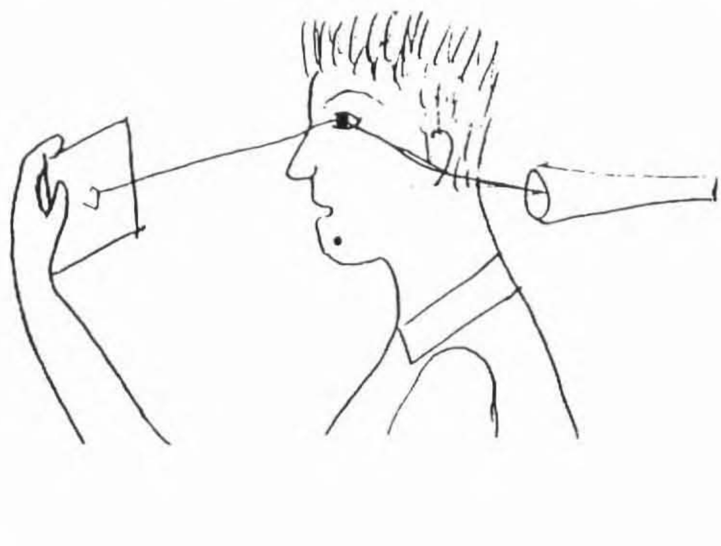


Fig 5.19 Age 11

The most common form of dual representation was one which showed the dual links both directed toward the object (Fig 5.20).

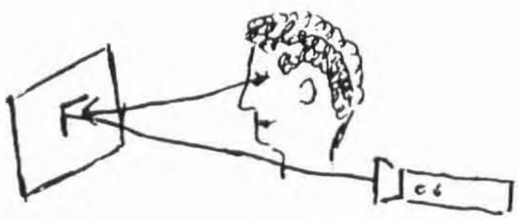


Fig 5.20 Age 10

This representation is a logical expression for children who believe that light 'gets stuck' once it reaches the object and fits with the conception of vision as being 'active'. This term is used to describe children who described and drew vision in terms of lines or rays emanating from the eye. Such a representation is clearly shown in Fig 5.21. Even though the object viewed is a primary source, children's diagrams still showed a representation of 'active vision'.

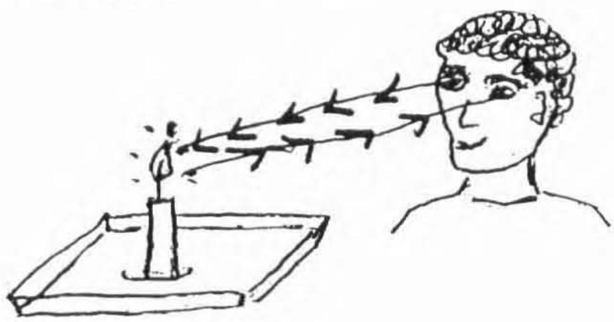


Fig 5.21 Age 7

However, some diagrams explaining how the light is viewed in a mirror, reveal that 'active vision' is a persistent concept which leads to representations of vision which contradict a simple observation that the torch is emitting light. Fig 5.22 shows an extension of active vision to the torch and an attempt to reconcile it with the emission of light from the torch. Lines are drawn to the mirror and then onto the torch but there is also a line from the torch towards the mirror.

Fig 5.22 Age 9

Another variation which again places pre-eminence on the notion that vision is active whilst recognising that light is necessary for vision, were drawings which showed the light coming to the eye and then passing to the object (Fig 5.23).

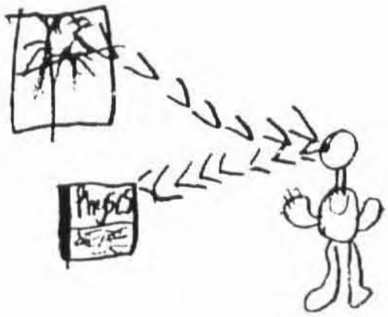


Fig 5.23 Age 10

Finally, there were a few children who show a representation consistent with the scientific view (Fig 5.24). Such children were a small minority and there was some evidence that the numbers increased with age.

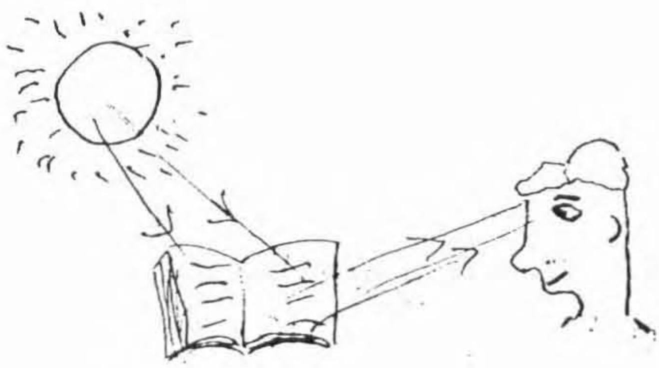


Fig 5.24 Age 10

Such examples for the book are comparatively rare and there are many more examples of a scientific representation for the torch and mirror (Fig 5.25). The simplest explanation for this would be that observations in the context of the torch and the mirror support the idea that light passes from the source to the mirror to the eye, as it is possible to see the light 'bouncing off' the mirror onto the face. However, there is no evidence to support such an idea with a secondary source of light such as a book.

