LINKAGE BETWEEN PRIOR KNOWLEDGE AND NEW EXPERIENCE IN SOME SCHOOL PUPILS AGED 9 - 16 YEARS

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C O N T E N T S

CHAPTER CONTENTS

A PREFATORY OVER-VIEW

The Teacher as Researcher

The investigation which this thesis reports was an attempt to study the effects of prior knowledge on children's learning in science; that is, their linkage of new ideas with their existing cognitive structure.

This prefatory over-view has been written, after that main investigation was completed, in order to show how the thesis developed beyond that original purpose.

I was attempting from the beginning to shed light on the broad notion that children's existing knowledge powerfully affects their understanding of new work in the classroom. Within this general area I eventually isolated three areas of learning for closer scrutiny. These were: to look for specific examples of pupils' use of prior knowledge (at the same time testing the theory that pupils formulate alternative frameworks of interpretation); secondly, to study the pupils' ideas of the purpose of their learning in science; and thirdly to look closely at how the context in which science words and concepts appears influences meaning and understanding.

I chose methods for the investigation which seemed appropriate for a teacher-researcher.

At pilot study stage - a short period of full-time research - I employed seven methods. During the later part of the research, which was undertaken whilst teaching full time in my own classrooms, three methods were selected for their potential in eliciting the required data.

It was while using these several methods that a good deal was learned, not only about the impact of prior knowledge upon learning but also about the conduct of research by a full time teacher.

The three areas of investigation stand as separate chapters with attendant discussion about the impact of prior experience. It is however the total contribution they make to knowledge about the full time teacher as researcher that this thesis chiefly reports.

Some of the issues about the teacher as researcher are raised in Chapter 3 but a full analysis, which includes a critical discussion of the methods I used, is given in Chapter 10.

CHAPTER ONE

CHAPTER ONE INTRODUCTION

Much attention is given in science teaching both to syllabus content and teaching methods. The content of science courses has shifted in recent years both to accommodate developments in knowledge and technology, and to capitalise on the results of research into such aspects of learning as the intellectual demands of science concepts. Teaching methods also have changed.

Little attention however has been given to the pupil's accumulating experience or its effects upon subsequent learning.

Recent research has suggested that pupils' understanding of ideas in science is greatly influenced by their earlier learning and experiences, and further, that when children meet a new idea in science they try to understand it by making links with previous knowledge.

If this is so it means that teachers must not only be concerned with what is being taught, and how, but also with those influences in the pupils' past which may facilitate or baulk their efforts to cope with new work.

If the question is asked: How do children learn? the answer would seem to include at least three components

relevant previous experience ⟶ successful linkages ⟶ new concepts

It is the linkages which pupils forge between old and new knowledge that this study seeks to explore. It will be necessary to find out what is going on in the mind of the child during learning, and methods have been chosen carefully to elicit this information.

STATEMENT OF THE PROBLEM

If the problem is posed: 'Does prior knowledge influence learning?' it immediately raises two particular questions which this thesis will explore.

> How does prior knowledge affect pupils' grasp of ideas in science?
>
> How does prior knowledge affect pupils' approach to science lessons?

Within these broad areas the following specific questions will be scrutinised:

1. What evidence can I find to support the view that pupils deliberately or unconsciously use prior knowledge in trying to understand new ideas?

   Does the pupils' reliance on prior knowledge (which is itself rooted in social and 'folklore' experience) lead them to build their own ideas about science concepts - formulations which Driver & Easley(1978) have called 'alternative frameworks'?

2. Does this prior knowledge and experience influence the ways in which they approach science lessons, for example by creating expectations which teachers may not be aware of?

3. If it is true, as Watts(1981) asserts, that the meanings for words which pupils bring with them to classrooms are very influential in determining what is learned there, can examples be cited of pupils using meanings which, deriving from an earlier context, determine their interpretation of new ideas?

CHAPTER TWO

CHAPTER TWO REVIEW OF SOME THEORETICAL IDEAS AND RECENT RESEARCH WHICH LED TO THE PROBLEM BEING POSED IN THIS WAY

In a perceptive review of literature related to pupils' conceptual development, Driver & Easley(1978) distinguish between misconceptions and alternative frameworks of interpretation. The former are deemed to exist in pupils who fail to understand formal scientific ideas as taught, and who are seen as forming erroneous versions of these. Driver & Easley, and others, hold the view that the pupil's so-called misconception is really an alternative conception. Their term 'alternative framework', called a preconception by Ausubel(1968) implies rudimentary or embryonic theories already held by the pupil and not arising from formal teaching.

These two extremes of assessment of pupils' early progress illustrate a development in science teaching away from an emphasis on a fixed body of knowledge, and towards a more fluid, conceptually-based discipline. They also indicate an increasing awareness that pupils use prior knowledge in formulating more mature ideas.

2.1 AUSUBEL'S THEORY OF COGNITIVE STRUCTURE

The learning theory of Ausubel(1968) has been a source of hope in crystallising ideas in this area. He distinguishes meaningful learning as occurring when pupils make links between their existing knowledge and new knowledge. This building process has most value when the pupil's prior knowledge is relevant to the new concept.

Another aspect of his theory is that, in linking old to new knowledge, both undergo change - it is a dynamic process. Ausubel calls the relevant prior knowledge the subsuming concept, the process of linking new to old, subsumption. Where the new, fuller, maturer concept is totally subsumed by the original knowledge obliterative subsumption is said to have occurred.

Far from being a problem as in rote learning where new facts oust old - like the dripping of a saturated sponge - obliterative subsumption tends to enhance the earlier knowledge, not only rendering it more useful but allying it to the increased usefulness of the new concept.

Ausubel also recognises what he describes as superordinate learning, that is that associations can be made between concepts.

Conceptual understanding is a crucial element of Ausubel's learning theory. He argues that if pupils are to understand new ideas they must learn meaningfully, and this involves the ability to form and re-form concepts in the mind. Toulmin(1972) suggests that concepts themselves are evolving with time and that the advancement of knowledge is dependent upon man's ability to develop and shift the nature of the concepts he understands and uses.

Ausubel had earlier applied similar ideas to the cognitive processes which pupils employ as they grapple with new knowledge, and his assimilation theory describes the interaction between new material to be learned and the existing cognitive structure - a 'mixing' of old and new meanings to form a more highly differentiated cognitive structure. Ausubel's theory thus includes the attractive attribute of focussing on practical issues at classroom level.

Ausubel emphasises the importance of the advance organiser, a sequence of instruction deliberately designed to precede the introduction of new work so as to make the transition from the point the pupil is at, to the new position, easier and more meaningful.

Novak(1976,1980) sees the most important role of the advance organiser as being to link the old and new knowledge, and has emphasised Ausubel's term cognitive bridge. Ausubel had described the advance organiser as being more general, more abstract and more inclusive than the subsequent concept(s) and suggested that, in order to be effective, it must precede information that is potentially meaningful. There must also be adequate existing concepts - hence Novak's preference for the use of 'bridge'.

It is clear that the effective use of cognitive bridges in teaching implies adequate knowledge not only of what the pupil knows generally but which part(s) of that heritage of learning he or she will select in laying claim to the new knowledge.

Ausubel also identifies the degree of meaningful learning, varying from pupil to pupil and being maximised if the new concept is itself meaningful (making sense with existing knowledge) and if the pupil is ready to learn meaningfully.

2.2 PUPILS' MISCONCEPTIONS

The notion of pupils' misconceptions arises logically from a view of science as being a body of facts and laws.

If a pupil is required to learn Boyle's Law, or the electrolytic extraction of aluminium, or the internal structure of spirogyra, any failure to reproduce the information or to use the underlying principles properly is seen as failure, the child's mind being partially or totally full of misconceptions which must be eradicated. Only when the pupil can recite the information perfectly and apply it satisfactorily is he or she reckoned to have mastered the work and to have made progress towards the next, more difficult, stage.

This is clearly an over-simplification but its usefulness lies in its ability to explain both classroom feeling and the direction of some educational research. For example, some pupils (many? most?) expect and fear that class work will get harder, harder, harder. (Experienced teachers will confirm that pupils, even at sixth form level, take some convincing that they will master the work with increasing facility). Much research has been undertaken by researchers who themselves accept this gloomy prognosis.

Pupils' misconceptions have, even so, been a fruitful focus for study. It has been shown quite convincingly by several independent workers that misconceptions are often specific and widely held. Thus, Kuethe(1963), on analysing the wrong answers that pupils gave to questions about astronomical and physical phenomena, discovered that their errors were not random but fell into specific areas of misconception. Boyd(1966), studying pupils' unfounded beliefs, isolated common misconceptions held by both science and non-science students. The work of Doran(1972), Duncan & Johnstone(1973), Za'rour(1975), and Johnstone, MacDonald & Webb(1977) has contributed to the identification of many misconceptions held by pupils in the three main branches of science.

Other workers have suggested that these common misconceptions are tenaciously held and persist despite attempts to counter them - a result which tends to support Ausubel's ideas about the tenacious nature of prior knowledge. Viennot(1974) showed that even at University level students of physics retain and make use of pre-Galilean ideas in solving sophisticated problems. See also Lebouter(1976).

The research into misconceptions, however, is not entirely satisfactory, for though it isolates specific cases and builds up some common threads, it fails to give reasons for the misconceptions and thus leaves us only a little further forward.

2.3 THE INFLUENCE OF PIAGET'S WORK

The study of pupils' misconceptions originates to a large extent with the work of Piaget(1929 onwards). Piaget's earliest research centred on the idea of stages of mental development; by the 1950's (see Piaget 1950) Piaget was certain he had established generalisable stages.

To some who have used his work this suggests that the average child of a particular age should be able to grasp certain types of ideas or, conversely, that no matter how hard a child tries there are some concepts which, at that stage of his or her development, he or she will not be able to understand.

From about 1950 onwards most studies of children's intellectual development have been based on Piaget's ideas. Some teachers have been keen to know at what stage specific concepts could be taught in class, and both Piaget's stages and Bloom's(1965) taxonomy have been used extensively in efforts to describe levels of conceptual understanding.

Many methods have been used to determine the age at which pupils can explain phenomena using mental models, including fixed response tests (Pella & Carey(1967); Pella & Strauss(1967); Helgeson(1968) and Billeh & Pella(1972)); concept perception tests (Kempa & Hodgson(1976)) and semi-clinical methods (Anderson(1965); Pella & Ziegler(1967); Pella & Voelker(1967); Buell & Bradley(1972); Hall(1973) and Voelker(1975)).

Kempa & Hodgson found that even 16 year old pupils of high IQ prefer to work at the concrete level, and that this may cause difficulties in problem solving. This would seem to be so, Watts (1983) citing the example of a sixth-former who had learned that a photon was a 'packet of light' but was no further forward in understanding light or its behaviour.

Other studies have focussed on the way in which science material of increasing complexity is organised for pupils. In what order, for example, should burning, rusting, oxidation, etc., be introduced? Or mass, density, gravity, pressure, force, etc? The studies have included ones in which data is collected by interview (eg. Archenhold(1975); Williams(1976)) and those in which the pupils perform tasks (eg Bell, Hughes & Rogers(1975)). Work in this area suggests that logical ordering of concepts is not the same as, and is less satisfactory than, psychological ordering (it would seem logical to introduce volume before mass, mass before density, etc., ... but ....).

Work along similar lines includes that of Ingle & Shayer (1971) and Shayer(1972, 1974) in relating concept development to Piagetian stages. By analysing Nuffield science teaching courses they showed that the conceptual demands of the courses are not related to the pupils' conceptual competence. Their work culminated in the book: 'Towards a Science of Science Teaching' see Shayer & Adey(1981) in which the authors introduce their curriculum analysis taxonomy.

The last mentioned studies illustrate the beguiling nature of the results of Piaget's work, hinted at in the second paragraph of this section, that discrete stages of mental development are supposed to exist and that it should be possible to match science concepts to conceptual growth. In the remainder of this section and the next (2.4) I will produce evidence to support the sceptics' question: would such a neat solution be likely to exist?

The important studies last mentioned, elegant though they are in design, have not yielded the results at classroom level which might have been expected. This may not be surprising. Studies have suggested that general levels of cognitive facility have less influence on success than specific ability and prior experience (eg. Selley(1973); Savage(1974)) which may explain the weakness of the nomothetic approach which seeks to evince general rules.

Later work by Piaget(1972b) himself has shown the crucial part played by context in the mastering of formal operations, and studies by Wason & Johnson-Laird(1972) reinforce this, suggesting that content and context are more important than structure in problem solving.

Piaget's theory of cognitive development suggests a continually advancing process of building of intellectual structures.

Because each child constructs the world from his or her own actions on it there must be interaction with the environment if development is to take place. It is the child's interaction with his or her environment which provides the raw materials for the processes which Piaget calls assimilation and accommodation, processes which work continuously towards an increasingly more organised mental structure.

Piaget's research, at both theoretical and empirical levels, yields useful and surprising results pertinent to this thesis. For example, he found that older children give explanations which do not have what are regarded as 'objective' connections, and that indeed the child's view of the term 'explanation' is often fundamentally at variance with that of teachers. Holding alongside this a further finding, that when children develop explanations their ideas sometimes lie alongside the path of the history of scientific ideas, the question immediately arises: why should children be uniquely childlike and not merely the miniature adults we might expect them to be? Piaget's evolutionary thesis seeks (1971) to explain this. He argues that knowledge about the world is constructed through interactions with it and, further, that the world is a world of each person's own building as he or she orders and interprets the information being received.

2.4 CRITICISM BY DONALDSON OF SOME OF PIAGET'S INTERPRETATIONS

Some of Piaget's interpretations of his findings have been strongly challenged, as Donaldson(1978) points out. Piaget & Inhelder(1956) had, for example, established the ego-centricity of tiny children, based on the results of particular tests. Hughes (1975) however, by devising tests which were essentially similar but significantly different*, derived results which suggested that such ego-centricity is neither all-pervading in the very young nor entirely lacking from all stages of human mental development.

Donaldson suggests that Hughes' tests were easier for the children because they made human sense; Piaget's did not. The importance of these findings for this thesis is to caution the comprehensibility of tasks for pupils if they are to be used effectively in deducing the pupils' mental processes, and the fact that even the youngest child has a valid view of the world and the ability to interpret the surroundings, the context having a profound effect even at that early age.

Donaldson sees a further most important implication arising from this, an implication whose significance is better understood if seen in the light of recent evidence and arguments about the ways in which children learn to use and understand language.

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* Hughes' tasks (for example) require the child to look at arrangements of objects and decide <u>what</u> can be seen but not exactly <u>how</u> it will appear. Donaldson suggests that the children faced with Piaget's 'mountain' problem did not fully understand what they had to do

She draws attention to important points about the influence of context upon meaning. After urging caution on the Chomskyan (1965) assertion that children have an inbuilt language acquisition device - that associations between words and objects are built up mechanically - Donaldson draws attention to McNamara's claim that children most often succeed in making sense of situations which involve direct and immediate human interaction, and that they learn language because of these efforts at making meaning.

She illustrates the point by citing the example of an Arabian child of 13 months who, having no understanding of English, obeys an English instruction because it is given in a family context accompanied by non-verbal patterns of interaction. Context bound understanding transcends speech.

Donaldson contends that children are constantly trying to make sense of things, and especially to make sense of what people do. As a child interprets situations, through active processes of hypothesis-testing and inference, so he or she acquires knowledge of language. She offers a most piercing hypothesis: 'It may turn out to be a very long journey from the primary understanding of what people mean by words they speak and by their concomitant acts, to the ultimate and separate understanding of what words mean.'

It is the development of understanding that this thesis seeks to speak about.

Donaldson goes on to emphasise the point by saying that not only are a child's language learning skills not isolated from his or her mental growth but that he or she first makes sense of a situation and then uses this kind of understanding to help make sense of what is said to them. The question may thus be posed: When a teacher says (anything) to a pupil or class, what sort of mental structural processes and experiences are being brought into play in order to process (make sense of) the teacher's words?

Having developed the argument that children's interpretation of language is powerfully influenced by context, Donaldson then brings forward evidence to show that failure to interpret within context has nonsensical results. Children, being questioned about a story they had heard, confused similar sounding words such as 'hair' and 'hare', 'quay' and 'key', and ascribed meanings to the words which were irreconcilable with the context. This tendency of children to 'acquiesce in the bizarre', that is, to be tempted to offer nonsense meanings for things they find inexplicable, seems to be linked with a lack of immediate context of a visible, non-verbal kind. It is almost as if, to make the context believable, children re-structure the context itself.

Donaldson favours this view, quoting similar results by Hughes & Grieve(1978). She suggests that children are given to 'structuring ... situations .... even when no words are uttered .... and ... when words are uttered the children's interpretation of the utterance is strongly influenced by his own independent structuring of the context. If there is one feature of a situation which is salient to him ... this can exert a pull on the interpretation of the words he hears. Just how powerful the pull may be is not yet entirely clear.' The thesis will seek to add clarification to this view.

Since context clearly influences understanding, the focus must constantly move back; understanding understanding will depend upon understanding the influence of context,

A further most pertinent point that Donaldson makes about context is the dynamic impact which it has upon meaning. She highlights the 'common but naive assumption that the understanding of a word is an all-or-nothing affair; you either understand it or you don't,' Rather, she stresses, the knowledge of what words mean is ever developing and evolving. She subscribes to Ausubel's views, discussed earlier, that understanding does not develop simply by adding one meaning to another. It is a constant re-building of concepts in order to make sense of the new situation. The 'correct' meaning for a word at one moment, either in history or in a person's experience, will be completely unsatisfactory in a new context, at a later time. (cf. Toulmin(1972))

2.5 'ALTERNATIVE CONCEPTIONS'

In contrast to the earlier mentioned 'misconception' studies, all of which seek to chart the pupils' failure to understand formal instruction, much recent theory and research has concentrated on the pupils' conceptual gropings. It stems from that shift in ideas about learning which Donaldson identified, that there are no absolute concepts but that concepts are ever-evolving, being dependent upon both the progress of the individual mind and its position in history (Toulmin(1972)).

If this is so it can be argued that science teaching should concentrate on concept learning, and science research upon how pupils form and re-form their ideas.

The problem is, not much is known about what children already know, how they acquire their knowledge or how they use it. The attention of researchers has swung in this direction, trying to discover more about concept formation in the earlier stages of pupils' learning.

Pines & Leith (1981) have suggested that a concept is a locus of meaning, a kind of summary of 'all the propositional relationships in which that concept participates.' They identify concepts which designate regularities among ordinary physical objects, and abstract concepts which designate regularities among other concepts. They see concepts as complex networks of relationships constructed over a long period of time, and maintain that the aim of science education should be to promote an internalisation of a conceptual framework which can then be used to produce further hypotheses.

Freyburg & Osborne(1980) make three points about the nature of concepts:

1. That conceptual ownership is manifested by the owner's behaviour and responses, as opposed to an ability to relate information.

2. That concepts are multi-directional and context based. A pupil's awareness and appreciation of a phenomenon will have many facets depending on his or her experiences.

3. That concepts are also the ways in which these experiences are organised. (Pines: internalised).

They see current problems in science teaching to include the assumptions that knowledge and concept acquisition are additive rather than re-organisational, and that the conceptual base of teachers and textbooks is identical to that of the pupils. On the last point it is clear that what pupils understand by, for example, a scientific or technical word is different in meaning from that communally agreed within the scientific and technical world.

Zylbersztajn(1982) takes these fundamental discrepancies further, arguing that the frameworks (cf. Driver & Engel, below) which children use are often at variance with accepted scientific method in pedagogical, didactic and scientific parts of their learning. He argues that to allow the pupils to learn on the basis of their own knowledge, ideas and hypotheses, however limited their grasp of the information, has massive precedence in the scientifc field and is indeed the very essence of scientific growth per se.

Watts(1982) makes the point that meaning is not in words but in people, and that meaning is concerned with the way an idea connects with other ideas a person already has. Meaning thus varies from individual to individual, but personal meanings usually overlap sufficiently for communication of ideas. Pupils' ideas, he contends, are serious imaginatively creative attempts to describe the world around them.

A most useful term for describing pupils' attempts at building their own concepts is the 'alternative framework' (Driver & Easley(1978); Engel & Driver(1982)) mentioned in introducing this literature survey. The authors emphasise that pupils' prior knowledge is intuition based and that meaning develops as the result of interplay between the learner's mind and the material being learned. Alternative frameworks are autonomous developments of the pupil's conceptualising effort and these may both dominate and determine any future understanding of scientific ideas.

Jung's research (1981) into pupils' understanding of the concept of light leads him to state that the pupils' common-sense framework cannot be discarded simply as false, and that the aim of teaching cannot be merely to teach the right conception as against the false one. He contends that the aim must be to become aware of the difference in context that makes one frame or the other appropriate.

Can children never be wrong? The alternative framework would seem to imply that children's scientific ideas, however rudimentary, always have some validity. This important theory requires testing, and this thesis will attempt to do so.

There is of course an enormously powerful connection between meaning and language. As people reason things out they talk to themselves within the brain, or articulate their ideas with peers and teachers. Bruner(1960) has described language as the amplifier of thought, and suggested that as thought becomes more elaborated it depends less upon concrete experience, learning to imagine. It is the imaginative leaps which are seen to give rise to tentative hypotheses, and Sutton's(1982) ideas about the interplay of imagery and language take hold. As children search for words to describe what they are learning they seem to rely heavily upon metaphor; the new experience is likened to something they have already experienced. The bridge is made between old and new knowledge.

Collins, Brown & Larkins(1980) showed that pupils make tentative links prior to final construction of meaning. It will need to be tested as to whether this is more generally true, since it could be argued that the initial ideas which pupils formulate about new concepts can become fixed and inadequate, or still-born, thus stemming the flow of further hypotheses. The above workers suggest ways in which these tentative constructed meanings can be checked by way of the plausibility of their assumptions, by their consistency with other available information, from sensed experiences, in terms of predictions, etc., and one of the most incisive techniques for such evaluation would seem to be the structured interview.

The findings of Brook, Briggs & Bell(1983) using techniques which will be discussed in the next chapter, support the view that pupils have had experiences of and formed intuitive ideas about scientific phenomena before they experience formal teaching, and that these ideas are different from the scientific ones. In addition their results suggest that the views held by pupils influence what is learned; the learning is not passive.

This non-passive nature of the process of learning is further examined in the model of conceptual change postulated by Hewson (1981a,b; 1982). He argues that when pupils meet new ideas they can assimilate them in three possible ways:

1. By rote memorisation.
2. By conceptual change, ie. the new idea usurps the old.
3. By conceptual capture, ie. the new idea is reconciled with existing experience.

Hewson stresses that the fate of a new idea depends upon the pupil's view of it as being intelligible(I), plausible(P) or fruitful(F). Any new idea has no status if it possesses none of these attributes. It may attain status (I) but lack plausibility and fruitfulness; it may attain status (I/P) but lack fruitfulness; or it may attain full status by possessing all of these qualities. The non-passive nature of the model is suggested by the fact that the status of a new idea changes during learning.

Hewson's model parallels the generative learning model (see Section 2.6) in highlighting the structural nature of learning, the part played by prior knowledge and the evaluation of a construction. At classroom level the pupils' horizon of satisfaction will be influenced by the status of the concept. They may not understand it; they may understand it but not believe it; they may understand and believe it but see no point to it; or it may assume full fruitful importance in their thinking.

Kelly(1955), giving primary emphasis to the active, exploratory propensities of individuals, stressed the over-riding importance of environment on learning. He contended that people do not merely react to external events, they represent their environment. A person may therefore construct different kinds of representations of his or her surroundings and is not bound by the environment, only by the interpretations or representations of it. Kelly maintained that each person makes his own model of the world. At an individual level he or she constructs and re-constructs to test ideas and modify them for better predictions. This Kelly called constructive alternativism. He denied the 'push = stimulus ; pull = needs' ideas which assume that man, like a physical object, is static till shifted. He therefore added the 'choice' corollary and suggested that man moves in the direction of increased meaning in his own terms. Kelly's view that people's motivation for learning is increased meaning in his own terms will be tested.

The recognition of the importance of prior knowledge in the pupils' learning of science, and the emergence of 'alternative conceptions' ideas, has led to a rapid expansion of research in this field. A recent paper by Driver & Erickson(1983) seeks to review recent literature and raises a number of theoretical and methodological issues. The authors survey studies of pupils' concept frameworks and suggest a need to clarify and re-define 'school science.' They assert that research programmes (cf. Hewson & Hewson(1983)) which offer a comprehensive theoretical description of conceptual change yet also remain firmly grounded in problems of instruction, exemplify the type of approach likely to be successful in bringing about significant advances in this field of research.

Gilbert & Watts(1983) also review the current disparate ideas about how pupils learn. They discuss science concepts, the generalisable and predictive requirement for the designation: 'alternative framework', and the outcomes of recent research into specific concepts.

2.6 GENERATIVE LEARNING

The latest work of Osborne, Wittrock and others has helped clarify ideas in this conceptual field, their theory and hypotheses being rooted in data from in-depth interviews with children.

Tasker(1981) and Osborne, Bell & Gilbert(1982) highlight points which will be closely scrutinised in this thesis. Tasker found that pupils spend less time thinking about concepts than making executive decisions, and suggests that this is encouraged by assessment procedures which reward well-written laboratory accounts. He also discovered that pupils generate different purposes for their class activity to those intended. Osborne and co-workers showed that pupils fail to gain depth of understanding due to being satisfied with their own conceptions.

The pupils' horizon of satisfaction, and its impact upon learning, will be tested.

These workers found also that pupils construct meanings compatible with prior knowledge (cf. Donaldson's: 'acquiesce in the bizarre') and that this is exacerbated by multiple meanings for words, for example the dual meaning for 'work'.

The Generative Learning Model (Wittrock & Lumsdaine(1977); Wittrock(1980); Osborne & Wittrock(1983)) is based on the notion that the brain is not a passive consumer of knowledge but actively constructs its own interpretations of information, drawing inferencesfrom them. The brain totally ignores some information, selecting what to attend to. The view is therefore held that the pathway to construction of meaning from any experience begins with selective attention to that experience. Such selected attention leads to selected perception. When meanings are being built the links generated are critical to the depth of understanding which results.

Osborne's and Wittrock's ideas, based on the generative learning model suggest, in line with Kelly, that motivation is the pupils' need to be willing to generate meaning. They also suggest that, since learning depends on perception, teaching needs to emphasise objectives, design features, strategies and problem solving. Research needs to be carried out at classroom level to test these ideas, and the current study should throw light on some of the issues.

CHAPTER THREE

CHAPTER THREE A REVIEW OF RESEARCH METHODS AND THEIR USEFULNESS IN THIS INVESTIGATION

The methods used to elucidate the process of learning in the child's mind are usually concomitant with two extremes of learning theory.

These are: (1) That science is precise and approaching perfection. The imperfect grasp of a child must therefore be continuously refined. A research sequence might proceed in this way: (a) the pupil is tested on his or her knowledge of a science fact or concept; (b) the pupil undergoes instruction in that area of knowledge; (c) the pupil is tested again to see how learning has developed.

(2) That science concepts at all levels of sophistication are continuously developing. The pupil's conceptual grasp is valid for his or her stage of development and can be the basis for continuously deepening understanding. Research from this standpoint would involve methods which encourage pupils to articulate (or otherwise reveal) the variety of their experiences of a phenomenon, and which allow the researcher to perceive the impact of that variety on subsequent learning.

(Although it simplifies the review process to categorise research methods in this way, it must be stressed that there is no such nice distinction 'in the field.' Methods from both extremes can be, and are, legitimately used, especially where the results they achieve give complementary or balancing insights)

The aims of this chapter are to describe the various methods available for use in educational research, their applicability, strengths and limitations, and to identify those which will be most appropriate for use in the present study.

Rather than embark on an arid method-by-method description I have decided to present the review in terms of research individuals or groups, many of whom used more than one method in their investigations. This way of presenting the review includes the advantage of highlighting those methods which have been used complementarily with success.

The sections which follow are not intended therefore to contain material solely about the method immediately under review.

3.1 <u>OBSERVATION SCHEDULES</u> Research in classrooms has made much progress since the initial impetus given to investigation by the Flanders(1970) observation technique. This was important not only in producing evaluative data about lessons, for example, the law of two-thirds (that $^2/_3$ of class time is spent on teacher talk, etc) but in focussing the attention of researchers on what was actually happening in the classroom.

The method was developed usefully by Eggleston et al(1975) into the Science Teaching Observation Schedule(STOS).

Systematic observation schedules are still in use and continue to be developed. Sinclair & Coulthard's(1975) scheme for analysing classroom discourse has centred upon teacher-pupil speech, its content and function. Their analysis has broken down the discourse into five hierarchical ranks: Lesson, Transaction, Exchange, Move and Act. They identify some 22 different categories of Acts (comment, cue, reply, aside, etc) in an attempt to provide a coding system which will help to analyse any class discourse. Zylbersztajn(1983) found it necessary however to invent an 'other' category in order to classify some acts in lessons he observed.

3.2 PARTICIPANT OBSERVATION The advent of individualised learning and group work in science lessons made such observation schedules difficult to manage, but the focus in research had shifted anyway, from teacher-class interaction to teacher-individual and intra-group learning.

Now the researcher began to sit alongside the pupil or group, observing the learning process. Fears had long been expressed that research data culled by a 'stranger' in the classroom was open to distortion caused by the presence of that person. As science lessons became less formal, more fluid, so the climate for this type of research improved. Research workers, and other visitors, being often in the classroom, began to be or maybe feel less obtrusive. The beneficial effect of this improvement was marked: the researcher, far from trying to be an 'unseenflyonthewall', could enter in to group activity, could ask questions, set tasks, help with experiments, etc.... He could be the teacher. Participant observation had arrived.

Participant observation has many facets. These give both many strengths to exploit and some dangers to be aware of. One immediate problem, as Walker & Adelman(1975) point out, is the need to get inside the perspective of the protagonists - teachers and pupils. Observation is never simply watching what is happening. It is important to complement 'objective' descriptions and 'subjective' impressions with a continuous attempt to see events as they are seen by those involved in them. Whatever methods the participant observer employs, if he is trying to discover ways in which pupils structure their knowledge, it is imperative that the pupils' perspective is clearly charted,

A difficulty for the observer, as mentioned above with respect to observation schedules, is the collecting of detailed and complex data such as emerges from a group of pupils co-operating on an experiment. To help with this, such devices as tape and video recorders have been employed, giving the advantages - to Walker's and Adelman's minds - of creating incidents more vividly than narrative accounts. Recordings also allow the researcher to delay coming to an understanding of the data, to separate out the processes involved in assimilation and accommodation.

The latter advantage is seen to arise because the narrative, on-the-spot account requires understanding, insight, even theory before recording is possible, since the writing down process of what is being observed demands selection, processing and organisation of the complex array of perceptions and ideas.

Since participant observation will be much used in this thesis, and long-hand descriptions of events employed, these dangers will need to be kept constantly in mind.

The narrative description does, however, have a fundamental strength, as Walker & Adelman emphasise: it conveys very clearly the interpretation of events by the observer, the incidents being of less significance than the meanings they convey. (cf Kelly(1955)

Any extra devices used therefore (see: Ford Project, later) will be of value if used in the context of participant observation by increase interpretation and understanding.

The value of the narrative content of Piaget's work has been stressed by Driver & Easley(1978) who deplore its apparent lack of esteem in the research data: 'It is a pity that the summary of the work in Understanding Causality is so brief and reports little of the actual dialogue with pupils, and that more detailed accounts of the experiments available have not been translated.' They suggest that a series of replication studies which focussed more on the actual content of the children's ideas and less on the supposed underlying logical structures would be useful. They further suggest that Piaget's accounts of children's thinking and explanations should be read for the indications they give of the content of children's ideas; and that valuable information could be gained by curriculum planners and practising teachers through interviewing children in order to understand their ideas and ways of thinking about questions.

3.3 CLINICAL INTERVIEWS: informal interviews Driver & Easley give a summary of a considerable number of research investigations intc conceptual grasp which use the techniques of the clinical interview and observations of children's classroom behaviour in attempting to analyse children's ideas. They advocate the use of interviews in order to focus closely on children's ideas, and although the range and style of interviews varies greatly this principle resides in most. The Ford Teaching Project, discussed below, used interviews as part of a multi-focus approach towards analysing enquiry teaching. By contrast Gilbert, Watts & Osborne(1981) developed and used the Interview-about-Instances technique (see later) as a means of identifying pupils' perceptions of ideas in physics.

Pines(1981) has taken this further and suggested that teachers should use interviews in class or at least acquire appropriate questioning skills and use them in the process of daily instruction.

The Ford Teaching Project(1975) has carried out much useful work using interviews as a significant part of participant observation. The project's main concern was the analysis and improvement of the logic and practice of teaching through enquiry. In the report: Three Points of View in the Classroom, (Subtitled: Generating Hypotheses from Classroom Observation, Recordings & Interview) Elliott et al describe the techniques used during a lesson's scrutiny.

These were

1. A transcript from a tape-recording of a lesson.
2. Observer's notes written during the lesson.
3. Observer's notes on the transcript (made retrospectively)
4. Interview with teacher after the lesson.
5. Interview with pupils (+ tape recording).
6. Discussion chaired by the observer between teacher and pupils.

The observer's notes were rapid impressionistic comments reporting and interpreting events which seemed to be of major significance. These were checked against those of the teacher and pupils.

3.4 TRIANGULATION This multi-focus approach, called triangulation, is intended to ensure cross checking of events, thus minimising subjectivity. For example, a researcher in the Ford Project noted that the teacher used the question: Do we all agree? several times. He questioned the teacher about this, as to whether he thought it was a rhetorical question, or an idiosyncracy which required acquiescent assent, or a real question demanding yes or no answers, etc. The researcher then asked the pupils for their assessment of the question. Finally, the researcher's retrospective notes record: 'Do we all agree?' is met with silence and an odd Mmm. Does this indicate pupils are afraid to express disagreement or a lack of understanding as to how the conclusion was arrived at?'

In fact neither of these postulations seem adequate in the context of the full data. Such retrospective 'pondering', laudable as it might seem as an attempt to reduce subjectivity, is a blunt tool for chipping away at the real issue; like a scent grown cold the event and the vital protagonists are too far away for recall and for such necessary techniques as re-interviewing. Only by comparing the various viewpoints at the time can valid assessments of events, and decisions about future strategy, be made.

The Project's discussions between teacher and pupils (see technique 6 in 3.3 above) 'didn't come off very well, ... partly because of the difficulty each party had in expressing their interpretations to each other in face-to-face situations,' hence their call for carefulness in interview techniques of all kinds. They point out one other difficulty with the interview: 'It is frequently difficult to get younger children to explain their thoughts and feelings.' This is not the same as saying that younger children find it difficult to explain their thoughts and feelings, and some suggestions and tried techniques will be explored and explained in the thesis on this aspect of interviewing.

3.5 ACTION RESEARCH The techniques of classroom research are also well explored by Nixon et al(1981). Nixon maintains that 'action research', that is research by the teacher in his own classroom, requires the selection of a manageable area for investigation. This is doubly true where potentially massive amounts of data can be accumulated by methods such as interview and observation, in anecdotal form. The danger will be kept in mind as the research develops.

In investigating pupils' prior knowledge it would be possible to seek all the way back to birth, trying to establish every influence, everything done, everywhere been. A hopeless, ineffectual task. Only that prior knowledge is needed which is being used at the time of learning specific ideas. The isolation of that information alone has its own and sufficient difficulties.

Armstrong(1981) in his classroom observation 'chose to concentrate on moments of intellectual absorption' in selecting from a vast quantity of notes. He valued the anecdote specifically as being part of the moment which 'gives meaning to reflection and to generalisation.' He reckons anecdote to be indispensable for the theory and practice of education.

Further useful work in this field, reported by Nixon, includes:

Diary methods (Enright, L)
Asking questions to monitor views (Jackson,D)
Tests and concept maps devised to ascertain pupils' knowledge of concepts (Gower, D)

3.6 INTERVIEWS AND COMPLEMENTARY TESTING Bell's(1983) methods for elucidating learning via reading employed interview techniques of a complementary nature. Pupils had been categorised by use of a science survey into three groups depending on their concept of 'animal' as being of scientific, everyday or in-between meaning. Each pupil was then interviewed twice, the interviews being tape-recorded.

The first interview of 5-10 minutes sought to elicit their reasons for their choice of answers in the survey. In the second interview of 30-50 minutes the pupils were asked to read a text about 'animal' and to

(a) learn how a scientist would answer the question:
What is an animal?

(b) stop at the end of each sentence and tell the researcher what they were thinking.

Probe questions were asked throughout the interview to clarify statements made or implied by the pupil. Then the pupils were given an informal interview-about-instances, to assess any learning which had occurred during the reading. Finally, after a period of 2-4 weeks they were given a parallel science survey to ascertain any change in the concept 'animal'.

Brook, Briggs & Bell(1983) and Brook et al(1983, 1984 CLIS Project)) investigated pupils' ideas about the particulate nature of matter. They based their study on six questions from a national science survey, testing some 300 pupils. In addition they tested 35 pupils orally to elaborate or explain the pupils' written responses. The total responses were categorised into:

(a) those including components of the accepted answer, completely,

(b) those including components of the accepted answer, partially,

(c) those containing alternative ideas on particulate lines,

(d) those involving low level macroscopic responses,

(e) nil or uncodeable responses.

The %'s were then displayed on a pie chart.

As far as the testing techniques were concerned they discovered that, though the interview responses were more elaborated and expanded than the written, and though there was a tendency for slightly more pupils to offer and use accepted particulate ideas when talking, for diagnostic purposes both methods adequately reflect the types of ideas used by the pupils.

Duit(1981) used a highly structured questionnaire to elucidate pupils' understanding of physics concepts, incorporating meanings of words, applications of the concepts, associations with and definitions of the words, etc., (cf. Schaefer(1980)).
Since, as Duit concedes, these techniques have limitations in providing evidence of real understanding in pupils, the questionnaire was 'enriched by interview.'

Jung(1981) tested 12-15 year old pupils on their concept of light. After they had undergone formal teaching they were invited to look through a double slit upon a distant light source, to report what they saw and to try to explain it. He was hoping to discover via these interview methods evidence of pupils' common-sense frameworks of understanding, and their validity in different contexts.

The investigations of Pfundt(1981) included the aims: to discover the general conceptions pupils bring with them to class, and to chart changes these concepts undergo during instruction.

She used transformations of chemical substances with which pupils were unfamiliar in order to see whether their developing concepts grew within certain pre-existing general concepts. She interviewed some 50 pupils with good verbal skills aged 8-13 years. The pupils then performed and watched experiments, and made statements about and descriptions of experiments. They were then questioned about similar processes and about their interpretations and reactions. The interviews began freely and became increasingly restricted, trying to ascertain which of the provided conceptions were accepted and for what reasons other conceptions were rejected.

Several other recent studies have used interview techniques to complement basic testing techniques. Osborne & Cosgrove(1983) investigated pupils' ideas about the changes of state of water, the pupils' ages ranging from 8 to 17 years. Pupils' answers during interview to questions such as: What are your ideas about what happens when ice melts? were broadly categorised into three views.

Hewson & Hewson(1983) studied pupils' alternative conceptions. Their study was concerned primarily to effect conceptual change from alternative to scientific conceptions. They identified the prior knowledge of a group of students and used this as the basis for special instructional strategy and materials, a control group being taught the same concepts by a traditional route. They used clinical interviews to establish prior knowledge and alternative conceptions, and paper and pencil tests to validate these.

3.7 NOMOTHETIC AND IDEOGRAPHIC RESEARCH METHODS At the beginning of the chapter I distinguished opposing methods of inquiry which on the one hand try to elucidate pupils' grasp of accepted scientific knowledge, and on the other focus on the pupils' tentative knowledge as being valid gropings towards sounder understanding.

Research in the first field tends towards a traditional approach, the generation of large amounts of 'objective' data which can be treated statistically with a view to establishing general trends or in order to postulate generalised hypotheses. Research in the second field tends to focus on individuals or upon small groups of pupils so as to probe more deeply into how they learn.

In this section I should like to concentrate on this apparent division, giving examples of recent research in both areas; in Section 3.8 I will discuss their relative contributions to knowledge and their limitations.

If experience has shown that certain methods are more reliable than others for generating certain types of information, a crucial feature of my investigation will be the choice of appropriate testing devices.

The methods which follow are all closely linked to the aim of my own study, seeking to elucidate conceptual understanding in pupils. They have some or all of these components:

(a) a theoretical base.
(b) an aim.
(c) the method.
(d) data rationalisation.
(e) issues arising.

West(1982) in a review of research methods, and researchers, has most usefully polarised them into revolutionary (1-7 below) versus evolutionary styles (8-15). These tend to parallel the nomothetic versus ideographic theoretical considerations discussed earlier, that is, trying to establish laws as opposed to gaining insight into conceptual development.

1. Erickson's(1975) aim was to identify patterns of pre-instructional knowledge which help or hinder learning. Pupils were interviewed about specific tasks and their responses categorised so as to yield context-specific 'inferred rules'. These were later transformed to general rules and used for hypothesis framing, to be further tested.

2. Engel & Driver(1982) asked pupils to answer written questions. The pupils were then interviewed on the same questions, with some additional tasks based on concrete materials. Some of the pupils were interviewed two years later. The data was analysed by assigning pupils' words into categories of response, thereby identifying pupil frameworks. The later research sought for evidence of the tenacity or otherwise of these frameworks over a period of time.

3. Solomon's work (1980, 1982) included asking pupils to explain words and to use them in sentences, in order to study pupils' background ideas about energy. The pupils' responses were then categorised using two contrasting themes which had arisen.

4. The aim of Nussbaum & Novak(1976) was to study conceptual change, both monitoring it and assessing a teaching strategy designed to promote it. Students were encouraged (via drawings) to articulate their ideas, thus revealing alternative frameworks. A discrepant event was then deliberately introduced to create conceptual conflicts, this and the students' further articulation of their explanations being designed to encourage cognitive accomm-

odation. A taxonomy of students' alternative frameworks (six categories) was drawn up.

5. Shipstone's work (1982) was aimed to explore misconceptions and to develop a hierarchy of error. He used paper and pencil tasks, with sets of questions.

6. The theoretical base for Pope & Gilbert's(1982) work is the model of G A Kelly(1969), their ideas seeking to influence, through the research into teaching, the teaching itself. They have used the Repertory Grid method which employs computer programs, and the Interview-about-Instances(IAI).

7. The latter technique has also been used by other workers of the Personal Construction of Knowledge Group, University of Surrey, eg Watts(1981). It consists of tape-recorded discussions with pupils, using a deck of cards which are concerned with the application of a particular word or concept. Each card has a line drawing of a situation which may or may not represent an application of the word. The pupil responds to the drawing and his or her reasons are then investigated further via interview questions. Frameworks of responses are later developed.

8. The work of Schaefer(1980) has been followed by other researchers. He tried to assess pupils' conceptual knowledge by constructing burr diagrams from the pupils' free associations. He was able to grade responses on the basis of colloquial, scientific and trans-disciplinary uses of language. He also used free definitions but contended that, since concept definition causes too great difficulties for younger children, phrases such as:'Tell me what you know about....,' could be used.

9. Ross & Sutton(1982) also employed free definitions, free

associations, and groups of related words in building concept profiles.

10. Freyburg & Osborne(1980) explored pupils' concepts and cognitive structures through structured interviews which were then followed by classroom observations and teacher interviews. They showed pupils' attempts at applying their everyday cognitive structures and concepts to classroom work, under five main headings.

11. Tasker & Osborne(1981) continued this work using in-depth interviews of pupils to explore teachers' assumptions about conceptual understanding. The latter three workers, while stressing the requirement of several months of interview work by trained researchers to appreciate specific concept grasp, broach the feasibility of pencil and paper survey questions for use by teachers in studying prior knowledge.

12. cf. also Stead & Osborne(1981a,b).

13. 14. Several other workers have used similar techniques, for example West(1982) with undergraduates, and Pines(1977).

15. Sutton(1982) has suggested the need for a system which charts the gradual shifts in pupils' use of language. He adds to Schaefer's techniques the following: sentence construction; mind's eye descriptions by pupils; interviews about responses; catalogues of pupils' available experience; and collections of the established language of a topic.

3.8 <u>NOMOTHETIC OR IDEOGRAPHIC? - A SUMMARY</u> In this chapter I have discussed a variety of research methods. I have suggested that they can be broadly categorised into two distinct modes of inquiry - nomothetic and ideographic. These distinct categories have a variety of pair-parallels in educational research. I have mentioned the revolutionary versus evolutionary above. Terms also widely used include quantitative versus qualitative (see for example, Roberts(1982)), agricultural-scientific versus anthropological (Power - 1976), scientific, experimental or traditional (Kapuscinski - 1982) versus ethnographic or naturalistic, etc.

There has been a continuing debate about which paradigm to apply and when because, as Roberts(1982) points out, each will yield different kinds of construction to be put on the reality of science education. Roberts argues for the complementarity of the extremes of approach since the two methodologies provide information for constructing a more adequate picture than one would obtain from either alone. He argues that researchers need a conceptualisation of the whole enterprise of science education research, to avoid an excessively narrow image.