Fig 5.25 Age 11

5.4 Context Dependence.

The other major feature of the answers and drawings provided by children was the context dependence of the answers. The explanation provided for vision by one child would vary from one question to another within a remarkably short time without any recognition of the of the contradictions that this raises for an adult. There are several possible explanations for this. The simplest would be to say that children saw these situations as instances of different phenomena. A light source shown in Fig 5.26(a) is very different from a book shown in Fig 5.26(b). Consequently the responses provided are different and non-problematic for the child. Similarly Fig 5.27(a) could be considered an instance of 'reflection' whilst Fig 5.27(b) an explanation of 'vision'.

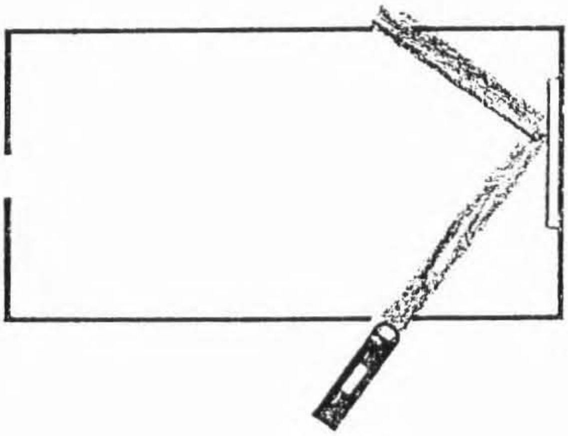
Fig 5.26 (a) Age 11 Fig 5.26 (b)

However, both responses were generated in response to questions about 'How we see'. It is interesting that this child recognised that the candle emitting light is a primary source, which enters the eye whilst with secondary sources, she fell back on the view that vision is active. This would imply that it is impossible for children to develop a scientific view of vision until they are aware that objects such as books are capable of scattering light. Another example of this is shown in Fig 5.27(a) and Fig 5.27(b).

Fig 5.27(a) Age 9 Fig 5.27(b)

Clearly with a luminous source the light comes to the eye but when the source scatters light, the response shows an interpretation that used an explanation of vision as 'active'.

Similar examples can be found for the representations that children use in their drawings. Fig 5.28(a) shows light represented as a line and yet later, on the same occasion, this child used a beam to represent light (Fig 5.28(b)).



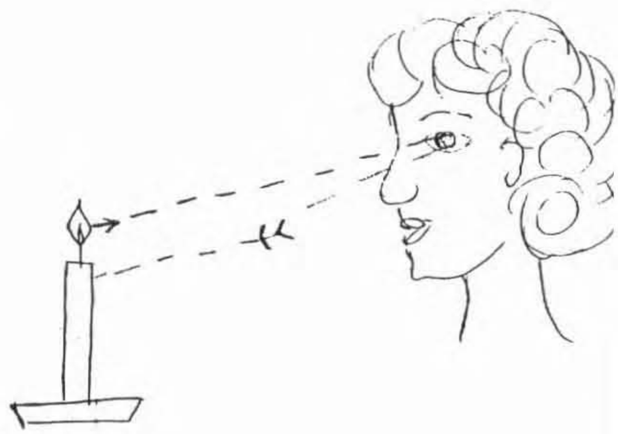


Fig 5.28(a) Age 10 Fig 5.28(b)

The previous examples show that children were using models which are specific to their observations within a particular context. Torches do appear to emit light in beams so the light was drawn as a beam whilst candles do not.

Context dependent responses were observed more often in older children as very rarely had younger children developed more sophisticated models of vision. The implication would be that children's ideas are fluid and lack generalisability, yet are evolving as they get older to incorporate a wider range of observable features which are context dependent. More sophisticated attempts would show object-eye and source-object links which reverted to only one of these links in another response. Table 7.10 shows the number of children using dual models to explain vision which are context dependent and data on this is presented in section 7.1d.

6. THE INTERVENTION PHASE

One of the primary aims of this project was to examine what potential there was for changing and modifying children's ideas so that they can become closer to the scientific ideas. To examine this, an intervention was designed that could be used by the teachers in the classroom. The design of the intervention was influenced by three factors

(a) A preliminary analysis of the data.