Both Rist(1982) and Easley(1982) contend strongly in favour of qualitative methods. Rist would argue that, far from the two categories of methods overlapping or being used complementarily, they are mirror opposites, address different questions, and will not eventually coalesce but continue to be refined and develop independently.

Rist stresses that the qualitative perspective leads the investigator in quite different directions than those predicted upon experimental designs. However, he contends that the approaches are not merely different; he maintains that the quantitative methods have failed at several levels:

(a) Researchers have come to recognise that there are multiple routes and destinations for their efforts,

(b) the 'scientific' method has failed

i) to answer many of the more pressing questions in education,

ii) to respect fluidity and change,

iii) to address the processes of education.

(c) results (often inconclusive or hedged by caveats) obtained by statistical methods have been sterile and largely rejected by teachers and educational policy makers, and have had little or no impact on classroom practice.

Rist sees the following three principles applying to qualitative studies:

(a) Researchers seek a holistic understanding of the event/situation/phenomenon.

("...the holistic approach to research design is open to gathering data on any number of aspects on the setting under study in order to put together a complete picture ... of a particular situation." Patton (1978))

(b) It uses inductive logic by studying the specific and building towards the general. It is from the intensive analysis of a few or even a single site that generalisations can be drawn to other situations not studied.

(c) They are naturalistic. They study people where they are, and answer the question: What is going on here?

Rist attaches to this method of inquiry three modes of data collection:

Observation: Interviewing: Document analysis

Easley(1982) recognises several advantages of the qualitative method:

(a) He suggests that all sciences go through a natural history phase in which one learns about the underlying structure of phenomena and how they are organised. Then, from that knowledge, one can proceed to a more quantitative or formal type of inquiry.

(b) He argues that if educational research is approached in a naturalistic way it can be simultaneously more scientific in the sense that it emulates the natural sciences and more helpful to classroom practitioners.

(c) The method does not intervene but describes things as they are, and

(d) it can focus on the individual.

This latter advantage is focussed on by Denzin(1978):

"The researcher who has not yet penetrated the world of the individuals being studied is in no firm position to begin developing predictions, explanations, and theories about the world."

My research tries to involve these qualitative principles. It develops from purely descriptive observational studies to more closely controlled questioning and interviews.

It seeks to describe what is going on in classrooms; to test assess and comment on earlier research findings; and to generate further research by raising fresh issues.

CHAPTER FOUR

CHAPTER FOUR METHODS USED IN THE INVESTIGATION

The data was collected over a period of three years, in two distinct ways:

a) An initial period of twelve weeks was spent in four schools. These included two primary schools, a middle school, and a secondary comprehensive. The ages of the pupils tested ranged from 9 to 14 years.

b) A continuing programme of data collection and testing of several classes in my own school, the pupils' ages ranging from 11 to 16 years.

4.1 The initial study was conducted as follows.

Each school chose six or more pupils for observation. I asked for a range of abilities to be included, both boys and girls, specifying only that the pupils should be self-confident enough to talk to me. This was vital. I was not concerned with eliciting passive learning styles, or behaviour patterns, etc., but in finding out how they learned, and what they were thinking as they did so.

Data about each of the pupils was collected using the following seven methods:

4.11) Initial structured interviews.
4.12) Observation.
4.13) Scrutiny of resource material.
4.14) Structured tasks.
4.15) Unstructured interviews.
4.16) Teacher/Parent questions.
4.17) Final formal interviews.

This chapter gives a brief description of how these techniques were used, with examples.

4.11 Initial structured interviews   Each pupil was interviewed at the outset using a structured set of questions (see appendices). The interview was designed to gain an initial perspective on each pupil, and to discover something of the ways in which they themselves thought they learned new ideas.

The answers provided an insight into the personality of the pupil and suggested further questions or topics which were followed up immediately or discussed at a later date.

For example, Robert (D1102)* said he sometimes liked school, sometimes liked science, and enjoyed PE best.   He said he learned most new things at school.

4.11a Question 9 May 5 1981	Suppose you hear a new word, or idea: what do you do to try to understand it?
Robert:	I ask people, friends, my brother, or I use a dictionary.
Res:	How old is your brother?
Robert:	Eleven years - he's my twin. He's ten minutes older.
Res:	Is he cleverer than you?
Robert:	Yes.
Question 10	Can you tell me some new things, perhaps in science, which you have learned lately?
Robert:	I've learned about different kinds of floating things, and Morse Code, and friction and ships.
Res:	Was *is* floating?
Robert:	Don't know.
Res:	What is Morse Code?
Robert:	This is like the alphabet in buzzes and dashes.
Res:	What is friction?
Robert:	This is like the upwards push of water or friction that slows things down, a ship slowing.

* See pupil notation at the end of the chapter

4.12 Observation The pupils were observed in class as much as possible over the twelve week period. The work I saw varied considerably, from formal class teaching to project work, from group experiments to individual assignments, from films to tests. The variety was not only between schools, or between the pupils; some pupils were experiencing a wide range of teaching and learning methods.

Some idea of the variety of the observations data can be gained from the following examples.

4.12a Note on class activity. June 10 1981 The class had been looking at films about ants and honey bees.

Teacher:	The workers collected food from the flowers. What is the food called?
(D1002)Allan:	Pollen ..... nectar.
Teacher:	Do you know the difference between them?
Allan:	No ..... not sure.
Teacher:	In the film it said that bees were certain animals. What sort?
(D1102)Robert:	Social animals.
Teacher:	Can you think of other social animals?
Robert:	Dolphins.
Teacher:	What happens to a bee when it has stung something?
(D0901)Clare:	It dies.
Teacher:	Why?
Clare:	Because the sting is barbed. It gets hurt when it's pulled out.
Teacher:	Yes. What does barbed mean?
Robert:	Brambly where the sting is.
Allan:	Hooks on.
Clare:	Arrows shaped.
Teacher:	Yes, it's jagged.

4.12b Notes on small group activity - pupils working informally.
June 10 1981 11.25am

Robert(D1102) and Allan(D1002) are working at a circular table with four other boys.

Robert is working on a Dolphin sheet; Allan on a Honey Bees sheet. Allan is working very slowly, watching Robert sharpen his pencil. The pencil sharpener on this table is a constant source of distraction. Allan is talking most of the time to his friends, his back to the teacher. The teacher comes across and says:

What I should like is for you to do it yourself.

Allan looks both slightly offended and off-hand about this, claiming that he is doing it himself.

Robert writes: Dolphins are social animals because they live together.

I asked him to make his notes fuller, based on the film he had seen.

He puts: Bees live together in a colony, they all have a certain job. If they work together they go out to do certain things and then go back.

(11.45) Teacher moves Allan from his mates to a separate table.

I ask Allan: Were you having difficulty? Why you weren't working?

Allan: I couldn't answer the question on the type of bee dance where the food is a long way off.

Res: Why did you find that difficult?

Allan: I couldn't find it on the sheets.

(11.50) The teacher sums up the lesson for the class.
Robert is close to the teacher, putting his hand up to offer answers. Allan is far off, his back to the teacher, uninterested.

4.12c Notes on small group activity - pupils co-operating on
June 16 1981 an experiment.

Sandra(K1301) Sarah(K1302) and Robert(K1303) are reducing ores on fire-proof paper.

Robert goes to the teacher for ore. Sarah has finished copying the method but still sits, then starts writing again.

Robert: I'm going to get the crusher. Is that all you take? (to himself; turns and looks at the board. The girls go and join him. He is pounding up the mixture. He lets Sandra do it and goes to fetch a spatula. Sarah's holding the tongs).

Sandra: Is that OK? (ie. the mixture. Continues stirring)

Robert: That's the right flame.

Sandra: Is that a piece of paper? (Slightly baffled because it does not burn)

Robert: That's enough. Keep the rest in case we have to do it again.

Sarah heats the mixture.

Sarah: (To Robert) What do you do after this? You've got to heat it for five minutes.

Robert: Alison, I'll light your bunsen.

(Later he gets a spill, lights it and watches it burn.

He tries the effect of a flame, sooty mark, on the plastic ruler)

Sandra is also lighting wooden splints and watching them burn, breathing on the glowing splint.

She talks to Robert about the ---- teacher crying: 'She might lose her job.'

Robert: One more minute.

Sandra: What's meant to happen?

Robert: One more minute, then we can stop. Put it down Sarah.

Sandra: We can have another go.

Robert goes to the teacher, then to another boy.
Sandra heats some ore on the spatula.
Sarah keeps heating it on the paper.

Robert: Write some results, get some conclusions. If you want to do iron ore use two bunsens, iron's more compact I think he said and needs more fiercer heat.

Girls come over.

Sandra: You've done it wrong. You're supposed to use lead oxide. (Recrimination for Robert - he had taken iron ore first)

Robert: That's what Mr - told me to use.

Res: (To Sarah) Do you know what lead oxide looks like?

Sarah: No.

Robert: It's gone red - back to yellow.

Sandra: There's little gold bits in.

Robert: Silver.

The importance of the accumulating observational data was at least fourfold:

a) To produce sufficient evidence to formulate initial ideas about learning. Later research techniques could then be chosen and refined so as to test these early ideas.

b) To build up a firm and consistent picture of each pupil's approach to science activity and learning. This was essential in meeting both Walker's & Adelman's point about the clear charting of the pupils' perspective on their science, and Tasker's & Osborne's call for in-depth knowledge of the pupils' mental processes.

c) To generate a wide range of different types of data. These would enable cross-checking and comparisons in a rigorous attempt to minimise subjectivity.

d) Following from a) above to isolate specific areas of inquiry. For example, data 4.12b and 4.12c above gave strong evidence of the impact of earlier experience on the pupils' view of the purpose of science lessons.

4.13 Scrutiny of resource material The pupils were questioned about their text books, worksheets or other materials they were using. In all the questions very simple language was employed in deference to the extreme youth and inexperience of some of the pupils.

An example of a technique employed is Schaefer's method of free association, as follows.

4.13a May 12 and June 9 1981. A teacher had become very concerned at the low general knowledge of a first-year set, about everyday creatures, and intended to take them to look at the school pond. I questioned several members of the class before they went, and then again a month later.

Question: When you hear the words 'pond life' what things come to your mind?

Allan(K1202)

May 12 Big pond of mucky water with creepy crawlies in; they are very simple creatures with only two cells. Very good. Interesting to look at under a microscope. You can also take water weed and do experiments on it - how much CO_2 it takes up I think.

June 9 They're usually very small, quite a few one-celled animals there; they are usually simply invertebrates. They are classified into groups with long names - algae, spermatophytes. There is a plant that lives in water, can't remember its name, it's a sort of lily and its roots move about in water like little paddles.

Garry(K1209)

May 12 Insects, plants, getting food from water, breeding of insects; rest of nature getting food from pond. Fish, frogs changing into tadpoles.

June 9 A whole view of life. You just take it for granted that there's nothing in there but if you take a microscope there's a lot in there. Most animals in a pond are small except for frogs and toads. Ponds don't only cater for animals, but seaweed, brycophytes. Found it pretty interesting.

4.14 Structured tasks Pupils were occasionally engaged, individually or in groups, in tasks to repeat, reinforce, or extend points of difficulty or those which needed clarification. A tape recorder was sometimes used.

A typical example is reported in Chapter 7 (7.1). Here a pupil's answers indicated a lack of understanding. In such a case the structured task may establish the fact, show the degree of misunderstanding and perhaps point to reasons.

4.15 Unstructured interviews   Pupils were interviewed regularly about the ways in which their work and understanding were progressing. The questions were framed in the light of teacher/text book/AV or other learning resources being used by the pupils.

Some pupils kept a diary of significant happenings, a technique recommended by Sutton & West(1982), and these formed the basis for informal interviews. For example:

4.15a

Robert(D1102)	This is a diary of new things I have learned in science.
June 2 1981	Today I learned about ants and how they talk to each other. They rub their feelers together and if one of them finds food it will fly back to the nest, and leave a scent where the food is, and then when it gets back to the nest it head-buts the other ones and they follow the scent to where the food is.
June 3	Today I learned that a mirror was glass and metal.
June 4	Today I learnt how bees talk to one and other when they find food.
June 5	Bees can tell how far away food is by doing a dance called the tail wagging dance or the circle dance.
June 8	Elephants can talk by rubbing heads, trunks and bodies.
June 9	Elephants do 2 charges, a dummy charge or a real charge, on a real charge it's ears will go straight back for it's tusks. In a dummy charge it does the same but turns back half way.
June 10	Dolphins talk by making rubbing and clicking sounds.
June 11	If a dolphin is in danger he will send out a message for help by clicking.
June 12	Dolphins are social animals because they live together.

4.16 Teacher/Parent questions The teachers answered questions about the lesson or the pupils, before, during and after lessons. They provided reports, both as form and subject teachers, and made exercise books, school reports, etc., readily available.

A typical tutor's report was:

4.16a

Robert(D1102) June 1981

Robert is a very inquisitive child. He is always eager to learn new concepts in all areas of the curriculum. He can quickly pick things up. When having to recall a piece of work that has already been covered he has a very good memory and does not need much prompting to help to remember. Other children look to Robert for help when he is working in a group but when he is on his own he tends to come up for reassurance on a piece of work and does not seem to have any confidence. He does not use books to help him most of the time when he wants to find something out unless he is sent to a book by the teacher.

The parents of the pupils provided answers to a set questionnaire (see Appendices) which was approved and sent out by the school. (One school declined to send the questionnaire: it was considered that the parents of the ethnic minority pupils would not understand the questions).

4.17 Final formal interviews At the end of the study the pupils were interviewed using questions similar to those employed initially. By this time I knew the pupils extremely well and their relaxed responses could be compared with those elicited under the more tense conditions prevailing at the outset.

4.17a Robert(D1102) July 6 1981

Res: How do you go about learning new things?

Robert: I look up things. If I can't understand then I ask the teacher - at the end.(ie. as a last resort)

Res: Do you like working alone or in a group?

Robert: In a group.

Res: Do you rely on others in the group?

Robert: No.

Res: Do they rely on you?

Robert: No.

Res: Why do you sit together?

Robert: Shaun asks me things like spellings, answers and things like reading - he doesn't always know.

Res: Which subject are you best at?

Robert: Maths.

Res: Why are you good at this?

Robert: I always come up with the right answer before everybody else and I have to work it out in my head.

Res: Have you always found Maths easy?

Robert: Sometimes. Once I find out how to do it it's easy ... it's just finding out how to do things.

Res: How do you find out?

Robert: I read, then ask and explain.

Res: Which things have you found difficult in the past?

Robert: Fractions and decimals.

Res: How did you master them?

Robert: One day I got one right. I copied it out and then they were all right.

Res: Do you take Maths home?

Robert: Yes. What I do first of all, then they check 'em up and if they're wrong I rub them out and start again.

Because the amount of data generated was large, several problems were evident as this phase of the research ended. Chief among these was that of selecting from the bulk of the data that information which was pertinent to the research thesis. The precise direction of the research had deliberately not been defined and the problem was turned into a benefit for two reasons:

a) The full data could be retained on file as a bank of results about the individual pupils on which to draw at a later stage.

b) Since the selection and processing of data derived by these techniques requires time for thought, the second phase of the research could be started while a full assessment of the first phase was being made.

A further problem had to be solved: to limit the scope of the study. The second phase of the research would be held under part time conditions while teaching, and it was vital to be realistic about the number of questions isolated for scrutiny.

4.2 Data collected from classes in my own school Data was collected from classes in my own school over a period of two years using the methods described and amplified below.

The earlier research had suggested ideas about learning which required further thought and evidence. I therefore chose methods which seemed most likely to generate data for developing and testing these ideas.

4.21 Questions were asked before topics were introduced at first year level to determine prior knowledge.

The same questions were asked exactly one year later to test the durability of that prior knowledge.

The pupils were interviewed and re-interviewed where necessary to probe more deeply into the reasons behind responses.

Questions were asked prior and subsequent to instruction in later years. Bur diagrams and lists of responses were constructed for comparison purposes and as a basis for discussions with the teachers and classes.

4.22 Private interviews and class discussions were held. The former were intended to authenticate and clarify unusual responses. Class discussion was designed to expose private responses to public scrutiny and criticism (with pupil permission). Further interviews were held to determine the fate of earlier responses.

4.23 Classes were questioned after certain lessons using pencil and paper tests, and their exercise books scrutinised, to discover the purpose of the lesson from the pupils' point of view.

PUPIL NOTATION WITHIN THE DATA

The first phase 26 pupils aged 9-13 years in 4 schools

School D	Junior(8-11 years)		School S	Primary(5-11 years)	
	Clare	D0901		Manjit	S1001
	Alison	D1001		Tahera	S1101
	Allan	D1002		Tejinder	S1102
	Cheryl	D1101		Anil P	S1103
	Robert	D1102		Ravi	S1104
	Stuart	D1103		Anil S	S1105

School K	Secondary(11-18 years)		School KC	Middle(9-13 years)	
	Andrew	K1201		Peter	KC1001
	Alan	K1202		Anne-Marie	1002
	Murray	K1101		Gail	KC1003
	Stuart	K1102		Martin	KC1101
	Kenneth	K1103		Claire	KC1201
	Sarah	K1301		Daren	KC1202
	Sandra	K1302			
	Robert	K1303			

Thus, at school D there was one pupil aged 9, two aged 10 and three aged 11.

The second phase 111 pupils aged 11 - 16 years

School Q Secondary(11-18 years)

Because some of the testing occurred over a period of months and years the ages of the pupils have been fixed, for ease of notation, as that of the chronological age of the academic year; ie. First Year -aged 12; Second Year - aged 13, etc.

The classes tested were: Q1201-1225 (this class is Q1301-1326 a year later)
Q1327-1354
Q1355-1367
Q1401-1427
Q1601-1619

CHAPTER FIVE

CHAPTER FIVE THE KEY QUESTIONS

The key questions are:

1. What is going on in the mind of the child when he or she meets new knowledge and ideas?
2. What impact does prior knowledge have on this process and on its outcomes?

Theory suggests that when a child meets new knowledge the process of learning is dependent upon context - both the context of the child's prior knowledge and that in which the new knowledge arises. This further suggests that children bring a selection of prior knowledge to bear in making sense of new ideas. Research has indicated that the prior knowledge is sometimes sufficiently stable to be termed an alternative framework of interpretation.

The following data chapters should shed light on these theoretical and empirical considerations, in three overlapping areas. (The way in which these areas were selected for study is discussed more fully in Chapter Six).

a) The influence of prior knowledge. To seek to clarify the influence of salient knowledge on the pupils' interpretation of words. Are tentative or not so tentative links made by pupils and, if so, do these help or hinder learning? 'Alternative frameworks' of interpretation: what sorts of alternative representations of experiences do pupils make, and has the study found evidence to support the literature on alternative frameworks? How tenacious are pupils' early ideas?

b) How pupils cope with science lessons. Do pupils invent their own purposes for class activity? What impact does selective attention have on the notion of pupils' varying horizons of satisfaction? Are pupils motivated to learn as meaning increases? What does increased meaning mean to pupils?

c) The effects of context: both to study the effect of context on the pupils' understanding of concepts, and to look for evidence of their reading the meaning differently in different contexts.

CHAPTER SIX

CHAPTER SIX HOW THE FIRST PHASE OF THE RESEARCH INFLUENCED THE DEVELOPMENT OF THE THESIS

In all limited-resource research, whether of time, materials or personnel, a judgment has to made: either to study a few subjects deeply using a multiplicity of techniques, or to involve considerable numbers of subjects using carefully framed tests, questionnaires, etc.

The initial phase of this research followed the former course, involving the study of 26 pupils aged 9-14 years, in four schools, over a period of 12 weeks.

Despite the considerable volume of data resulting from this investigation no firm inferences were drawn; rather the results enabled hypotheses to be framed and compared both with theoretical ideas and the empirical results of other workers, and methods isolated which seemed most capable of producing data to test those hypotheses during further study.

The real value of this pilot study became apparent only in retrospect, its contributions to the later study including the following:

1. It provided that initial bulk of data which is essential for minimising subjective inferences.

It is not important what the researcher thinks. It _is_ important what the researcher thinks about the data. The quantity and quality of the data are directly related to the value of research inference.

2. It provided a perspective from which to see more clearly, a) the effect of research method upon the quality and reliability of data derived,

b) the need to generate alternative hypotheses from the data, so as to keep the selection of evidence as widely based as possible,

c) the breadth of interpretations of evidence derived from the pupils' responses.

3. It enabled more specific areas of probing to be focussed on.

6.1 EXAMPLES OF WAYS IN WHICH THE DATA INFLUENCED LATER THINKING AND STRATEGY

I have chosen a sequence of interviews with Alison(D1001) to illustrate the way in which the initial phase of my research helped to focus my attention on specific areas of learning.

I selected this sequence for several reasons:

1. Alison, being both articulate and ingenuous, provided responses which I could confidently assume were clear mirrors of her thoughts as she tried to understand new ideas.

2. The sequence spanned eight weeks, and the final interview came without warning. Alison's understanding was therefore not spur-of-the-moment, nor contrived on the spot to satisfy an inquisitive visitor.

3. The sequence started nicely with an apparent misconception, and ended with partial understanding. It seemed also

to provide clues about her ideas which I could think about as I tried to discover how her understanding had developed.

4. It included interview questions, worksheet exercises and dictionary searching, ie. the basic methods by which she would normally learn her science. The research sequence was as near as possible to ordinary lessons.

13 May 1981 In the initial interview with Alison, I asked:

> Can you tell me some new things - perhaps in science- which you have learned lately?

Alison: Submarines - a submarine has a ballast tank for water to make it submerge and come and dive. It has a tank for air and comes up to be serviced, but some like nuclear make their own air and fresh water from sea water.

This answer seemed to put 'submerge' and 'dive' as opposites, and I wondered if there might be some lack of understanding about the word submerge.

My next questions were:

> When you can't understand something, do you try to learn it by yourself? If not, who do you ask? Which person?

Alison: First I try to work it out for myself and then, if I can't honestly work it out by myself I go and ask the teacher.

A later question was:

> Can you think of something you understand now, but which you used to find impossible?

Alison: About how submarines go under water and the people can live but people who go under water without diving gear just die, and how submarines can dive and submerge, their ballast.

Again, Alison seemed not to understand the word submerge, apparently using it as opposite to dive, and did not appear to be aware of a lack of understanding.

I questioned her further:

> What does 'submerge' mean?

Alison: To appear.

Res: Sometime in the future, maybe next week, or in six weeks' time, I shall ask you what submerge means. Can you look it up and have the real meaning ready?

In the structured interview from which the above questions are taken Alison had said that she preferred to work out problems herself before turning to a teacher or parent. This was confirmed by her parents. Their answers on a questionnaire (see appendices) had revealed that Alison does try to cope with difficulties herself, and both reads widely and uses dictionaries, being a keen member of the local library. I was interested to know (a) whether she would look up the word (b) what she would learn (c) what she would remember over a period of time. I therefore left the problem with her for a long time and asked her some weeks later, without prior warning:

July 8 1981 Alison, do you remember us talking about submarines, a few weeks ago? Can you tell me what 'submerge' means?

Alison: Oh, I looked that up. I think it means to go under water because merge means to come above water and sub means underneath, so it means..... (trails off).

Res: Take the word 'merge'. Can you think of work you've been doing lately where you might have used that word?

Alison: The sheets I used I didn't use the word merge.

Res: Take the two words: Disguise and Camouflage. Which do you think merge is nearest to in meaning?

Alison: I think camouflage because it's whatever it is, it's camouflage on top or underneath the water.

Alison's difficulties with submerge seemed to be continuing. She now, quite rightly, thought it meant 'to go under water,' but it was the context of the 'water' which appeared to present problems. It seemed as if she was equating merge with break surface, so that when she put 'sub' with it the whole word failed to make sense, hence the trailing off in her explanation.

The reason that I introduced disguise and camouflage was because the class had been studying these extensively. Alison, unlike several other pupils, had a good understanding of the difference between them.

Her responses in a written test which I set her were:

> Disguise is something or someone dressing up or covering their selves with some piece of clothing or materials such as leaves and paint.
>
> Camouflage is something or someone hiding by mixing with the colour of its own skin. Animals hide from their predators (enemies).

One part of the Disguise versus Camouflage exercise had been to read six different dictionary definitions of each, and choose the 'best' meaning. The definitions of camouflage included such phrases as:

> 'by making it merge into its background.'
> 'to blend in with....'

Although Alison now understood what camouflage meant she could not remember using the word 'merge.' In her second interview she seemed to be using 'sub' as a negative prefix for 'merge'. (cf. normal and abnormal; septic and aseptic).

Now, if Alison has assumed that merge is opposite to submerge it would explain the mental struggle she has in reconciling merge with camouflage, hence the rather tentative:

> 'camouflage on top or underneath the water,'

where she tries to keep the explanation within the wider context of submarines.

There is another possible explanation: that Alison is confusing merge and emerge. This would explain her idea that merge means:

'to come above,' and give credence to her theory that 'sub' as a prefix converts merge into a word of opposite meaning.

Alison's attempts at trying to explain submerge and merge in terms of camouflage, while keeping all the words within the earlier contexts of water and submarines, impinge on aspects of pupils' understanding which are currently under discussion in science research and which have been discussed in earlier theoretical chapters of this thesis.

They include:

(a) <u>the notion that context dominates and may determine the meaning of words.</u> Alison's apparent idea that sub- is a negative prefix has created a litotical quandary for her, resulting in the interpretation of the meaning of submerge as opposite to its real meaning. Because she has in her mind a very firm picture of submarines going down into and coming up out of water even her explanation of the meaning of 'merge' must be fixed in that same context.

Another issue which might be connected with Alison's quandary is (b) <u>the theory that pupils, faced with seemingly irreconcilable issues, will 'acquiesce in the bizarre.'</u>
Alison arrives at the point where she knows that submerge means

'<u>to go under water,</u>'

and her understanding of camouflage is precise. But when she is required to extend her understanding of these two words in an effort to explain her professed meaning of the word merge, she 'acquiesces' and offers a nonsensical answer:

> <u>'It's whatever it is, it's camouflage on top or underneath the water.'</u>

A further aspect of current learning theory is contained in Alison's answers: (c) that pupils' misconceptions are tenacious and resistant to extinction.

The fixation in Alison's mind that submerge means 'to appear' influences her later use of the word and determines her subsequent mental processes.

The whole sequence seems to be:

STAGE 1	May 13	Alison states: 'submarines .... submerge and dive.' Thus, submerge is opposite to dive. Res: What does submerge mean? Alison: To appear.
STAGE 2	Dictionary + Period of time	Alison learns from the dictionary that submerge means 'go down' and sub- means 'under.' Thus merge = to come above water; a kind of positional (+) v (-) cancellation.
STAGE 3	July 8	Alison is required to explain the words and extend their meanings, linking merge with camouflage. She has the idea that merge is 'to appear/come up'. She retains this, explaining her idea of camouflage (blending or mixing) in terms of 'on top or underneath the water.'

It seems that Alison's earliest idea that 'submerge means appear' was so stubbornly fixed that she contrived to transfer it to the word merge, and then allow it to alter her ideas about camouflage. Finding her meaning for individual words ill-fitted to new situations she pushed the latter out of shape in an effort to produce a match.

This sequence illustrates that aspect of pupils' learning which is the centre-piece of Ausubel's theory: (d) that prior knowledge influences subsequent understanding.

On the basis of considerable data obtained in this way, I decided to focus my attention on three aspects of pupils' science learning, outlined more fully in the previous chapter.

1. To discover ways in which prior knowledge influences understanding, and to test the contention that pupils formulate alternative frameworks of interpretation.

2. To try to discover pupils' understanding of the purpose of their science lessons, based on their earlier experiences.

3. To probe the effects of context upon meaning.

CHAPTER SEVEN

CHAPTER SEVEN SOME EXAMPLES OF HOW PRIOR KNOWLEDGE INFLUENCES PUPILS' LEARNING; AND EVIDENCE FOR AND AGAINST THE CLAIM THAT PUPILS FORMULATE ALTERNATIVE FRAMEWORKS OF UNDERSTANDING

7.1 An investigation into the ideas of a 10 year old pupil about the amount of substances

7.2 An investigation into the impact of prior knowledge on the ideas of a class of 12 and 13 year old pupils about volume and mass

7.3 A study of the ideas of some 10 year old pupils about water vapour and air

7.4 A close study of the ideas of some 13 year old pupils about acids - before and after a teaching sequence; and of some 14 and 16 year old pupils about acids

7.5 An investigation into the impact of prior knowledge on the ideas of some 13 year old pupils about acids

7.6 Using the apparent misconceptions of some 14 year old pupils about acids to test the tenacity theory of Ausubel

CHAPTER INTRODUCTION

Pupils are constantly being introduced to new words and ideas in science. The way they receive and assimilate new knowledge will be dependent on many factors, including their earlier knowledge and experiences. The aim of this chapter is to look for evidence that pupils' attempts at understanding new work are influenced by specific earlier experiences, and to interpret the effect of prior knowledge in helping or hindering understanding.

The chapter will focus on those parts of my data which relate to current ideas about alternative frameworks. Much recent work (for example, Driver & Engel - 1978) suggests that pupils try to understand new ideas by formulating highly personal conceptions and appraisals of the new material. They claim that these are not entirely idiosyncratic but that common patterns are found, and that these can last for a long time.

In a final section of the chapter some apparent misconceptions of pupils about acids are used to test the tenacity theory of Ausubel.

CHAPTER STRUCTURE

Although the main thrust of the thesis - prior knowledge, and its more specific components: 'alternative frameworks' and the tenacity of conceptions - runs through the chapter, the results are presented in discrete sections, these being separate investigations. The data and commentaries are structured around two areas of pupils' learning, each having three sections.

The first area considers specific examples of how pupils cope with the idea of the 'amount' of substances. It includes observation, task work and interviews with an individual pupil; observation of class discussion and interviews with selected pupils; and close questioning of pupils before and after teaching sequences. The science concepts studied are change of state of ice and water, water vapour and air, and volume and mass.

In the second area pupils' ideas about acids are investigated. The three sections develop along the following lines: pupils were questioned about their ideas of acids before and after being taught, and selected pupils interviewed to see if examples could be found of the direct impact of prior knowledge. Next, similar questions were asked of older pupils to see whether prior knowledge is retained or returns after formal contrary teaching. Finally the ideas of a class of pupils were 'fed back' to them in class discussion in a controlled and rigorous attempt to shake their original conceptions, and selected pupils interviewed to assess the impact of this attempt.

The data is drawn both from my initial observational studies and from the second close questioning phase.

7.1 An investigation into the ideas of a 10 year old pupil about the 'amount' of substances

Alison(D1001) had been working on her own at Topic, an integrated studies course which includes history, geography, science, etc. The work included worksheets about the industrial revolution and the development of machinery. I tried to find out what she understood of the work.

7.1a June 24 1981

Res: Alison, you've been doing work on machines. Can you say what a machine is?

1. Alison: Well, they used weavers and things to make wool, machines for making things and doing jobs instead of people. (At first) they weren't used for transport and things. They had engines. They used coal for power.

Res: What other things did they use, to make work easier or quicker?

2. Alison: They used water.

Res: Yes; anything else? What else flows? What about wind?

3. Alison: Oh, yes - sails, ships, weathercocks, vanes.

Res: Yes. How do we use the wind in machines? (thinking of the windmill).

4. Alison: In the steam engine. There is something in the engine that the heat affected to make it work.

Res: Is it water?

5. Alison: Water turns to steam?

Res: What happens when water turns to steam - what big change? Think of the kitchen.

6. Alison: It would turn to a gas.

Res: What about the amount - of steam?

7. Alison: There'd be less.

Res: How do you mean?

8. Alison: Well, say you boiled a litre of water there'd be only about a half a litre of steam, because less of the steam would come out of the water than there is in the water, because the heat of the electricity would probably dissolve the steam or magic it away.

Res: So you think that when water turns to steam there is less steam than there was water?

9 Alison: Yes.

Res: What about when water turns to ice? What then?

10 Alison: There'd be probably more water than ice, because the same as water going to steam, water going to ice would probably make it less because it's all pressed together and the more you turn water to ice the less you'd have at the end.

Res: What are you basing your idea on?

11. Alison: Well, I've seen that steam turns to water and water to steam because when you boil water it vapourises to steam and I've seen ice melted and there's more water than ice.

Res: Where have you seen this, that there's more water than ice when it melts?

12. Alison: When I have a cold drink, I leave the ice cube to melt. There's more water in the cup than there was ice.

Res: I know, let's do an experiment to see if your idea's right.

We found a very small plastic cup and filled it exactly to the top with water. Then we put it carefully in the school canteen fridge. I said to Alison: Have a look at this when the water has frozen solid. See if the cup has the same amount of ice, or if it has shrunk or expanded. What do you think will happen?

13 Alison: The ice will shrink.

7.1b 12 noon the same day. We looked at the beaker in the fridge. Unfortunately the water had not frozen through. There was a slight bulge upwards but an untrained eye would not have seen this.

Res: Well, what do you think has happened?

1. Alison: It's gone down a little bit ... (pause) ... I think.

I had to leave the school then, and said to Alison: Have a look at the cup again at about 3 o'clock. When I come next week I'll ask you what you saw.

However, Alison went on holiday and when I saw her again it was a fortnight later

7.1c July 8

Res: Did you have a look at the ice in the cup? What did you see?

1. Alison: The ice was the same when it was solid as it was when it was runny, but when I melted it again it was less than it was as a solid.

The above extracts of interviews and simple experimental work with a ten year old illustrate the impact of prior knowledge upon understanding.

The machines which Alison had been studying included steam engines, and a glance at her written work showed that these created keen interest in her mind. When I tried to guide the interview chronologically via windmills Alison's mind leaped immediately from wind to steam.

Trying not to suggest answers, and also trying to avoid the word 'volume', I ran into trouble with the word 'amount', but fortunately elicited information about Alison's ideas on steam.

She has the concept of vaporisation: 'It would turn to steam,' but thinks that some of the water is being lost during boiling. Her 'amount' (a litre) of water is being heated by electricity. This awesome entity somehow has the property either of dissolving the steam or magicking it away. One can almost hear Alison thinking: 'How else can you explain the fact that there is less steam than there was water?'

Alison's ideas are based on her own experience, and this prior knowledge has two directions of impact.

a) <u>She constructs her own explanation of what is happening.</u>

Alison's ideas start from concrete 'fact'. An ice cube left to melt in a cold drink cup will produce 'more' water. Her ideas then go on to more abstract rationalisation - that the more compressed something is the less there is of it. So there is less ice than water. But, she says, there will be more water than steam. How can some of the water be destroyed when turned to steam? Alison, faced with a very difficult situation, says:

8. 'The heat of the electricity would probably dissolve (it) or magic it away.'

These are Alison's early mental wrestlings with the problems of density, volume and energy. Although she cannot understand she is anxious to; so keen in fact that she is making her own tentative meanings in order to make sense of her, as yet, limited factual knowledge.

Some parts of her understanding are still at the representational level; she clings to the child's assumptions of volume (that there is more liquid in a filled tall container than in a small fat one of the same capacity) when she sees the small lump of ice spread out to form a pool of liquid; and she is prepared to acquiesce in the bizarre by bringing in magic to support her ideas. (cf. Alison's similar acquiescence, cited 6b, p62)

There is much here to compare with evidence from other workers. Alison's desire to construct a tentative meaning supports the ideas of Collins, Brown & Larkins(1980); her need to generate meaning by thinking out the facts is in line with Kelly's(1969) views of learning; her tendency towards the bizarre adds weight to Donaldson's (1978) claims; and this tendency to construct meanings compatible with prior knowledge is a fact which complements the assertions of Osborne et al(1982).

However, this example suggests a particular difficulty for children: that their explanations, tentatively built from prior knowledge, will be inadequate and have a tendency towards bizarre distortion if the pupils do not understand the basic science concepts inherent in the hypothesis.

This result has a remarkably exact parallel with results obtained by Osborne & Cosgrove(1983) who investigated pupils' ideas about the changes of state of water, by interviews.

The pupils' agea ranged from 8 to 17 years. When asked for their ideas of what happens when ice melts they gave answers which could be broadly categorised into three views. The third view that was isolated was: 'The heat makes the particles move further apart.'

This view was expressed by pupils aged 14-17 years.

An interview with a 15 year old pupil contained this fragment:

Res: What happened when the ice melted?

Pupil: It's going to be more .... if you took the volume of that(the water) it is going to be more.

Res: Can you talk about what is happening in terms of molecules when it freezes?

Pupil: The colder the heat the less vibrations there are between them .... so that is why the ice doesn't take up as much room as when it is a liquid or gas ...

This 15 year old pupil's response:

'It's going to be more,'

precisely parallels both Alison's idea that

10 'There'd be probably more water than ice,'

and her experience

11 'I've seen ice melted and there's more water than ice.'

Alison's explanation is not therefore idiosyncratic (nor is it a misconception since the volumes of ice and water are anomalous anyway and would defy 'reasoning' at the molecular level by pupils so young) and this seems to be an alternative framework of interpretation as understood by Driver & Easley(1978) and others.

Alison's explanation cannot wait until she knows all the answers; it must be built on what she knows now, however limited the knowledge. It is not an explanation for an audience, or to satisfy an externally promulgated question, but an essential formulation of the mind. She has not framed her explanation because she was asked to (she articulated it because she was asked to) but had all the 'meaning' for her experiences already working in her imagination. This is a most important aspect of pupils' learning for teachers to be constantly aware of. When children hear or are introduced to words, ideas and concepts these things do not lie dormant in the mind, waiting for a teacher's explanation or embellishment, they are processed at varying levels of understanding or sophistication, depending upon the individual mind and its previous experience.

In these examples of the change of state of water the pupils' difficulty centres round the idea of less and more. These words may seem simple, unequivocal; but when they are extended into the more complex realm of density, volume, change of state of substances, etc., they take on much greater complexity and subtlety.

Alison and other such pupils are trying to cope with concepts which not only introduce new ideas in themselves, but change the very nature of the 'simple' words the pupils had hitherto 'understood.' The word 'more' is now extended into the realm of 'more substance'; the word 'amount' can mean 'quantity of substance' or 'quantity of space taken up', these being extended to ideas of mass, volume, capacity, etc.

(I will discuss this further in Section 7.2 where pupils' ideas about volume and mass are considered)

Alison's use of prior knowledge is used not only to build her own explanations of phenomena, but has another important direction of impact.

(b) <u>Her prior knowledge and the tentative hypothesis she is framing affect both her expectations and interpretations of coming events.</u>

Alison finds difficulty in re-shaping her ideas because she has expectations of what will happen, based on earlier experience and thinking. When she is asked what she thinks will happen to the water when it freezes, she says:

13 'The ice will shrink.'

Later on, when the water has partially frozen, she looks at the cup expecting to see a significant shrinkage. She cannot understand why this has not happened, imagines it must have, but is prepared to be doubtful.

7.1b 1 'It's gone down a bit ... (pause) ... I think.'

Alison's readiness to allow fanciful ideas in her mind does not stretch to disbelieving the evidence of her own eyes. She is beginning to alter her conceptions. Alison completed the experiment alone, and two weeks later talked about it lucidly, explaining how she extended the experiment and discovered by stages something which went counter to her earlier experience and ideas.

Res: (When the water had completely frozen) What did you see?

7.1c 1 Alison: The ice was the same when it was solid as it was when it was runny, (her expectation that it would be less has been thrown into doubt) but when I melted it again it was less than it was as a solid (her more accurate test of a definite volume of ice, where the water cannot be spread out, has helped her to a more accurate contextual assessment of what is happening).

Alison's immediate tendency to cling to her expectations lends assistance to the contention (cf Ausubel) of the tenacity of misconceptions. It would seem though that such tenaciousness will not persist where irrefutable evidence to the contrary is discovered by the pupil. It is doubtful whether Alison would have changed her mind so readily or so completely if she had been presented with counter argument rather than personal experience.

In recent years there has been some questioning of the value of the heuristic method as a way of learning science. In this instance at least the pupil's learning was enormously enhanced by making the discovery herself. This gives support to those who advocate some type of guided discovery approach.

The work of Osborne & Cosgrove(1983) would also support this view - that pupils be allowed to test their ideas. The first and most important part seems to be to encourage pupils to generate and articulate their own explanations of experiences.

7.2 An investigation into the impact of prior knowledge on the ideas of a class of 12 and 13 year old pupils about volume and mass

Following the observational phase reported in part in section 7.1 I decided to test a class of 12/13 year old pupils before they were taught about volume and mass, and then to test them again a year later to see if their earlier experiences had any impact on their learning at secondary level.

The method of approach was to ask the class to write down the answers to seven questions before the words volume or mass were mentioned, to ask the same questions one year later, to analyse the results, and to interview selected pupils to find out more about what they had written.

The results are given, with commentary as appropriate, in the following order:

(a) The answers they gave to questions about volume (Table 7.21 - Pupils Q1201-22/Q1301-22) Nineteen pupils completed both tests. The answers to two of the questions are presented in burr diagrams Chart 7.21/2.

(b) Interviews with four pupils.

(c) Similar before and after questions about mass, the answers to two of the questions summarised in burr-type diagrams.

A class of 12 year old pupils was asked the following questions about volume (16/11/82) and (5/12/83).

1. Spell the word 'VOLUME'.
2. Have you ever heard the word before?
3. If so, where did you first hear it?
4. What do you think it means?
5. Can you give another word which means the same thing?
6. Have you ever measured the volume of a liquid? If so, what piece of apparatus or equipment did you use?
7. How would you work out the volume of a solid, such as a cube, using arithmetic?

The pupils' answers to the questions 3-7 are given in Table 7.21 overleaf.

Name of pupil	Quest	16/11/82	5/12/83
Sandra	4	It means a space of a square	The amount of weight
	5	Fill	Mass
	6	I have never done it	Scales
	7	Don't know	Dropping an object into water
Pauline	3	At my Junior school when I was doing maths	I have heard it in my old school
	4	I think the volume means the quantity	Volume means the weight
	5	Capacity	Mass
	6	Never done it	Arm balance
	7	Measure it on one side and then the other side and times it and your answer would be right	Length breath
Kerry (Q1313)	3	On TV referring to the volumes of the book Brittania encylopedia	Maths lesson
	4	The area of an object etc (science) a part of a series of books, one of	Amount of space occupied by something
	5	Area	Mass
	6	No, never done it	Pipette, measuring cylinder
	7	Length x Bredth	Length x bredth x height
Michael B	4	Volume means when you turn on the tv	Space occupied
	5	Sound	Mass
	6	Never done it	Don't know
	7	Scales	-
Christine	4	The space around an object	Space
	5	Distance	Vacuum
	6	Millileter jug	Ruler
	7	Use a ruler and add all the sides and add them together	Length x breadth x height

TABLE 7.21 Pupils' answers to questions about VOLUME

Cont/

Name of pupil	Quest	16/11/82	5/12/83
Amanda (Q1309)	3	I was listening with my mother and father to a television programme	Science(Mr -) Secondary
	4	It is weight and height	Space occupied
	5	Weight or height	Weight
	6	Never did it	-
	7	Don't know	Weight x height
Thomas (Q1319)	3	I never heard it yesterday but the day before in the house when my mum was polyfilling	In last year
	4	A knob on the tv	Space occupied and sound
	5	Cup full	Mass
	6	I have not done it	Do not know
	7	Scales	Using the pie method
Michael W	4	The amount of space something has in it	How much space something has
	5	Mass	Mass
	6	No	Displacement can
	7	Multiply the length by the width and multiply it by the height	Length x height x width
Nicky	4	Volume means high or low	The amount of space it occupies
	5	Weight	Mass
	6	Yes I have. A container a cup	(Drawing of scales)
	7	Cutting it up into bits	l x h x b
Juliette	4	Volume means weight	The space an object occupies
	5	Weight	-
	6	Never done it	-
	7	Don't know	Length x width x height
Alison (Q1308)	4	Different balances of weight	The space occopied
	5	Weight	Space used
	6	Never done it	Arm balance
	7	Don't know	Breadth, length

TABLE 7.21 cont.

Cont/

Name of pupil	Quest	16/11/82	5/12/83
Stephen	4	Mass that is high or low	The mass of something
	5	Hevey	Mass
	6	Wigh it	(Diagram of balance)
	7	-	L x H x W
Rachel	4	Means how much space something occupies	The amount of space something occupies
	5	Area	Mass
	6	Never done it	-
	7	Length x Width x height	l x h x w
Lorna	4	Means to turn up the sound	Means the weight of something
	5	-	Mass
	6	No	(Diagram of balance)
	7	No	No
John	3	In the first year Juniors	Before Seniors on the TV for sound button
	4	Volume means sound or it can mean space, room	Space occupied and also sound
	5	Space, sound	Space + mass
	6	Yes, by using a jug with the $^1/_2$ $^1/_4$ on it	Weighing machine
	7	Measure the sides and width	Using the pi method
Gary	3	I heard volurem I first started science	In the Junior in a lesson of science
	4	Volurem is a gas, how hi it gets	Volume is and occupe area and sound
	5	Mass	Mass
	6	Did not do it	cm^3
	7	The size, long x beath	A pie chart method

TABLE 7.21 cont.