(b) The framework of a 'scientific' understanding reviewed earlier.

(c) The teachers' contributions and ideas.

The first elicitation phase had shown that many children had a very limited understanding of light that was rooted in observation. Very few children had a representation of light which consistently approached that of a line or rays and their models of vision were based on explanations that were mechanistic or personal e.g 'You need light to see with', 'You see with your eyes.'

The rationale underpinning the intervention was twofold. Firstly that children should be provided with an opportunity to express their own ideas and hypotheses about phenomena, and that experiences provided by the intervention should be appropriate to developing their thinking from their current conceptions. Secondly, that since one of the purposes of science education is to develop an understanding which is closer to the scientific perspective, intervention activities should facilitate the development of this understanding.

Thus for the design of the interventions, a list of concepts commensurate with a scientific understanding was compiled (3.3). These were then compared with the evidence of the nature of children's thinking observed from the data to guide the design of the interventions so that they would reflect the principles previously outlined. Intervention activities were selected that would require children to hypothesise about the way light travels and how they were able to see light, requiring them to use a representation of light.

It was considered unlikely that any limited intervention would achieve a major shift in children's understanding of vision. Therefore, it was felt that this phase should concentrate on providing experiences which would develop the simplest ideas in the framework; that light travels, and travels in straight lines. Activities which led to the development of these ideas would establish a solid platform for later work. In addition, they might lead incidentally to the growth of a more sophisticated understanding of vision which was more stable and less context-dependent.

Common to all these activities was a requirement that children should discuss and represent their ideas about possible solutions prior to any attempt and for the successful solution to be drawn and discussed with their peers and teacher.

Many of the teachers expressed a desire for simple activities that could be performed by groups within a topic-based approach, focussing on light. This would provide an informal context for teachers to introduce the activities and allow the children to try out their own ideas on a collaborative basis. The teachers were then able to take a non-directive role without losing enthusiasm for the work. Teachers had commented in an earlier meeting that the role expected of them was one that they were not used to. The work required that teachers should be less judgemental than normal and gave children an opportunity to discuss and express their own ideas without criticism from the teacher. In addition, the emphasis placed by the project on conceptual development was one that was unfamiliar to teachers.

Consequently a set of activities was designed for use by teachers that would allow children to test some of their own ideas and develop a wider experience of phenomena associated with light. One of the inherent problems in designing such activities is that the light does not perceptibly travel. As a result, the activities were all designed to help the development of such a hypothesis from their observations. Teachers were asked to avoid 'telling' children that light travelling in straight lines would explain what they see and allow children an opportunity to express and evaluate their own thoughts before contributing such an idea to the discussion.

All of the activities used simple materials and a common process of presenting to the children a simple piece of factual knowledge about light. A problem was then posed to the children who were asked to devise a solution to the problem, sketching their solution first and then testing their idea. Full details can be found in Appendix 4.

Activity 1: Bouncing Light around a table

This problem (Fig 6.1) was set in the context of a simple game for the children. Children were reminded that light can be 'bounced off ' i.e reflected from mirrors. The problem was posed as one of 'How could they make the light go round every side of the table?' A strong torch, mirrors and plasticene were provided and the children had to discuss a preliminary solution before attempting this exercise. When they had devised a possible solution,the children would work as a group and use the mirrors, held in position by the plasticene, to test their idea. The mirror angles could be adjusted easily and the light directed from one child to another.

The intention of such an exercise was that it would provide an experience which *may* develop the concept that light travels and goes in straight lines. Children would have to talk about a solution in terms of 'light going from one mirror to another' and implicitly recognising it as a medium which travels. Children's interest in performing this task was generally good though the manipulative skills required were quite demanding.

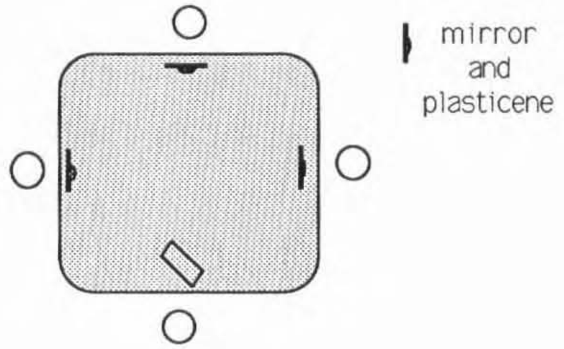


Fig 6.1

Activity 2: Investigating Shadows.

Again the intention of this activity was to develop the idea of light travelling through space in straight lines and to encourage the use and development of a method of representing light. The activities were presented as prediction exercises and children were asked to guess and predict the shapes of shadows formed by a variety of objects, to construct a method of testing their ideas and record their results afterwards. Teachers were asked to provide an opportunity for children to use their own ideas, by discussing with the group initially what caused shadows and when did we get lots of shadows. This activity was emphasised as an important process if any conceptual adjustment was to take place. No development of, or conflict with existing models, could occur unless the child was aware of his or her ideas.