Cont/

Name of pupil	Quest	16/11/82	5/12/83
Marie	3	In maths doing graphics	Before Senior
	4	Finding the volume of something means finding the mass	Means the weight of something
	5	Mass	Mass
	6	No	A ruler
	7	A whiegh machine	-
Roy	3	When we did an experiment at (Junior) school	
	4	When a sutan thing has gon up	Wayt of a sutan thing
	5	-	Wayt
	6	-	)Diagram of arm
	7	-	)balance
Jane	3	In the second year in -- school	In Mr -- lesson (Secondary school)
	4	Weight	The hiegt, wight of something
	5	Mass	Mass
	6	No	Diagram of arm balance
	7	Have not done	No
Brian	4		Drifria parts of it
	5		-
	6		top pan barens l x h x w
	7		legthe

TABLE 7.21 cont.

It can be seen from the pupils' responses given in Table 7.21 and also in condensed form in the burr-type diagrams (Charts 7.21 and 7.22, that the pupils draw on an enormously wide range of experiences in trying to explain their ideas about volume.

On the first occasion that they were questioned they understandably drew on pre-secondary school experience. Although the questions were being put in a science lesson by a science teacher they do not answer always in the science context, and indeed where they refer back to Junior school work the answers they give are usually in a maths context despite considerable primary science experience.

For example: (Pauline)

'At my Junior school.'
'I think the volume means quantity.'
'Capacity.'
'Measure on one side and then the other side and times it and your answer should be right.'

The pupils' responses can be categorised into two broad groupings: the volume of sound,
and space or amount of substances.

Their answers show (cf. Pauline above) that they confuse volume and capacity, that is the amount of space which a body occupies and the amount of space (in a container) available for occupancy. It is not easy to see how this arises. The confusion could derive from their earlier experiences which are a medley of (at least) both maths and science. Their answers show that they can hold a wide range of experiences in their minds but there are indications that, in trying to solve problems, they select only a narrow band of those experiences. Their experience of volume has arisen formally from maths measuring - length, area, volume. Having presumably mastered the measurement of a cube via the lengths of sides, they then measured fluid

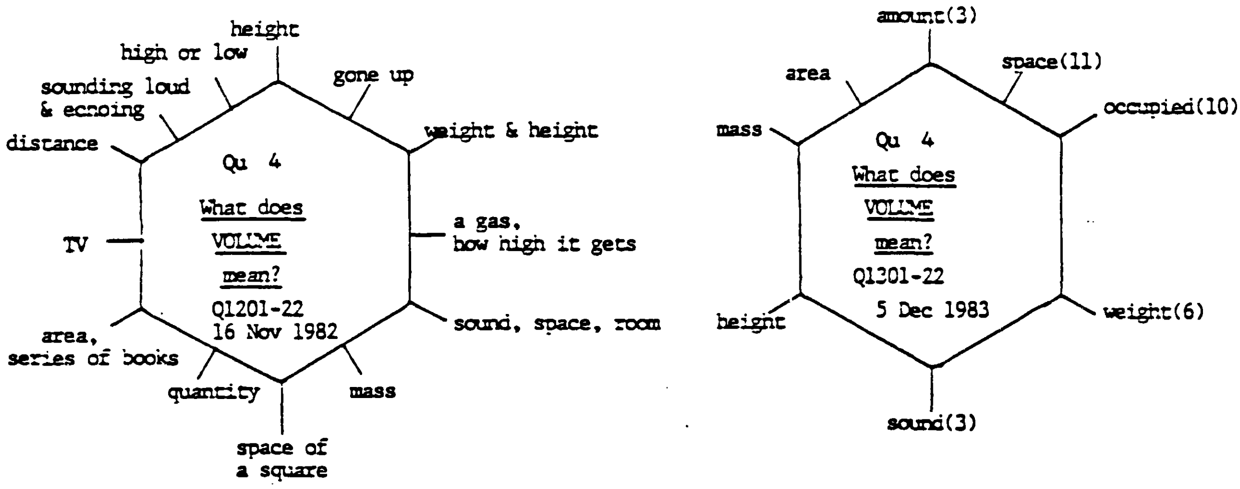


CHART 7.21 Burr-type representations of pupils' responses

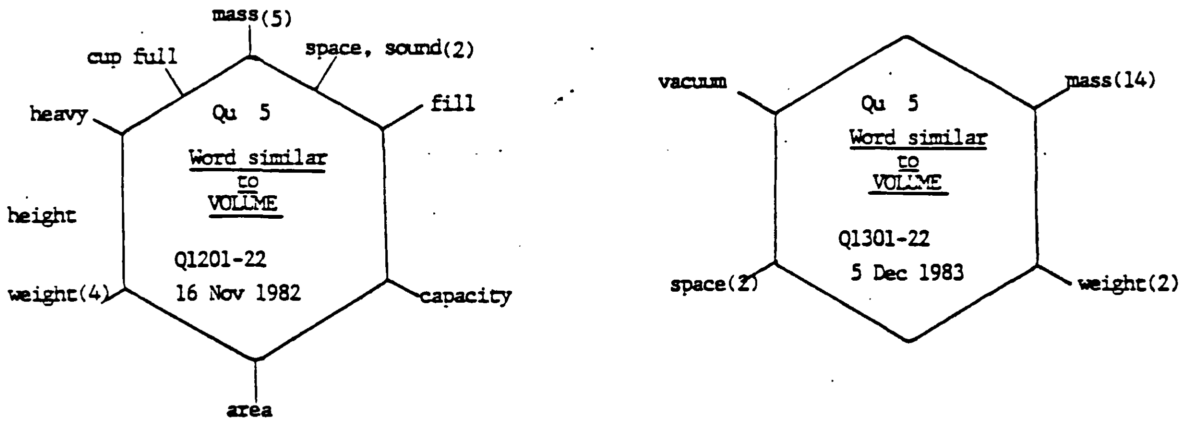


CHART 7.22 Burr-type representations of pupils' responses

volumes using

(Nicky) 'a container a cup.'

(Christine) 'millileter jug.'

However, apart from the responses to Qu 6 which relates specifically to liquids, their answers are almost exclusively connected with linear measurements, quantities and amounts of (solid) substances which seem to reveal confusions with mass, these persisting a year later. It was this apparent confusion which led me to interview the four pupils whose interview data is given later (7.2a-d).

Kerry is the only one of the original class to mention the volumes of books (but see the comment on Brian later). Her answer to question 4 shows that she has no difficulty isolating the different contextual meanings for volume.

'The area of an object (science) a part of a series of books.'

John also mentions different contextual meanings:

'Volume means sound or it can also mean space, room.'

It is significant that he retains these meanings and mentions them the following year,

'Space occupied and also sound,'

even though he 'knows' that the contextual meaning that I was seeking had nothing to do with sound. (More consideration will be given to this aspect of children's learning in Chapter 9).

The pupils' responses indicate that they tend to adopt preferred conceptualisations which, in contradistinction to the alternative frameworks theory which I will test more closely later in the chapter, are highly personalised, idiosyncratic and persistent over time.

Thus, whereas Michael W uses the word 'width' on both occasions, Kerry uses the word 'bredth' even to retaining identical incorrect spelling across the year. (NB also Roy: sutan and sutan, way and wayt).

It could be argued that the words width and breadth are simply different words for an identical idea. However, since it is well established that different people impose different meanings even on the same word, it is quite likely that the preferred use of these two words reveals not simply different prior experiences but different conceptualisations. Much work would need to be done to establish the reasons for pupils' preferred use of supposed synonyms since, as will be argued later, their struggling to differentiate between pairs of related words (popularly: synonyms) such as mass and weight, includes widespread conceptual difficulty.

When pupils pick up an object and describe it either as 'heavier' or 'more dense' than another object, they are not merely using different ways of saying the same thing, but revealing either a facile tactile experiential or a more thoughtful, conceptual understanding of a physical property of matter.

Brian's written answers baffled me. He had just joined the class and I had no experience of deciphering his writing. He had insisted on taking part in the exercise even though I pointed out that I wanted to compare the results with earlier replies. He did not 'know the game we were playing' - that is, he had no pre-conceived ideas about the context in which the answers were being given. The rest of the class knew this context; they were now familiar with the research questioning and thus were trying to frame their responses within the science context which they knew I wanted.

Brian was unaware of all this. His mind was contextually unbiased, as his answers show.

I asked him: Brian, I can't quite make out what you've written here:
'drifria parts of it.'

Brian: It says: Different parts of it.

Res: What is it?

Brian: A volume - it's part of a lot of books.

Brian's contextual responses will be considered further in the Context chapter - 9.

But it is Thomas's answers which seem to be most illuminating. The four answers he gives to questions 3,4,5 and 7 relate to widely different earlier experiences:

He was watching his mother fill holes with Polyfilla.(Qu 3)
He was altering the volume of sound on the TV. (Qu 4)
He was using scales and weights in his Junior school.(Qu 7)

His response 'cup full' is of unknown origin, but one may speculate that his mother mixed the Polyfilla in a cup. The first three of these experiences are given in fuller detail by Thomas during a subsequent interview (see Data 7.2a). I think Thomas's experiences are not unusual. My observational research and interviews have shown that in the years 9-11 children are soaking up an extraordinary variety of experiences from all parts of life. In subsequent, especially secondary science, learning they are trying to plait all these separate strands together into a coherent whole.

The skill of the weaving, what thread to include, what patterns to produce, is part of the learning process. Sometimes the strands become ravelled; sometimes they are left purposefully unbound. How does Thomas's particular mixture of experiences influence his grasp of volume? His answers on the second occasion give clues.

Question 3 He says he remembers hearing the word volume

'In the last year.'

Thomas has, for the moment at least, forgotten his mother and the Polyfilla. His memory of volume goes back to his first year science work. Is he, though, merely adjusting to the science context of it all; giving the answer he thinks I would expect?

His answer to question 7

'Using the pie method,'

is shown to be spurious during the interview and can be discounted.

His answer to question 4 that volume means

'Space occupied and sound,'

is excellent. Thomas can still hold apart these distinct meanings for volume. A study of the pupils' answers shows that they use the words 'space occupied' a great deal. But do they know what that means? This will be discussed shortly.

Returning to Thomas's answers it is seen that he gives the synonym 'mass' for volume. This is clearly inferior in some senses to his 'cup full' of a year earlier, before the formal teaching. The interview shows that he can offer no reason for putting mass. A study of the pupils' synonyms offered the second time (see Chart 7.22) shows that they predominantly use mass, and Thomas is therefore not unusual. The interview with Kerry (Data 7.2c) who is an above average pupil, indicates that the pupils have this synonymous association between volume and mass quite firmly fixed.

Why should this be?

The answers Thomas gives, which relate to earlier experiences, seem to have a common factor, that is, amount.

He is watching his mother use a certain amount of Polyfilla,
turning the TV knob to alter the amount of sound,
giving a cup full as a definite amount of measured substance,

and using scales and weights to find the amount of 'big bits.'

The interview with Amanda (Data 7.2b) confirms this link between volume and mass. When asked to give the meaning for volume she had said (Table 7.21 - qu 4 - 5/12/83)

'space occupied,'

and yet, when asked in interview to say what mass means, she replied

'space occupied.'

Kerry (Data 7.2c) shows similar confusion. When I asked her why she gave the word mass as being similar in meaning to volume, she said:

'I was trying to remember what I put last time - I wasn't sure. I was trying to remember the work we did, was it volume and mass or the other way round.'

(This, incidentally, illustrates how crucial the order of learning experiences is to some pupils, and much more research could be done into this aspect of science curriculum structuring. It is not the same as evaluating the conceptual sequence of science concepts).

The problem seems to be that, since most pupils' earlier experience of volume, however varied or abstruse, is connected with amount, difficulties arise when the concept mass is introduced simultaneously, as it often is when volume leads on to density, etc. There seems to be confusion between

volume as the total amount of space occupied by a substance,

and

mass as the total amount of substance contained in that space.

The interview with Alison (Data 7.2d) lends support to this contention. She gave, as her meaning for volume, on the first occasion

'Different balances of weight.'

When questioned about this unusual answer she revealed that she was drawing on prior knowledge and gave the example which has fascinated and sometimes baffled generations of school children:

> In explanation she says:
> 'Well, things are the same weight but you wouldn't expect them to be heavier.
> Well, like if you had feathers, a ton of feathers and a ton of something else.'

I think what she was trying to say was: If you saw a ton of feathers and a ton of something else (much denser) because they are the same weight they would have obviously different volumes.

Her synonym for volume at the first stage was 'weight.' A year later she gave the answers

> Volume meaning: The space occupied.
> Synonym: Space used.

When I asked her: How do your ideas of weight and volume vary now? How are they different? she gave nearly perfect answers.

> 'Weight is how heavy something is. Volume is how much the object you are weighing takes up.'

It seems that Alison has avoided the potential confusions in mass, weight and volume by ignoring mass entirely and sticking to the more familiar and more easily understood concept of weight as heaviness. My questions to these pupils about mass (why objects on the moon weigh less than on the earth, etc - data not presented here) showed much confusion at this age. If this confusion exists widely then it would argue for a radical appraisal of the use of the concept mass, whether to use it at this stage at all, or at least demanding a careful look at the sequence of events which Kerry so clearly pinpointed.

(Hewson & Hewson(1983) report similar results in a study of South African Students' alternative frameworks. They discovered that the terms mass and weight were used indiscriminately because the conceptual differences between the terms had not been established. For many of the students the more undifferentiated concept of heaviness is closer to their understanding of mass and weight).

Data 7.2a THOMAS Q1319 9/12/83

Res: Can you remember what you said last year about the first time you heard the word volume?

Thomas: I think I said on a television set.

Res: Do you mean on a television programme?

Thomas: No, on the instructions - where it tells you how to turn up the volume.

Res: Do you remember your mum Polyfilling?

Thomas: (Slightly surprised) Yes.

Res: Can you remember what happened? Why you mentioned it in connection with volume?

Thomas: I think it might have been a big hole - it needed a big volume to fill it up.

Res: Last year you said that another word like volume was 'cup full'. Where did that idea come from?

Thomas: I just thought, because it's the space occupied so I just put it down.

Res: Did you know that last year, that volume was the space occupied?

Thomas: Yes.

Res: Why did you put down: 'A knob on the TV?

Thomas: I don't know. It was just the first thing that came into my head.

Res: Can you say why you said 'Mass' this year, instead of cup full?

Thomas: Don't know . . . no.

Res: When I asked you last year how you would measure volume, you said 'Scales.'

Thomas: (Incredulous) Scales.

Cont/

Res: Have you ever used scales?

Thomas: Yes, I think we used them in the Juniors, just weighing big bits of .... 5lb and that ..... a little ring on .... kilogrammes.

Res: Why did you think to use the pie method for finding the volume of something?

Thomas: Oh, John told me to put that.

Res: How would you find the volume?

Thomas: I don't know, can't remember.

Res: Would you measure something?

Thomas: With a ruler.

Res: What would you measure?

Thomas: Anything you could measure .... a bit of paper.

<u>Data 7.2b</u> <u>AMANDA Q1309 9/12/83</u>

Res: Do you remember what you put last year when asked where you had first heard about volume?

Amanda: I think I put no - I'm not sure.

Res: You put that you were listening to a science programme.

Amanda: Yes, in the holidays, a children's science programme.

Res: I'm interested in the difference between your answers about volume. Last year you mentioned weight and height. This year you put mass, crossed it out and wrote weight.

Amanda: Was mass right?

Res: Not really, but a lot of members of the class put mass or weight. Can I ask you - why do you connect volume and weight? Why are they similar in your mind?

Amanda: I put that because I get muddled up between mass and height.

Res: Let's see what your ideas are about these things. What is mass?

Amanda: Space occupied.

Res: And height?

Amanda: The height of something. The space occupied between two levels

Res: I'm not sure what you mean.

Amanda: The space between that (pointing to a position on a chair leg) and that (pointing to a higher position).

Cont/

Res: And weight?

Amanda: How heavy a thing is.

Data 7.2c KERRY Q1313 9/12/83

Res: Can you remember what you said last year in answer to the question: Where did you first hear the word volume?

Kerry: It might have been on television .... or in a maths lesson.

Res: Last year you said that volume was similar in meaning to area. Where did that idea come from?

Kerry: Area? What I classed it as would be length times breadth.

Res: This year you said that volume is the amount of space occupied - which is a good answer. Why did you give the word mass as being of similar meaning?

Kerry: I was was trying to remember what I put last time - I wasn't sure. I was trying to remember the work we did, was it volume and mass or the other way round.

Res: If you had to find another word for volume, ignoring what you put last year, what would you say?

Kerry: I think the same - mass.

Data 7.2d ALISON Q1308 9/12/83

Res: Can you remember what you said last year, about the first time you heard the word volume?

Alison: Yes, I think in school, when I'd just started doing it in science.

Res: Would you be surprised to know that you put: In Junior School, in a science lesson?

Alison: Yes.

Res: Can you remember anything about it?

Alison: Can't remember. We didn't really do science. I remember we did something with ink and water.

Res: Last year, when asked to say what volume meant, you said: Different balances of weight. Where did that idea come from?

Alison: Well, things are the same weight but you wouldn't expect them to be heavier.

Cont/

Res: How do you mean?

Alison: Well, like if you had feathers, a ton of feathers and a ton of something else.

Res: How do your ideas of weight and volume vary now? How are they different?

Alison: Weight is how heavy something is. Volume is how much the object you are weighing takes up.

I am contending that pupils' responses to questions about volume, and subsequent interviews, show that they are confusing volume and mass. If this is so the results from similar questions about mass should show a similar confusion.

Charts 7.23 and 7.24 show burr-type diagrams of representations of the meaning of mass, and synonyms, before and after formal teaching. They show that before being taught at secondary level the pupils draw on a wide range of prior knowledge, their meanings varying from a birthmark to an acidy liquid, and their synonyms from a church service to weight. When a year has elapsed their synonyms all lie within the science context, with volume now being quoted. A count of actual responses shows that, of the 22 pupils, only four give weight as being synonymous with mass, whereas 12 give volume. This indicates that this particular class has a larger proportion of pupils who favour volume as a similar word for mass than those who choose weight.

In addition to reducing the pupils' meanings for mass after the year had elapsed to fit a burr-type diagram I have reproduced them completely below (see TABLE 7.22) inorder to preserve the quality of their content.

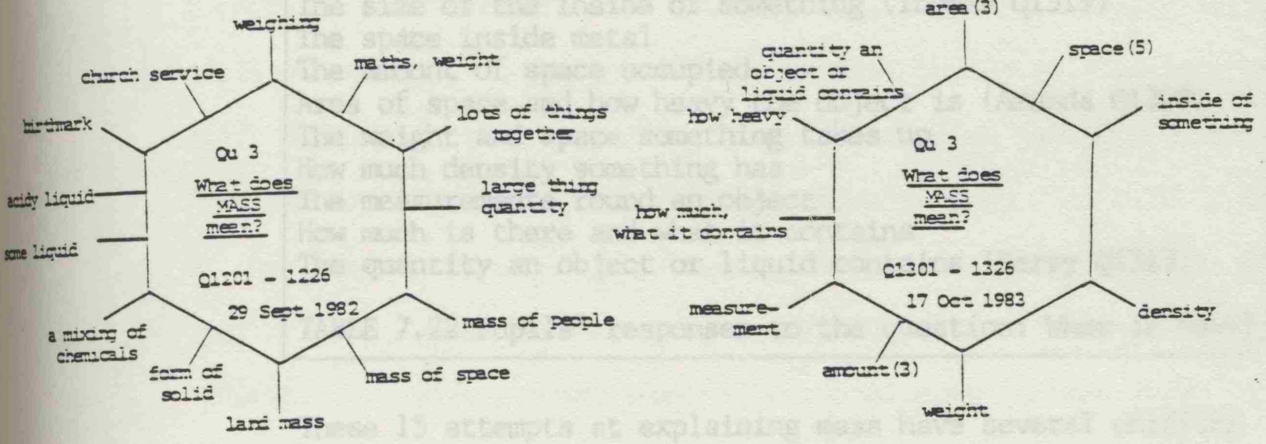


CHART 7.23 Burr-type representations of pupils' responses

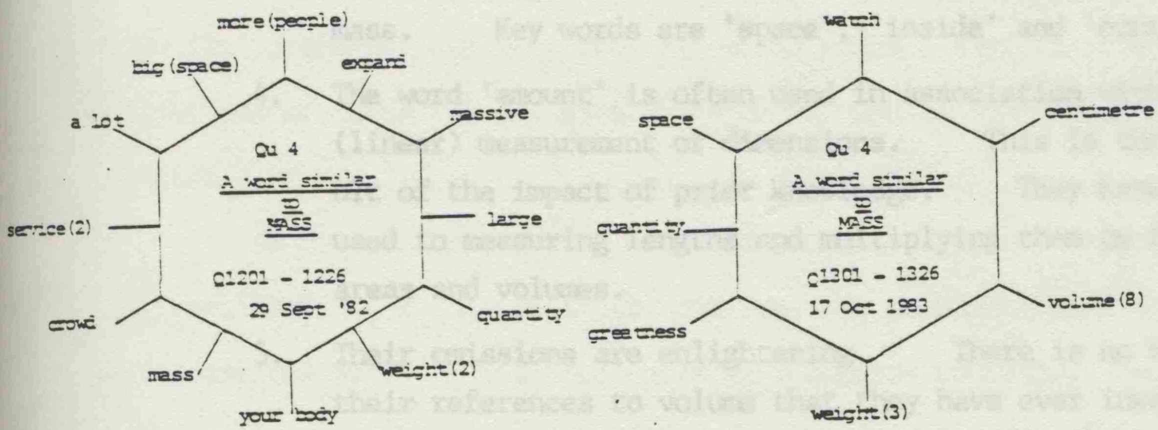


CHART 7.24 Burr-type representations of pupils' responses

Area and space
The amount of space that is taken up
The area of a box
The weight of something, the whole thing
Amount is what mass means
Measurement something
The size of the inside of something (Thomas Q1319)
The space inside metal
The amount of space occupied
Area of space and how heavy the object is (Amanda Q1309)
The weight and space something takes up
How much density something has
The measurements round an object
How much is there and what it contains
The quantity an object or liquid contains (Kerry Q1313)

TABLE 7.22 Pupils' responses to the question: What is mass?

These 15 attempts at explaining mass have several unifying features.

1. They nearly all include confusion of volume and mass.
2. They often mention or allude to space.
3. They indicate that the pupils are anxious to know what is going on inside substances, a knowledge crucial to their understanding of and distinguishing between volume and mass. Key words are 'space', 'inside' and 'contains.'
4. The word 'amount' is often used in association with (linear) measurement or dimensions. This is the result of the impact of prior knowledge. They have been used to measuring lengths and multiplying them to find areas and volumes.
5. Their omissions are enlightening. There is no hint in their references to volume that they have ever investigated the volumes of irregular solids or of liquids. Kerry alone begins to move in this direction.