Activity 3: Passing light through boxes.

This activity made use of shoe boxes with small holes positioned on each side(Fig 6.2). In addition, the box had a mirror placed at one end of it. Children were asked to predict where the light would go when the torch was turned on by adding to Fig 6.2 and then, to repeat this process in a second situation, where the torch was directed at the mirror through the hole in the side. As an activity, they set up the box with the torch in the situations shown and tested whether the light from the torch was visible at the various holes in the box.

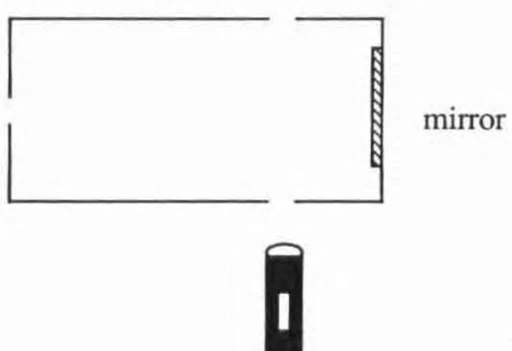


Fig 6.2

When they had completed the exercise, they were asked to draw again where they thought the light went in the box and compare their current thoughts with their previous drawings.

The intervention took place over a month and teachers were asked to try all activities with groups of children when appropriate to their normal classroom work. Teachers received a visit from one of the researchers during this phase of the work to provide support and guidance. In addition, researchers were involved in trying activities with groups of children.

Obviously, there is a methodological problem here in that there is a lack of definitive standardisation. However, one of the available afternoon meetings was spent in introducing the materials to the teachers, providing them with an opportunity to test and evaluate the materials and raise and share problems that might occur in the classroom. In addition, the extended time allowed for such material meant that all teachers had time to complete the interventions with all their pupils. This means that the work is not a tightly controlled research study but possibly provides better data about what is possible in normal situations facing teachers in normal classrooms. Finally, teachers were not restricted to these activities and some extended the work further to investigating light bulbs and work on colour.

The activities are different from a process approach in that they focus on conceptual understanding and its development at a level which would be appropriate to the existing ideas shown by children. In addition, the activities have provided an opportunity for children to test and evaluate their own ideas by experimentation. They represent a limited approach, constrained by the time available, which is a reflection of classroom realities. They do at least have the benefit of being an empirical response to the data gained from the initial elicitation of children and their design was based on an appreciation of the levels of understanding of phenomena associated with light in young children. However, any attempt to judge the value of one activity would be to place too much emphasis on anyone aspect of the intervention which is best judged by the overall and holistic view.

7. THE EFFECTS OF THE INTERVENTION

7.1 Changes in Children's ideas

This section gives the technical analysis of the data gathered during this study. The main findings are summarised in section 9. Analysis of the data identified three main areas of focus in children's ideas. These were ideas about

a. Sources of Light
b. Representations of Light
c. The nature of Vision
d. Context dependence

This data on children's ideas about light was gathered in two phases, the elicitation phase, prior to the intervention and by a second elicitation exercise after the intervention. This produced a large collection of data for analysis which is presented and discussed in this section. The elicitation activities consisted of activities that were designed to focus and orientate children's thinking on particular phenomena associated with light. Children were then asked to draw and write answers to specific questions about the phenomena and this provided the vast majority of the data. Some data were also collected by interview. Ideally, in the interest of reliability and validity, it would have been preferable to collect much more of the data in the elicitation phase by interview. This would also have provided an opportunity to pursue in further depth some of the interesting responses that children provided to written questions. However, the limits imposed by the staff resources available meant that the research team was constrained to use methods that were broad in their focus, if lacking in depth and rigour. This problem was addressed in two ways. Firstly the study was limited to specific activities that the early exploratory work had shown to generate meaningful and interesting responses from children. Secondly, a substantial amount of redundancy was built into the elicitation activities in order to evaluate the consistency of the responses provided by the children. The issue of consistency is discussed in part (iv) of this section.

One advantage of this strategy is that allowed a reasonably large sample that represented a mix of abilities, school catchment areas and sexes to be used. One constraint that was imposed by circumstances relatively early in the project was a decision to limit the study to junior age children only. Teachers in the schools used were unwilling to involve infant children in the project at this stage till they had developed a body of experience about the methods of the project.

It is also worth noting that substantially more data was collected than shown in the sample sizes given. Data presented here is from elicitation activities with children who were present before and after the intervention. Inevitably, there was some erosion of the sample due to illness and movement of children.