Summary of results and commentary so far

Section 7.1 gave evidence that children try to build their own explanations of phenomena, and that these explanations act as hypotheses which affect both their expectations and interpretations of later events. Section 7.2 showed that pupils rely heavily on prior happenings in interpreting and understanding new ideas, and that the order in which they meet phenomena becomes a critical feature of the learning process. Thus, if they find something baffling they retrace events in their mind to try to arrange it in a meaningful context. This process seems almost analogous to that which the mind uses in locating something that is lost physically: 'I remember having it when I was on the bus, but it had gone when I was passing the butchers - so I must have lost it somewhere between...'

Difficulties which pupils have with the idea of 'amount' were noted in Section 7.1 and confirmed in Section 7.2 in the specific case of the concepts of volume and mass. I have suggested that pupils' preferred use of particular words reveals their conceptualisations of ideas and may give clues to any mental confusions which exist.

Is the confusion noted here caused by prior experience, and if so, how? I am sure it is, and that the problem arises in this fundamental way: Children entering secondary education have heard the word mass; their understanding of it is that it means 'a lot of', or 'a large amount of.' (This after all is the answer that the mass of the population would give). At this early age they have no grasp of the concept of mass as being the quantity of matter in a body, a concept which is nebulous anyway until much later when ideas about atoms and relative atomic and molecular masses, etc., become apprehendable.

The pupils' use of 'simple' words is complex and idiosyncratic. For example, Amanda (Data 7.2b) uses the word 'space' in relation to height: 'The space occupied between two levels.'

It is seen that pupils will confuse bodies which are voluminous with those having a large mass, unless careful thought is given to the way in which ideas are presented to them, and considerable opportunity afforded them to gain wide experience before moving on to the next concept. More will be said about this in the implications discussed at the end of the thesis.

The four interviews reported in Section 7.2 have shown the value of the interview as a means of establishing pupils' ideas. The earlier questions had shown, for example, that when asked to give the meaning of volume many pupils had put 'space occupied.' That result by itself might have been construed as evidence that they understood volume. However, in order to understand volume, as with many concepts in science, it is necessary not only to be able to say what it is but how it differs from allied concepts.

The interview with Amanda showed that, although she can give a seemingly flawless answer to the question about volume, she gives exactly the same answer for mass.

The interviews were successful in identifying the spurious response. Thomas had given the answer which John told him to put down. Inferences based on 'bald' answers alone cannot be assumed valid. The interview seems to be an effective method of establishing the real meaning of pupils' responses.

7.3 A study of some ten-year old pupils' ideas about water vapour and air, using classroom observation and interviews

A search of my initial observation notes revealed the following two sets of data taken during lessons on 22 May and 12 June 1981 when a class of ten-year old pupils (which included pupils KC1001 and KC1003) was studying water vapour and air. This sequence might be entitled 'The pupils' concept of nothing.'

In the first lesson the teacher was leading a class discussion about water, intending to stimulate an awareness of water vapour. I took down in long hand all that was said but, although I knew the two children under special scrutiny, and Matthew, I did not know the names of other members of the class. They remain anonymous in what follows.

DATA 7.31 22/5/81

Teacher: Have you ever noticed at home, if you leave ordinary table salt - what happens to it?

Pupil 1: It dries up.

Pupil 2: (Following a pause) It goes damp.

Pupil 3: Because all the air gets to it.

Matthew: It sort of evaporates.

Peter: The moisture of the air.

Teacher: If you breathe out on a window - what's happened?

Pupil 4: The window's gone steamy.

Teacher: Yes. If you wipe your finger through it, what does your finger feel like?

Pupil 5: Wet.

Teacher: If you put a plastic bag over a plant, what happens?

Pupil 6: It steams up.

Pupil 7: (Pointing excitedly) There's some on that little greenhouse (propagator).

Cont/

Teacher: What does that tell us? What's in the air?

Pupil 8: Water vapour.

It occurred to me that Matthew probably did not understand the idea of evaporate, so I talked to him briefly at the end of the lesson. His answer showed that he did have some realisation of what was happening during evaporation.

DATA 7.32

Res: What do you think evaporate means?

Matthew: It means things sort .... if you have some water and it boils .... a little bit will disappear. It goes .... it sort of goes into little air watery stuff, if you blow your breath on to the window, sort of drying up or getting wet or dampish.

On the next occasion the investigation had switched to the air itself. In the data I collected Matthew makes one small contribution. I could not identify the other pupils.

DATA 7.33 12/6/81

Teacher: We're going to look at air, its properties, what does it do or not do, how things fly through air, and so on .... to think about air more, because we take it for granted.

(She takes a gas jar, sealed with a glass slide)

I've got a jar here, full of air.

Pupil 1: No, it's empty.

Pupil 2: It's sealed.

Teacher: It's still full of air.
How do we know?

Matthew: Dampness .... condensation.

Teacher: What does air look like?

Pupil 3: Clear.

Cont/

Pupil 4: Transparent.
Teacher: How can we make sure there's air in it?
Pupil 5: Take the lid off and put it on again.
Pupil 6: The air will get trapped inside.
Pupil 7: Wash it out with water.
Pupil 8: Take the lid off, turn it upside down.
Teacher: If you waft your hand you can feel the air.

Data 7.31 shows that several pupils are fully aware of water vapour in the air, and that it will condense on windows when the temperature is low enough. There is nothing here to suggest that Matthew is not aware of this. However, his use of

'It sort of evaporates'

does indicate a haziness of understanding about the dampness of salt, arising perhaps from a lack of understanding about the processes of evaporation and condensation, or of the nature of water vapour in the air.

Data 7.32 sheds some light on this, but is inadequate for more than a tentative comment. Matthew knows that heating causes boiling, and that boiling includes evaporation, because

'a little bit will disappear.'

Thereafter he is not sure what happens. It seems that he cannot visualise the 'invisibleness' of water vapour and is reluctant to let the 'wateriness' of it disappear from his mind, because as soon as he has described the water disappearing

'it goes...'

he switches the scenario to that of water vapour condensing as droplets on to a window. His lack of conviction about what is happening is further evidenced by his linking

' sort of drying up,' with 'or getting wet or dampish.'

Matthew's use of the phrase

'...Little air watery stuff ...'

could indicate an alternative framework. Whether it is wise to assume that the other pupils, by their ready and easy answers, are able to visualise a gaseous water phase, I am not sure. Maybe they can. But Matthew is probably not there yet. More interview material or other evidence on this point would have been extremely useful. Even with much older pupils, however, the same problem of understanding arises. Secondary pupils, faced with the concept of the water cycle, find it easy to visualise evaporation from the sea's surface, but difficult to explain the formation of clouds, and seem not to be aware of the fact that the intervening air can be saturated with totally invisible water vapour.

There is, however, an entirely different way of looking at Matthew's ideas. To postulate that these constitute an alternative framework is to suppose that his ideas have an identity separate from that of the accepted view of evaporation and the gaseous state. This cannot be correct. Matthew's ideas go a long way towards an insight into current scientific beliefs on this subject, and I suggest that they constitute an approximate concept.

Such a close approach to the accepted meaning of a concept has a number of ingredients; these give evidence of:

a) The pupil's rudimentary or imperfect articulation of his understanding.

b) His reluctance to jettison prior knowledge based on personal experience or 'folklore accretions'.

c) His partial appreciation and acceptance of scientific evidence as his awareness increases.

The postulation of the approximate concept in Matthew's case would avoid a number of dangers. One of these is to suppose that prior knowledge must (often or irrevocably) lead to some pupils formulating alternative frameworks. This would seem not to be the case.

Another danger in seeking to identify the existence of alternative frameworks is that they can assume an identity separate from the accepted view of the science concept and, though often parallel, can be construed as being in contrast with or opposition to it. This in turn could lead to the view that the alternative framework, however much validity it is given, stands outside the ambit of accepted scientific ideas. It would not be far from here to that right-or-wrong attitude towards conceptual understanding which formerly hindered our appreciation of how pupils learn.

I am suggesting that, though definite alternative frameworks do exist, there is in some cases no clear-cut line which allows these either to be identified easily or to be rejected as being non-existent. Put another way, teachers should be on the look-out for approximate concepts as they seek to guide pupils to a fuller understanding and appreciation of scientific concepts.

This realisation of the overlapping layers of the pupils' understanding will mean that the teacher does not ask the question: Has the pupil grasped this concept or not? but: To what extent is he or she understanding, and how can I lead him or her on from this partial grasp of ideas to a fuller awareness?

Data 7.33 gives further evidence of pupils' difficulties with gases. It is a remarkable episode. If the pupils were much older it would obviously be a corporate joke because it reads like a

TV comedy script. Each additional suggestion as to how to make sure that there is air in the jar, as opposed to nothing or another gas, seems more crazy than the last. Even the teacher seems overwhelmed by the pupils' attempts at reasoning through something that she had hoped would be assumed.

Her comment: 'If you waft your hand, you can feel the air.', seems to be her way of saying:'Why the stuff's everywhere; even in this jar. Isn't it obvious?'

But her opening statement: 'I've got a jar here, full of air.', has run counter to her initial gambit which states that: 'We take it (air) for granted.'

So often in science we take 'empty' beakers, or put dilute acid into 'empty' burettes. But when it is the teacher's intention to study the air, the apparatus suddenly acquires a lack of emptiness.

The pupils are right not to assume that the jar is already full of air. It is the teacher who assumes it, having started from the debatable premise that 'we take it for granted.'

In the same way, science teachers will emphasise, for example, the colour in crystals but take for granted the importance of white. This data shows that the pupils do not approach new knowledge with grown-up assumptions and that there is a quality in their innocent perceptions which is worth harnessing. For the teachers' part they must always analyse their own class preparations and discourses so as to make sure they are not making assumptions which will baffle or baulk the pupils.

(This impinges on the work of Robertson & Richardson(1975) who questioned the logical as opposed to psychological ordering of science concepts. It seems logical to begin a study of gases with air, but the question is worth exploring: is air, having neither colour nor smell, the best gas to use as an introduction to gases for young children? Would an approach to gases through exploring those with colour, smell,flammability, heaviness, etc., be more suitable? It also reinforces the point I made earlier (see Kerry's answers Data 7.2c) that the pupils place much emphasis on the order in which new ideas are presented to them or discovered).

The data sequence indicates the pupils' unusual concept of the air sample that is to be studied, as opposed to air in general. They talk of emptying the gas jar, which they do not assume to be empty, in order to fill it with air, as if they were ridding it of a contaminating liquid.

'Take the lid off, and put it on again.'
'Take the lid off, turn it upside down.'
'Wash it out with water.'

The pupils' concept of the air in the jar varies:

'(It) will get trapped inside.'
'dampness .... condensation.'
'clear.'
'Transparent.'

But if, to get the air in, one must

'Take the lid off and put it on again.', it seems that the air must rush or run in like water. The pupils are all bringing their particular perceptions to bear and they would learn much about the nature of gases in general and air itself if their ideas could be followed through in discussion or some practical work set.

The difficulties they are having in visualising air and its properties are forerunners of later conceptual problems connected with gas pressure, particulate theory, relative densities, etc., and any early work in establishing ideas will be invaluable.

There is another facet to this discussion data, that of the corporate nature of learning. The value of group discussion has been long recognised and much studied. Its deficiencies have also been investigated. For example, the pupils' ability to 'read' the teacher's intended response, as seen in 7.31 above.

Teacher: Have you ever noticed at home, if you leave ordinary table salt - what happens to it?

Pupil: It dries up.

Pupil 2: (Following a pause) It goes damp.

Here the teacher's pause after the first pupil gives an unwanted answer tells the class that the opposite is wanted. This technique or trait of prompting or steering by silence is well-known to teachers and utilised by pupils.

In the context of pupils' alternative ideas about concepts, however, the discussion can have an entirely different quality and aim. It seems to me that the two discussions 7.31 and 7.33 above are in sharp contrast. In the first the teacher wants the pupils to recall factual experience, and leads them towards the intended realisation that there is water vapour in air. In the second the teacher's hope that an assumption can be made about the gas jar being full of air is immediately challenged. Thereafter the pupils offer answers which reveal what they are thinking about air, rather than any remembered experiences.

It is this type of discussion, allowing pupils to articulate ideas, which is valuable both for the teacher as a diagnostic device and for the pupils in sharing immediate understanding.

The teacher's questions in 7.33 are apt for generating the pupils' ideas:

How do we know?
What does air look like?
How can we make sure ....?

This data suggests that the pupils' learning is both cumulative and catalytic, each of the responses by pupils 5-8 leading from one to the next. A great deal of skill is needed by teachers if they wish deliberately to generate and identify pupils' approximate concepts through discussion as a means towards developing real understanding.

Research needs to be done to study class discussion in the light of recent ideas on alternative interpretations so that benefits can be isolated and capitalised on. Two helpful recent articles which could stimulate further research are McClelland(1983) and Russell(1983).

7.4 A close study of the ideas of some 13 year old pupils about acids - before and after a teaching sequence - and of some 14 & 16 year old pupils about acids

In this section I am reporting the results of investigations into the ideas of 3 classes of pupils (72 in total) aged 13, 14 and 16 years.

The class of 13 year olds was asked to write down the answers to seven questions about acids, before and after a teaching sequence. Their responses to the question about their 'picture' of an acid are given in full in Table 7.42. Their synonyms were also categorised to study the impact of prior knowledge on the pupils' ideas, the categories (see Table 7.41) being displayed on burr-type diagrams and column graphs.

Pupils aged 14 and 16 were similarly questioned, their responses being categorised and displayed in comparison, to see the effect of time on their understanding of acids.

(N.B. Three of the 13 year old pupils were interviewed later about their answers, the results being reported in Section 7.5. The ideas of the 14 year old pupils were later used in a class discussion, the results of this being given in Section 7.6. Further results from the study with the 16 year old pupils are given in Chapter 9).

The pupils tested were:

a) Q1327-54 - a mixed ability class which was about to study acids for the first time.

b) Q1401-27 - the second group by ability of a six-group band. These had been through the same acid teaching sequence a year before, but had not 'touched' acids since.

c) Q1601-19 - a group of 5th year pupils studying for a Mode 1 CSE chemistry examination.

The questions I asked them were:

1. Have you heard the word acid before?
2. If so, do you remember where you first heard it?
3. What do you think an acid is?
4. When you hear the word acid, what picture comes to your mind?
5. Put the word acid into a sentence to show its meaning.
6. Give as many words as you can which are like acid in meaning.
7. Give as many words as you can which are opposite in meaning.

The answers they gave in response to Question 6 above were allocated to categories as described overleaf.

LIQUID .... acid described as a liquid.
CHEMICALS .... acid likened to various chemicals.
BURNING .... acid ascribed a burning character.
DANGEROUS .... acid ascribed a dangerous nature.
SWEETS .... acid related to edible sweets.
TASTE/NATURE .... acid recognised by its taste or nature.
OTHER .... extraneous descriptions.

TABLE 7.41 Pupils' synonyms allocated to above categories

Q1327 - 1354 7/11/83 (72 responses)			9/1/84 (115 responses)	
Number	%	category	Number	%
12	17	LIQUID	11	10
35	49	CHEMICALS	13	11
16	22	BURNING	7	6
3	4	DANGEROUS	29	25
-	-	TASTE/NATURE	38	33
3	4	SWEETS	5	4
4	6	OTHER	10	9

The 'before and after' examples which the pupils give of words which are similar to acid are very different. Before the teaching sequence they tend to use words culled from general knowledge, the chemical nature and burning character of acids predominating. Apart from odd references to acid drops, no-one thinks of acids in terms of taste.

After the teaching sequence there is a dramatic change. Now the words they use as synonyms have shifted completely from chemical and burning to being at the same time both more specifically dangerous and yet centring on their experiences of taste and other physical characteristics of acids.

TABLE 7.42 Pupils' 'pictures' of the word ACID

Pupil ref	7 Nov 1983	9 Jan 1984
Q1327	Liquids bubbling in beakers	People mixing solutions together
Q1328	A liquid in a container	A picture of a test-tube smoking with red liquid in it
Q1329	A bloke getting killed by it	A mad scientist killing people by throwing them in it
Q1330	Car battery	Liquid, and a car battery
Q1331	Car battery	My sister getting killed by a nasty person (+ diagram)
Q1332	A liquid in a bottle	Vinegar in a test tube
Q1333	A test tube with blue stuff in	A bottle of vinegar
Q1334	Vinegar	Something that burns, a battery or citrus fruit, eg orange
Q1335	Hot bubly liquid (+ diagram)	(Diagram only of beaker and crossbones)
Q1336	Clean liquid, death	(Diagram of beaker, skull and crossbones, and word: poison)
Q1337	A bubbling liquid in a big cauldron	It brings to mind a bubbling clear liquid
Q1338	Liquid in a beaker bubbling and steaming	(Diagram of beaker, liquid and word: acid)
Q1339	A fumy coloured liquid in a beaker	A beaker containing a coloured liquid
Q1340	Using it in an experiment with petrol and other liquids	A test tube with a fizzy liquid in it
Q1341	Nothing	(Diagram: beaker, liquid and bubbles)
Q1342	Liquid (Diagram of test tube dripping)	A bottle full of acid (+ diagram)

cont/

/cont

Q1343	Clear (burning) liquid	A clear (bubbling) substance
Q1344	I think of a picture of bubling liquid	I see a beaker of bubbling red liquid with a person with goggles on beside it
Q1345	A person sizzling up in a big bowl of acid (+ diagram)	When I hear the word acid I see a person trying an acidy tasting substance and screw-ing their face up because they don't like the taste
Q1346	A bottle with acid on it (+ diagram)	A bottle with acid on it (+ diagram)
Q1347	Little round white acid drops (+ picture)	A picture of a test tube with a clear liquid in (+ diagram)
Q1348	A hole (+ hole in paper!)	Sweets and a thing used in science
Q1349	Liquid	Something like a lemon or vinegar
Q1350	Drops of liquid like snowflakes falling to the ground (+ picture)	Bubbles and water sizzling through a person
Q1351	Nothing	A beaker with liquid in it
Q1352	Someone with a hole burned in their hand by sulphuric acid	-

TABLE 7.43 A comparison of words used in pupils' 'picture' of ACID

Words used in pupils' picture of ACID	Times used 7 Nov 1983	Times used 9 Jan 1984
Liquid	14	11
Bubbling	5	5
Battery	2	2
Vinegar	1	3
Killed	1	2
Burning	2	1
Clear	1	2
Sweets	1	1
Fumy/smoky	1	1
Danger	–	3
Death	2	–
Poison	–	1
Hot	1	–
Clean	1	–
Steaming	1	–
Fizzy	–	1
Substance	–	1
Orange	–	1
Lemon	–	1
Acidy taste	–	1
Blue coloured	1	–
Red coloured	–	1

This would have been an interesting comparison on its own. However, many more questions are raised when the shift in these words is compared

a) with an analysis of words which they use to describe their mental picture of acids (See Table 7.43)

b) with a class one year older who did the identical course a year before and have not touched acids since, and a class three years older who have had a fair amount of experience of acids (See Charts 7.41 - 7.45)

The pupils' responses to the question about their picture of acid, reproduced verbatim Table 7.42 were scanned to produce the lists of key words given in Table 7.43. These columns reveal a remarkable degree of similarity. Indeed, though written over two months apart - and with the teaching sequence and the Christmas holidays intervening - some responses are almost identical.

Q1329	A bloke getting killed by it.	A mad scientist killing people by throwing them in it.
Q1339	A fumy coloured liquid in a beaker.	A beaker containing a coloured liquid.
Q1343	Clear (burning) liquid.	A clear (bubbling) substance.
Q1346	A bottle with acid on it. (+ a diagram)	A bottle with acid on it. (+ a diagram)

When the two lists are looked at (Table 7.43) the similarity is so close as to be scarcely believable. Whereas the data from the synonym question suggested a marked change in the pupils' perception of acids, this 'picture' data indicates no change at all. (It would be interesting to see if this result could be confirmed by other researchers with pupils in other schools). Does this suggest that the teaching about acids has not (yet) had a significant impact on the pupils' mental picture of acids, that is, that their view of acid has not really progressed?

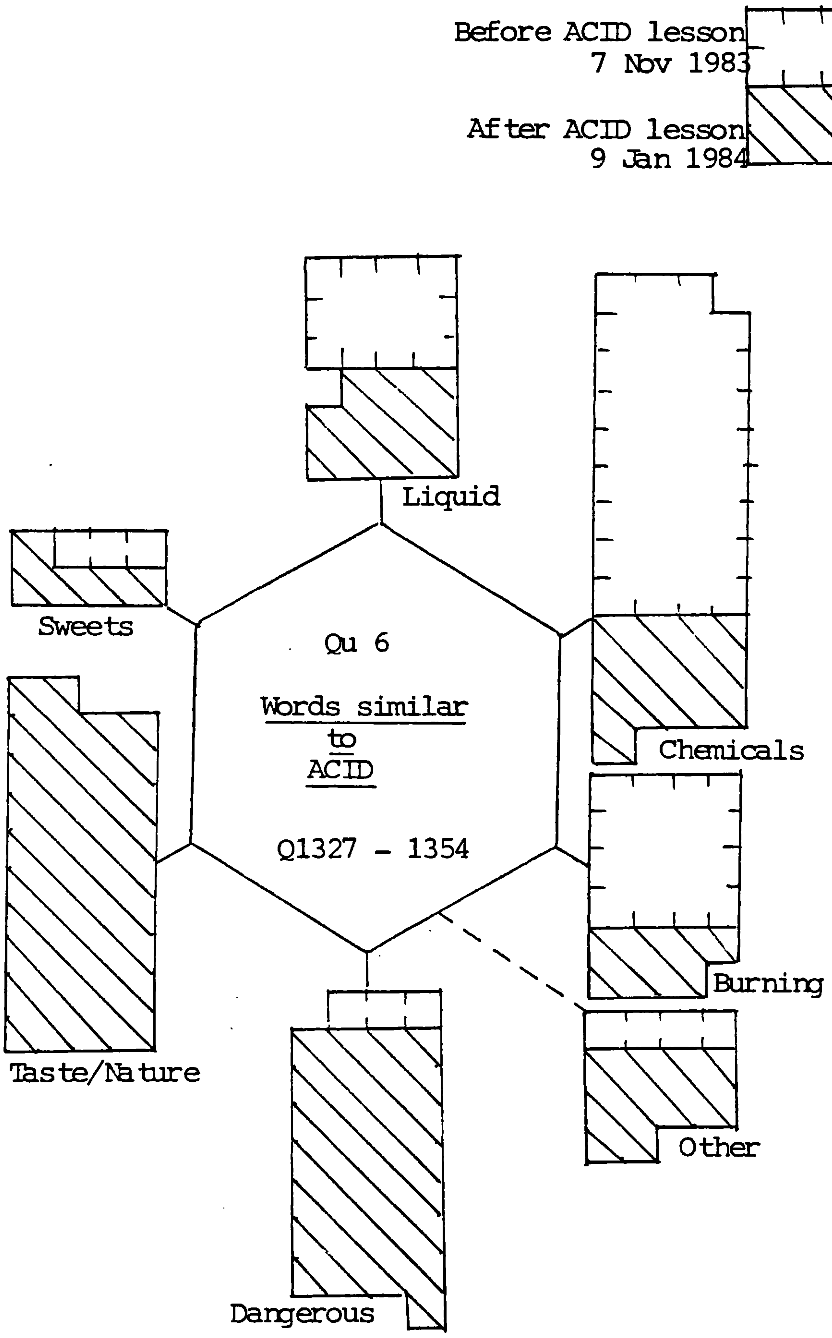


CHART 7.41 Burr-type representations of pupils' responses

14 Oct 1983 - One year after introduction to ACIDS

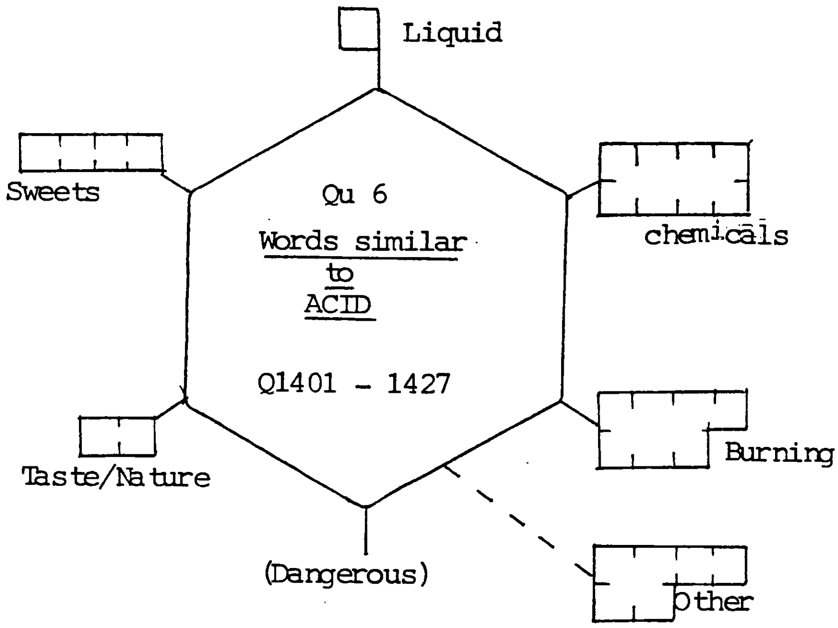


CHART 7.42 Burr-type representations of pupils' responses

3 Nov 1983 - Three years
after
introduction
to ACIDS

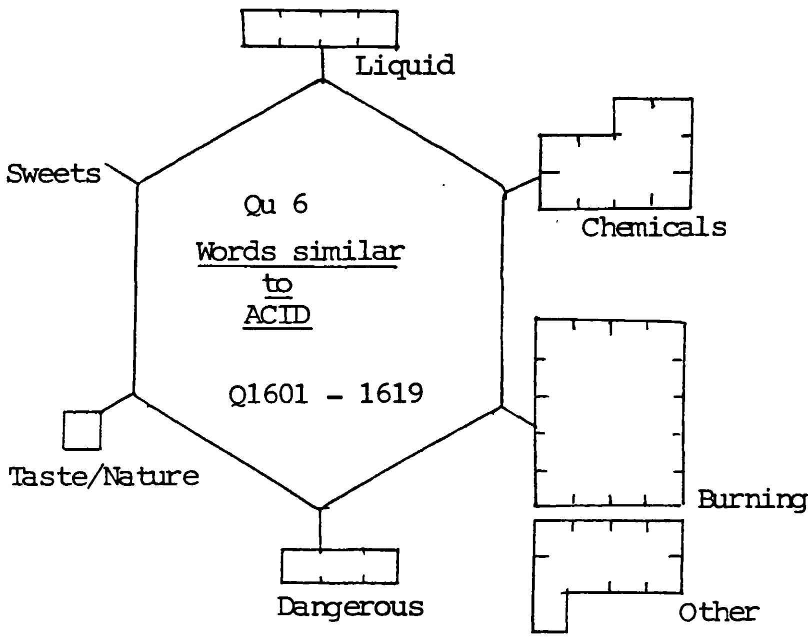
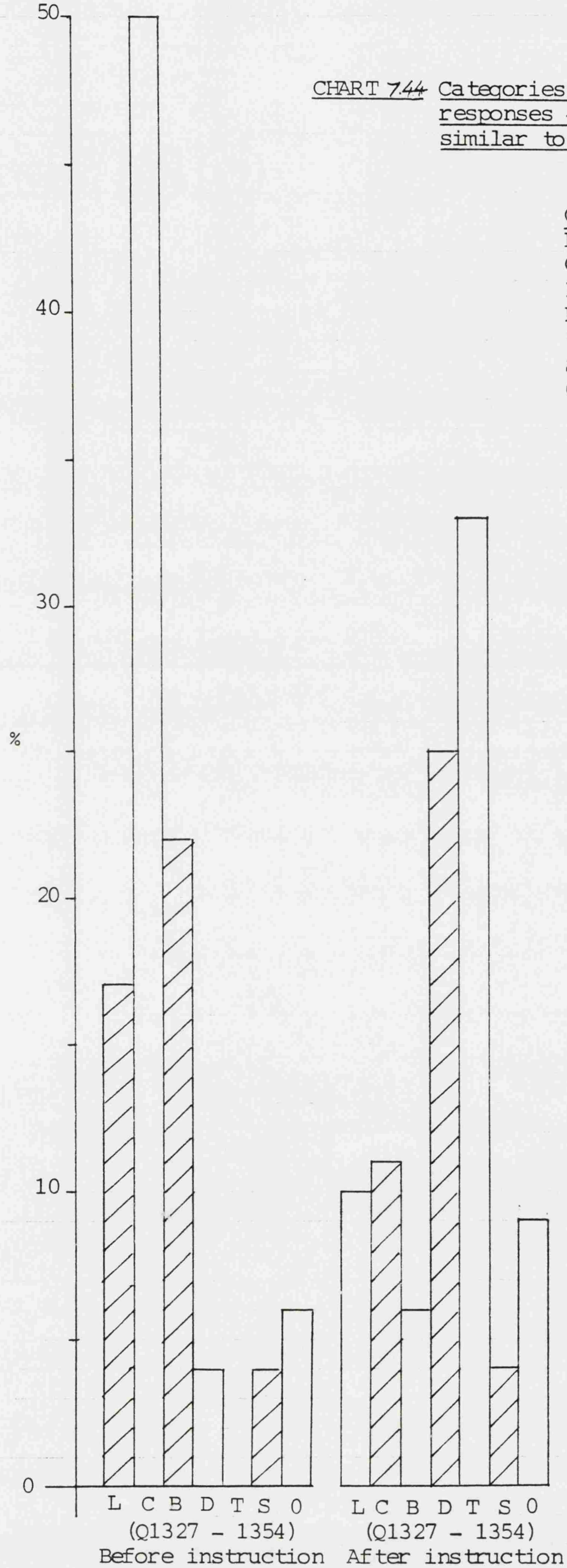


CHART 7.43 Burr-type representations of pupils' responses

CHART 7.44 Categories of pupils' responses - giving words similar to ACID - as %

Categories key
L = Liquid
C = Chemical
B = Burning
D = Dangerous
T = Taste/Nature
S = Sweets
0 = Other



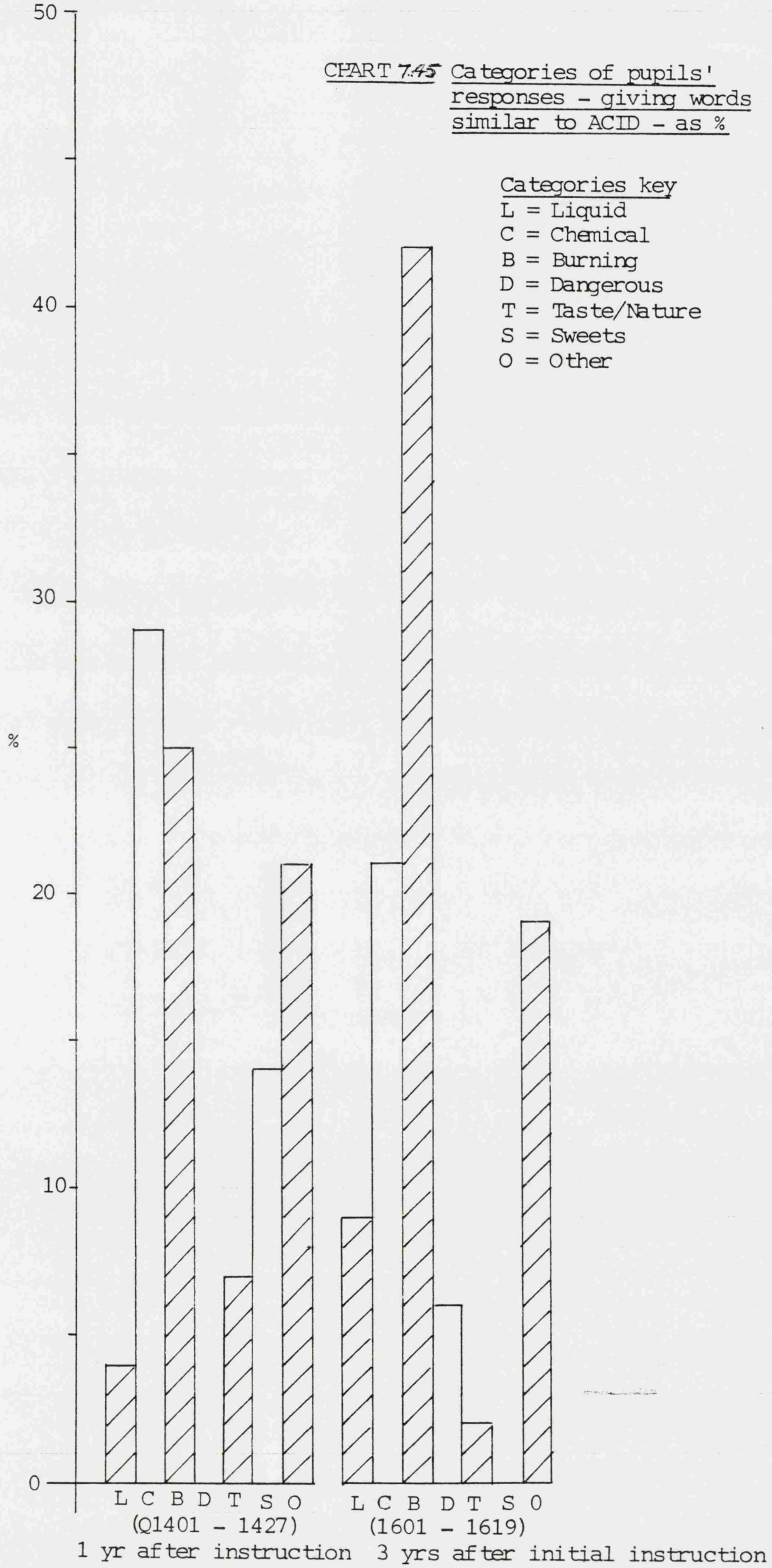


CHART 7.45 Categories of pupils' responses - giving words similar to ACID - as %
Categories key
L = Liquid
C = Chemical
B = Burning
D = Dangerous
T = Taste/Nature
S = Sweets
O = Other
50
40
30
20
10
0
%
L C B D T S O
(Q1401 - 1427)
1 yr after instruction
L C B D T S O
(1601 - 1619)
3 yrs after initial instruction

If this result is valid there must be some explanation for the pupils being able to offer different synonyms whilst retaining an identical mental picture of acid. Either the accumulation of science words precedes the incorporating of them into a coherent concept in the pupils' minds, or it precedes the pupils' ability to articulate the enlarged concept.

A further hypothesis can be offered; perhaps the problem is that instead of the concept being simply enlarged, that is, the teaching growing out of the pupils' prior knowledge and experience, it was radically altered, resulting in both a ready superficial acceptance and a tenacious underlying rejection. (The words 'superficial' and 'rejection' imply a value judgment of the work by the pupils. This is highly unlikely to occur. Put more benignly the opposing results could be explained as a ready acceptance of new words accompanied by a struggle to incorporate new concepts).

The teacher of this class should not be despondent however. A more thorough look at the lists (Table 7.43) shows evidence of the beginnings of change in the pupils' mental picture. The synonyms suggest that a definite alteration in perception results in a large swing towards the use of a 'taste/nature' idea of acid; this table shows a slight but definite trend in the same direction. Apart from the clear evidence that the pupils' picture of acid remains predominantly of a 'bubbling liquid', the words which appear only in the pre-instruction column are

death, hot, clear, steaming, blue-coloured;

whilst those appearing only in the post-instruction column

are (danger, poison) fizzy, substance, orange, lemon, acidy taste, red-coloured.

This suggests, leaving aside the references to danger and poison which increase in any case (see Chart 7.41) a change from the 'burning' idea of acids to the taste/nature idea.

A comparison of Charts 7.41 and 7.42 shows that the pattern of the words the pupils use one year after the formal teaching more nearly approaches that in existence before the teaching than immediately after. Although the total numbers of pupils and words are extremely small, and any general conclusions must be broached very tentatively indeed, the comparison seems to suggest:

a) that the pupils' view of acid is initially rooted in a 'folklore' realm of chemicals and their burning nature;

b) that the effect of the teaching is to alter this dramatically. It impresses on the pupils' minds the dangerous nature of some acids whilst emphasising the general way of identifying acids by their taste or other physical characteristics;

c) that the pupils quickly lose this new view of acids where no revision or reinforcement exists, and revert to some parts of their earlier folklore concept.

(The immediate impact of the teaching is obvious in another way. The pupils suggested a total of 72 'synonyms' before being taught, and this increased to 115 subsequent to the teaching sequence. A year after studying acids the group of 22 pupils offered a mere 28 words, and by the fifth year the group of 19 pupils suggested 47 words).

7.5 An investigation into the impact of prior knowledge on the ideas of some 13 year old pupils about acids

In this section I am reporting the results of interviews with three 13 year old pupils. They were members of the group of pupils (Q1327-54) whose pictures of acids have been given in Table 7.42. The group had been questioned before and after being taught about acids. After an interval of four months these three pupils were selected for questioning about the answers they had given on the previous two occasions.

The questions they had to answer are given at the beginning of Section 7.4 page 104.

Data 7.5a

Abigail Q1337 7/11/83	9/1/84
1. Yes, I have.	Yes.
2. I heard it in a science lab in my Junior School.	I heard acid first about five years ago when my Dad was talking about it.
3. Acid can be dangerous liquid, it may burn you or worse.	The word acid means to me a liquid which can be dangerous or very harmful and useful.
4 A bubbling liquid in a big cauldron.	The word acid to me brings to mind a bubbling clear liquid.
5. The devil had a cauldron of bubbling acid in front of him.	The vinegar we use is an acid we can tell because it has a sour taste.
6. Chemicals, liquid, dangerous, bleach, hot, scolding, fire.	Dangerous, harmful, liquid, strong, useful.
7. Vegetables, bread.	Harmless, solid, weak, safe.

Data 7.5b Interview with Abigail Q1337 10/5/84

Res: Abigail, can you remember the picture you gave of acids before you did the work on them?

Abigail: No.

Res: You said an acid was a bubbly liquid in a big cauldron. Can you remember where that idea came from?

Abigail: No.

Res: Had you ever met acids before you studied them here?

Abigail: No.

Res: The second picture you gave, of a bubbly clear liquid - where did that idea come from?

Abigail: I don't know really. I just put down what I thought.

Res: When you studied acids, what sort of work did you do?

Abigail: Can't really remember what we were doing.

Res: Can you remember anything?

Abigail: Not really.

Res: What would you say your picture of acid is now?

Abigail: A liquid.

Res: Were all the acids you used liquids?

Abigail: No.

Res: Which weren't?

Abigail: We did this thing with sweets and baking powder and that.

Res: What did you do?

Abigail: The teacher had a bag of acid drops. He brought round baking powder and you had to put them in your mouth and say what the difference in taste was.

Res: You could detect a difference?

Abigail: Yes.

Res: What word described the acid taste?

Abigail: Sour.

Res: When you put acid into a sentence to show its meaning, you put: 'The devil had a cauldron of bubbling acid in front of him.'

Abigail: (Laughs) My mum used to tell me when I was little that if you tell lies you'll be sent down to hell and put in a big cauldron of acid and melt away.

Cont/

Res: How old were you then?

Abigail: About 4 or 5.

Res: So that's where your picture of a cauldron came from. Why did you suddenly remember?

Abigail: It's when you mentioned the devil.

Abigail was chosen for interview for two reasons. She gave a graphic picture of an acid before the formal teaching, and an equally graphic sentence containing acid. Secondly, despite the teaching which had convinced her of the useful and edible aspects of acids, she retained the basic picture of acids as being bubbling dangerous liquids.

I wondered (a) exactly what her prior knowledge of acids was,
(b) what had led to her graphic mental memory,
(c) why this should be powerful enough to counter a fairly benign elementary investigation using dilute and weak acids.

The interview was, at first, alarmingly fruitless. Her answers to my first six questions were:

No.
No.
No.
I don't know really ....
Can't really remember.
Not really.

When I asked her about her current picture of acid she replied:

A liquid.

This 'liquid' picture of acid is confirmed by her answers (see Data 7.5a). Despite using the taste test for solid acid-drop sweets, and the edible vinegar, her picture after the teaching retains the harmful dangerous liquid nature of acids.

It is only when Abigail is reminded of her exact words on the first occasion that the break-through comes and the significant prior knowledge is revealed. The impact on the five year old child's mind of a cauldron of acid melting people away is so powerful that it continues to determine her conception of acids beyond formal teaching at the age of 13.

This result contains an important implication for the teaching of science. In Section 7.2 I suggested that the pupils' preferred use of a word hints at their conceptualisation of that word and of the concept which the word seeks to describe. I also drew attention to the importance to pupils of the order in which they receive and assimilate information. This data shows that Abigail's prior experience has affected her subsequent use of information without her being aware of it. Indeed, only when I used a question in which the word 'devil' acted as a trigger for her memory did she remember the important experience which she had earlier quoted.

This and earlier data indicates that pupils process information in personal preferred ways, and that the processing method can become a powerful constraint on their ability to cope with new experiences. (I will investigate a practical aspect of this problem in Chapter 8). It is the opposite of flexibility of mind, and it explains the inability of pupils to cope, for example, with examination questions which seek known information but demand drastic re-structuring of that information.

If the pupils' organisation of information involves inherent constraints which militate against the ready assimilation of subsequent allied experiences it would argue for teaching methods which can help pupils to become more flexible in their minds as they meet and process science ideas.

Data 7.5c

Robert Q1332 7/11/83	9/1/84
1. Yes.	Yes.
2. In the lab and on a sauce label.	First year science with brown sauce.
3. Acid can burn your thumb off if you spill it on you.	Something with a sharp taste or very hot.
4. A liquid in a bottle.	Vinegar in a test tube.
5. I burned my hand with some ACID	My mate's thumb was burnt off with some acid which his dad had.
6. Bleach, brown sauce.	Sharp, strong, smelly, pH scale, coke.
7. Alkaline.	Alkali, neutral, weak, odourless, brick.

Data 7.5d Interview with Robert Q1332 10/5/84

Res: Robert, can you remember the picture you gave of acid before being taught?

Robert: No.

Res: Can you remember the picture you gave the second time?

Robert: No.

Res: What is your picture of acid now?

Robert: Well, it's sort of a plastic bottle with a picture on the side with a thumb and half a thumb and a drip and half a drip - the drip going through the thumb and burning it off.

Res: Where does that picture come from?

Robert: Well, my mate's dad had it - it was a bottle with that on, sort of a square shaped bottle with a plastic handle.

Res: When did you see that bottle?

Robert: Dunno. We moved house. When I was about 6 or 7.

Res: Your meaning for acid at first fits in with your earlier experience, but after being taught you said that the picture in your mind was vinegar in a test tube.

Robert: Well, that's a sort of acid. There's also tomato sauce or brown sauce.

Res: The meaning you gave for acid after being taught was a sharp taste or very hot. Where did these ideas come from?

Robert: The vinegar and the lemon juice.

Res: How do you know they are sharp or very hot?

Robert: I tasted them.

Cont/

Res: Your sentences which contain acid both mention burning but in the later one you say: 'My mate's thumb.' Where did that idea come from?

Robert: From my mate's dad's bottle in my mate's house.

Res: How long is it since you saw him?

Robert: A long time ago. In the Juniors.

Res: What do you remember about the work you did on acids this time?

Robert: Just the acids lined up in a test tube rack, adding each to the other. This fizzed up like cider and it smelled like cider.

Res: Before being taught about acids you gave the words bleach and brown sauce as being similar to acid.

Robert: Well, in the first year we put a dead old penny in brown sauce and the sauce took all the dirt and yuck off.

Res: After being taught you used the word coke.

Robert: We also did some work in the first year and my tooth fell out, and Miss - said if you put it in coke it will dissolve away.

Robert was also chosen for his graphic repeated pictures of acid (see Data 7.5c) but especially because he mentioned a wide range of substances.

sauce .... bleach .... alkaline .... vinegar ....
coke .... brick

Robert said he could not remember what he had given as his pictures on the previous two occasions, but gave a precise memory description of the actual bottle of acid which was currently in his mind. This is significant in itself because it shows the relatively unimportant impact on the mind of vicarious incidents compared to the fundamental impact of the original experience. This is the fate of much of what teachers would call 'important learning experiences' - the pupil's mind unconsciously treats with disdain those things it deems trivial.

Robert's oral description is, in its detail and precision, far superior to his curt written responses (see Data 7.5c(4)) and shows how much more information can be obtained from pupils in the personal atmosphere of an informal interview. The important thing is that the mental picture does not come, as I would have assumed, from a laboratory shelf, but from an experience which occurred, like Abigail's,when he was very much younger - at least six years previously.

The interview goes on to confirm that this earlier experience is the one he draws on when putting acid into a sentence after being taught, and maybe before also.

The other prior knowledge which is having a considerable effect on his current conception of acids comes from his previous year's science work. This in turn was strongly influenced by the earlier powerful experience. From the work on acids 'this time' he remembers:

> Just the acids lined up in a test tube .... fizzed like cider and .... smelled like cider.

But the previous year he had been impressed by the ability of brown sauce to take the dirt off a penny, and the ability of coke(Cola) to dissolve a tooth. In neither instance has he been told that these two substances are acidic. He assumes it. The asumption has been made because their dissolving power links with that of the acid in the bottle with its warning that it can burn a hole in a thumb.

Robert retains the word coke in his mind as a synonym for acid even after the formal teaching about acids.

Data 7.5e

Alison Q1350 7/11/83	9/1/84
1. Yes.	Yes.
2. My house - my dad.	I heard it from my dad when he was talking to somebody.
3. An example of an acid is a sweet, acid drops or a liquid	It means a liquid that can burn you or poison you, if you drunk it or ate it.
4. Drops of liquid like snowflakes falling to the ground.	Bubbles and water sizzling through a person.
5. I ate an acid drop today.	Lemon and vinegar contain acid.
6. Drops, liquid, sweets.	Burn. fizzy, bubbles, hot, lumps, sweets, different colours.
7. Coal, cold, hot.	Makes your hands soft, hard, colourless, it is safe.

Data 7.5f Interview with Alison Q1350 10/5/84

Res: Alison, I was very interested in the first picture you gave about acid. Can you remember where the idea came from?

Alison: I don't know. I just thought of it.

Res: Your second picture was entirely different. Can you think where the idea for that came from?

Alison: No.

Res: Where did the idea of the bubbles come from?

Alison: Just as if when you mix them together it bubbles and that.

Res: Why did you think of the acid burning a person?

Alison: Don't know.

Res: What picture do you have now of an acid?

Alison: I don't know.

Res: What chief thing do you remember about your work with acids? (Now some six months in the past)

Alison: Just that if you get them they bubble a lot and if you get them on your hand they burn you.

Res: How do you know? Did you spill some on your hand?

Alison: No. But last year we used nail varnish remover. I did some with that and you put it on your hand.

Cont/

Res: Is nail varnish remover an acid?

Alison: It burns like acid. When I had my verruca burned off that's acid stuff. I've had it on my hands before.

Res: How did that affect your ideas about acids?

Alison: I don't know. When I had my verruca burned off it felt cold. The doctor said some people feel it hot and others feel it cold.

Res: When was the verruca burned off?

Alison: Last June. (ie. before both the first and second testings)

Alison, like Abigail and Robert, had given an unusual picture of acid. However, her answers generally ran counter to those given by the majority of the pupils. For example, she gave much prominence on the first occasion to acid drops, a feature of acids rarely mentioned by other pupils, even after using acid drops during formal teaching. But then she gives only a passing mention to them in the synonyms.

After the teaching sequence Alison stressed the burning harmful nature of acids and her picture became one of a liquid ' sizzling through a person.'

Another interesting feature of Alison's answers is the extent to which she links opposing qualities for acid and its opposite:

fizzy, bubbles,.... lumps
cold,............... hot
soft,.............. hard

The interview sought to probe these facets of her answers,

At the beginning of the interview Alison claims that she cannot recall where her picture of acid comes from, but she can trace her claim about their bubbling nature directly to the effervescence seen when acids are mixed (whether with themselves or otherwise she does not specify). Nor can she think of any reason for conjuring in her mind the picture of acids burning people. She has or admits to no 'new' picture of acids and begins to say that acids 'bubble a lot.' Then the interview turns and begins to become frutiful because she says:

and if you get them on your hand they burn you.

This is a direct link with her second picture of acid. It gave me the opportunity to delve into any direct experience she may have had. As before, with Abigail and Robert, the memory trail led back beyond the formal teaching to her prior knowledge, to her previous year's work and to out-of-school experience.

In trying to understand acids she fuses these two earlier experiences, the bond being the physical sensation of burning which she felt. The ethyl acetate of the nail varnish remover gives a definite tingling sensation on the skin; Alison interprets this as burning and ascribes the word acid to the liquid.

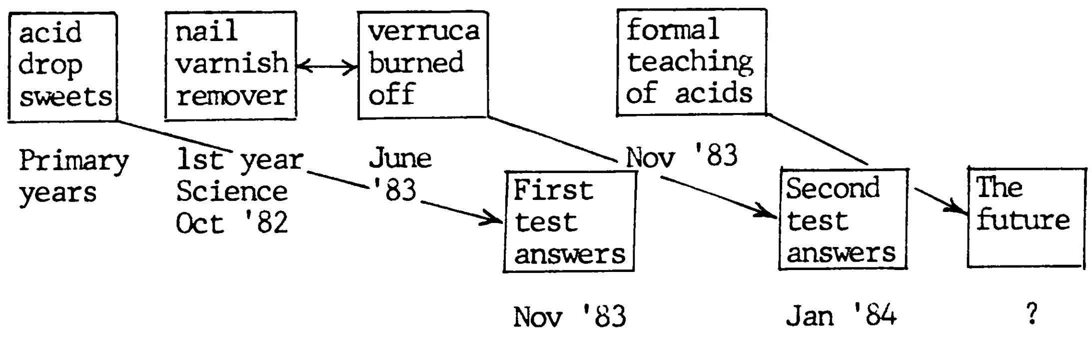
It burns like acid.

That she links in her mind the nail varnish remover with acid is forcefully confirmed because she goes on without prompting to mention the removal of the verruca:

.... burned off .... (with) .... acid stuff

These experiences have clearly influenced Alison's approach to acids. Far more significantly they seem to be having a bigger impact on Alison's retained ideas about acids than does the formal teaching. The leapfrogging impact of experiences, noted elsewhere,*seems to be operating here, as shown in the diagram overleaf.

* Chapter 9 Section 9.2



Alison's formal teaching experience (hinted at in such responses as 'lemon and vinegar contain acid' and 'fizzy, bubbles, different colours') will be slowly assimilated and, when confidently possessed, built on in future study of acids.

Alison's prior knowledge has influenced her thinking in another important way. She has incorporated into her answers some seemingly incongruous couplets:

hot ......and.....cold
hard .....and.....soft

When she had her verruca burned off she must have been surprised to discover that burning can be cold. She probably mentioned this to the doctor because he reassures her:

' .... some people feel it hot, and others feel it cold.'

That would be another surprise, the opposite sensations. The other sensation she felt, apart from the physical removal of the hard core of the verruca, was the drying and hardening effect on the skin of the acetate solvent. It is these experiences which are being articulated very tentatively in her answers as she tries to explain acid and the opposite of acid.

The ability of pupils to discover and accommodate opposing properties of substances or theories is very important. They find the black-and-white of 'either-or' very easy to accept, but the many shades of grey of 'both-and' much more difficult. The latter ability is most important in developing ideas about acidic properties. It may be sufficient for the careful physical handling of chemicals for pupils to be aware of the invariable burning nature of mineral acids, but such a stereotyped and exclusive view will hinder a fuller appreciation of the wide and useful role of acids which the majority of pupils will benefit from.

These insights which Alison has provided into her understanding of acids have implications for the classroom teacher. Alison's prior knowledge has not thwarted or delayed her understanding but enriched it. A teacher will not be able to capitalise on or extend this earlier experience until he is aware of it. This means that, especially when teachers introduce new topics to pupils, they must inquire fully into the pupils' earlier experiences, incorporating them into the earliest stages of the scheme of work.

Methods need investigating to determine efficient ways of eliciting prior knowledge. The informal interview immediately presents itself as an invaluable device and, though time consuming, could well work alongside rather than be displaced by any quicker or sharper technique.

Secondly, if the leapfrogging impact of experiences suggested in different parts of this thesis is found to be a general feature of pupils' learning it affects our testing of pupils' knowledge. It is usually the case that short tests seek to determine pupils' memory of work just completed, whereas longer more formal examinations probe their understanding of ideas developed over a period of time. My contention would be that when pupils complete the former tests their answers would, far from being as the teacher hopes a re-iteration of immediate facts, incorporate a varying amount of prior experience.

This would tend both

a) to invalidate the test because it is not efficiently testing what it purports to, and

b) call for different styles of tests based on a new awareness of how pupils learn.

Work would need to be done to test this, maybe in the following way:

1. Teach a carefully chosen group of facts/ideas .... A
2. After a lapse of time teach a further group of facts/ideas on the same subject .... B
3. Test, ostensibly on B. Examine the results to see the relative emergence of A in B.
4. After another period of time teach a further group of facts/ideas on the same subject ....C.
5. Test on C and examine the results to see the relative appearance of A and B in C. Etc....

7.6 Using some 14 year old pupils' apparent misconceptions about acids to test the tenacity theory of Ausubel

Results in earlier parts of this chapter suggest strongly that pupils' ideas about acids differ markedly from those being taught in chemistry lessons, and that ideas which are formulated early in life are not easily dislodged by formal teaching. These results are in line with earlier research findings (eg Engel 1982).

I decided to test them more rigorously in this way:

A group of 27 pupils (aged 14+) was questioned about their ideas of acids. These pupils, being in their third secondary year, had already undergone two formal teaching sessions on acids (See Chapter 7, Section 7.4)

One of the questions I asked was

'What picture comes to your mind when you hear the word ACID?'

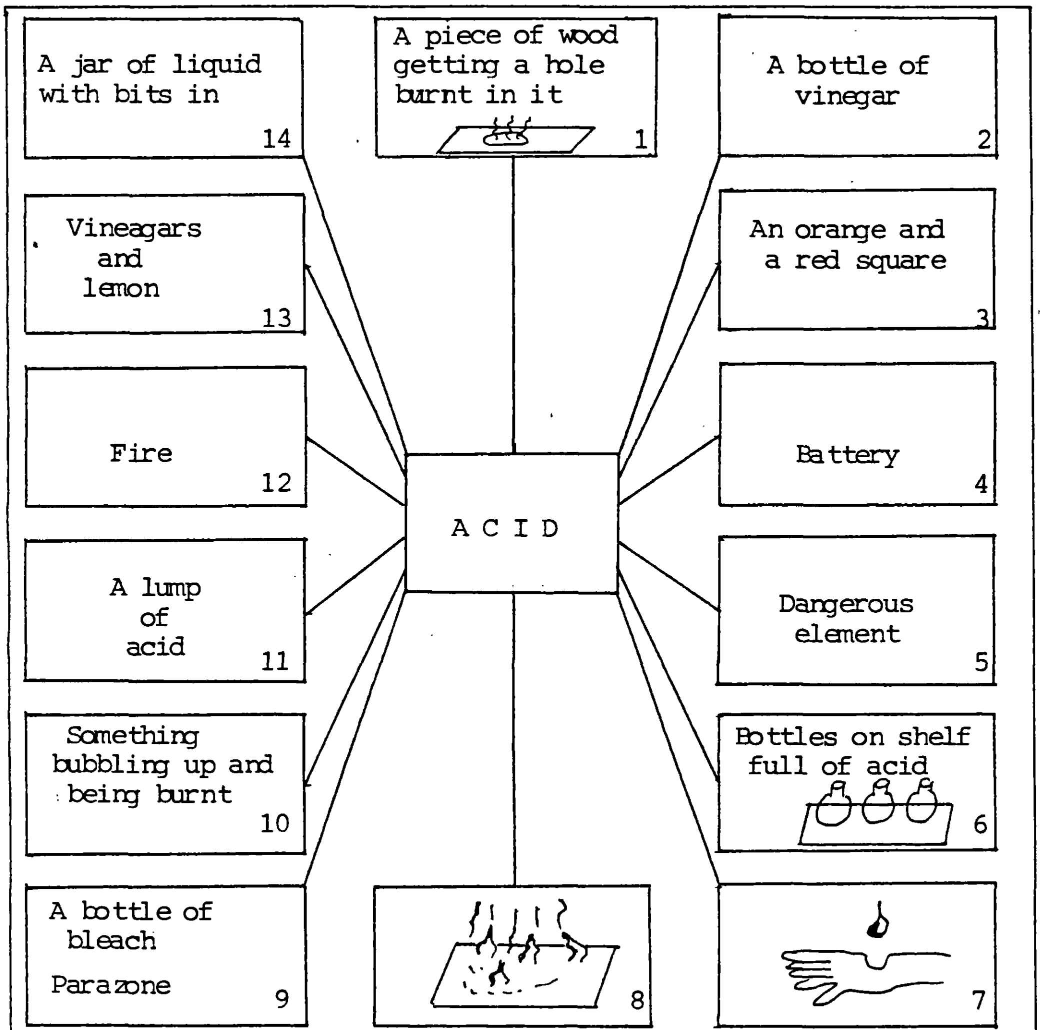
It was inevitable that within a group such as this there would be some unusual responses. So it proved. Having identified a fair number of apparent 'misconceptions' I wanted next to find out more about the pupils' ideas - to ascertain the extent to which they were either misunderstanding or expressing some alternative understanding - and then to discover whether the pupils persisted in holding these alternative views despite attempts to discredit them.

To find out more about their ideas I conducted brief formal interviews. These readily gave me the information I needed. For example, I had been baffled by Amanda's answer

An orange and a red square.

Interview revealed that she was visualising the acid colours of Universal Indicator, and no further probing was needed.

In order to try to shake the ideas of pupils who had given quite obscure responses I transferred the 'pictures' to a duplicated sheet and distributed them to the class. (This sheet is reproduced overleaf, Chart 7.6a). We then talked about the various responses. During the discussion these more obscure ideas were mentioned (for example, a lump of acid; a jar of liquid with bits in). I wanted to see the class's reaction to these ideas. They provoked a ripple of private discussion and the occasional expression of slight incredulity or mirth. I reckoned that if the pupils who had volunteered the pictures felt at all uneasy or ashamed about their views they would change them at a later date.



NAME ____________

1. Which 3 descriptions do you think give the best picture of acid?
2. Which do you think are poor descriptions?
3. What do you think Number 3 means?
4. What do you think Number 4 means?
5. VINEGAR; FIRE; LEMON; DANGEROUS. Underline the one nearest to your idea of ACID.

CHART 7.6a Sheet distributed to pupils Q1401 - 1427 (Oct 1983) in order to probe further into their ideas about acid

Some five weeks later I interviewed the two pupils who had given these pictures:

Mark (Q1424) A jar of liquid with bits in.
Wendy (Q1418) A lump of acid.

Data 7.6a Interview with Mark 3/12/83

Res: Mark, can you tell me again, what picture comes to your mind when you hear the word acid?

Mark: A jar on a shelf, like, with red bits in.

Res: Have you ever seen such an acid, or jar? If so, where?

Mark: No, I didn't ever see it. I just thought that when they corrode they go like sticky, with little bits in?

Res: So the picture you say you saw isn't an actual memory?

Mark: No, I just thought of acids.

Res: But, where does you idea of the bits come from?

Mark: I don't know .... just, when I've had batteries, after a while bits have started to come out, sticky and that.

Res: Ah. And the red .... where does that come from?

Mark: It just seemed like the colour of rust and that.

When I scanned the pupils answers to the questions on the duplicated sheet 7.6a I saw that Mark had answered Question 4 'What do you think No. 14 means? with:

The acid coming from a battery.'

This confirms his responses during interview.

Mark's answer to the question: Where did you first hear the word acid? had been

My dad whilst he was mending his car (dealing with car battery)

Mark's ideas about an acid are not therefore a misconception but a valid assessment of the nature and quality of an acid, its ability to corrode and disintegrate metals, especially iron which yields a reddish product, and so on. Mark's ideas are extremely tenacious. As with other interview examples quoted earlier his picture of acid is retained over several weeks unshaken from its structure of words even after the battering it had received during discussion.

I suggest that Mark's ideas are tenacious for two reasons. They are rooted in his experience. He has seen acid batteries and the corrosive substances released as dry batteries degenerate, and the 'bits' and 'red bits' he mentions have been seen with his own eyes. Secondly, his ideas have validity from his point of view because nothing he has heard or seen since - even during formal teaching - has shaken his conviction that they are right.

Any teacher who simply gets as far as finding out that Mark thinks of acid as being 'a jar of liquid with bits in' and not only assumes that it is a misconception but also a close-fistedly held misconception, is doing him a disservice and will not be able to capitalise on his valid experience.

Data 7.6b Interview with Wendy 3/12/83

(Wendy's picture of acid was 'a lump of acid' and this came in for some derision during discussion. Would she abandon it?)

Res: Can you remember what you said last time when you had to write down your picture of acid?

Wendy: No.

Res: What is your picture now?

Wendy: A lump of metal that's got steam coming from it and it sizzles with it.

Res: What did you mean when you said a lump of acid?

Wendy: A lump that's reacting.

(To the question: What do you think an acid is? Wendy had written: I don't know. But to the instruction to put acid into a sentence to show its meaning she had written: Suzy said in chemestry acid was a liquid but I didn't believe her.

Clearly, although Wendy's ideas of acids are hazy she is not only prepared to stick to her beliefs but to defend them on paper and re-iterate them later when the earlier response is 'forgotten.')

Res: Why didn't you believe Suzy?

Wendy: Because I thought of a lump of acid and she said no acid was solid.

Res: Can you remember or picture in your mind an event or happening when you saw a lump of metal with steam coming from it, and fizzing?

Wendy: No.

In view of the fact that some acids are solid Wendy's beliefs are fascinating, even though she has confused a metal being attacked by acids with the acid itself. She is prepared to cling very tightly to her ideas. Her disbelief of Suzy's claim is based on her own observation and it is this prior personal experience which is dominant in shaping and maintaining her concept of acid. Her ability to resist going along with accepted general ideas, having the courage to disbelieve, is a strength that could be built on.

Chapter Summary

This chapter has considered examples of the impact of prior knowledge on pupils' understanding, using observation of pupils at work in class, close questioning and interviews.

Evidence has been found that pupils try to build their own explanations of phenomena based on their prior experience, and formulate hypotheses which affect their expectations and interpretations of events. Results indicate that they organise their experiences in personal preferred ways and that this can impose powerful constraints on their ability to cope with new information. Their preferred use of words can give a clue to their understanding of concepts. Evidence also exists that the order in which an individual meets new ideas becomes a critical feature of the learning process for that pupil.

The study found evidence of confusion about some elementary concepts and this seems to be linked with their prior limited understanding of key terms, the confusion continuing because teachers are not taking account of their limited view.

Examples have been given which suggest that pupils use alternative interpretations in trying to understand science concepts. However, the rigid postulation of alternative frameworks is cautioned, sufficient evidence existing to indicate that many pupils' conceptions contain insights into the accepted scientific meaning for the concept being studied. The term approximate concept has been suggested in order to ameliorate difficulties arising from the alternative frameworks view of learning.

The data has shown that pupils do not approach learning with adult assumptions; their innocent perceptions - what they see, detect or emphasise are both valid and important - must be harnessed, most especially as a debating springboard.

Pupils' views of the nature of acids were shown to be rooted in prior knowledge. Although formal teaching alters their view towards a more scientific understanding, there is a marked tendency to revert to earlier ideas if revision or reinforcement are lacking. Interviews with pupils revealed that the powerful and dominating influence of prior knowledge is often rooted in personal graphic experiences which have a social rather than scientific origin.

Evidence has arisen to support the selective attention ideas of the Generative Learning Model of Osborne & Wittrock. Examples of pupils' propensity to sieve out from their past and link together those graphic experiences which impress them most add weight to the generative learning theory that the brain actively constructs its own interpretations and draws inferences from them. However, other examples indicate that prior experiences are influencing pupils without their being aware of it; they seem to be prisoners of their own unawareness.

The pupils' ability to grasp concepts and use them confidently seems to be one step behind.

Results obtained here have significant implications for classroom practice. If it is true that pupils make their own links between phenomena, based on experience, how does this affect the teacher's approach since he is hoping that they will make different, scientific, links? Also, an example has been given which shows that problems identified by Ausubel - the tenaciousness of pupils' prior knowledge - and Donaldson - the pupils' tendency to make bizarre assumptions - give way when pupils are able to test their ideas constructively.

CHAPTER EIGHT

CHAPTER 8 HOW PUPILS COPE WITH SCIENCE LESSONS: THEIR UNDERSTANDING OF THE PURPOSE OF THE WORK

8.1 The pupils' approach to project work. Observation of two primary school pupils aged 10 and 11 years

8.2 The pupils' approach to practical work. Observation of a group of three 13 year old pupils

8.3 A further look at project work. Notes about the observation of a primary school pupil aged 11 years

8.4 A closely controlled testing of a class of 14 year old pupils over a period of seven months, to study their response to a deliberately declared purpose for each lesson

Chapter introduction

I decided to look closely at the question of whether pupils invent their own purposes for class activity. Earlier research had suggested that they do. For example, Tasker's(1981) results, based on observational techniques similar to my own, had indicated that pupils sometimes invented a purpose for a lesson which was subtly but significantly different from the purpose intended by the teacher, that pupils often showed little interest in or concern about those features of an investigation which the teacher considered to be critical design features, and that pupils involved in teacher or textbook guided investigations spent much of their effort on the mechanics of the procedure (What do we do now? What instructions are we up to?). Tasker called these 'executive type decisions.'

It seemed to me that if a difference existed between the teacher and pupils about the purpose of a lesson it could be rooted in the pupils' prior experience, and the data was searched to test this idea.

The data for this chapter is again derived from both phases of my research. In the first part of the chapter I have drawn on data quoted in Chapter 4 about two pupils working together. There are also notes about a group of three pupils working together on an experiment, and observational notes about the pupil Stuart which are given in Appendix A. In the final part of the chapter I report the results of work with a class of 14 year olds.

8.1 The pupils' approach to project work; observation of two primary school pupils aged 10 and 11 years

A study of data 4.12b and 4.12c (See Chapter4) tends to support Tasker's view.

In 4.12b Robert and Allan are among a group of boys working from a worksheet. The exercise is fairly mechanical, one of comprehension, reading the sheet and finding the answers to questions. Allan, only ten years old, is a bit surly, not yet anti-school but 'going through the motions' with yet another worksheet.

When I asked him why he was not working, he said he could not answer the question.

Res: Why not?

Allan: I couldn't find it on the sheets.

Allan's failure to answer the question is in part the fault of the worksheet, since a specific answer is required. However, this class was encouraged to use other sources of information such as notes from a film, a range of books, or to ask the teacher.

Observation of the two boys showed that, whereas Robert cheerfully used all sorts of sources of information until he got a satisfactory answer, Allan morosely limited himself to the sheet and became a victim of his own lack of interest.

This is an example of the limiting influence of a pupils' low horizon of satisfaction.

Allan has little interest in the subject - bee dances. He does not want to learn anything about them and searches for answers simply to satisfy the teacher's requirements. As far as he is concerned, the purpose of the lesson is to find answers on a worksheet. Nothing more. His approach to the work, and the purpose he sees for it, seem to have been conditioned by his earlier experience of this type of exercise - find the answer, write it down neatly, get it right, and earn teacher approval.

8.2 The pupils' approach to practical work; observation of a group of three 13 year old pupils

Data 4.12c describes a totally different situation. Three secondary pupils are cooperating on an experiment. It is clear that Tasker's 'executive type decisions' (What do we do now?) riddle the experimental notes.

Robert: Is that all you take?
Sandra: Is that OK?
Sarah: What do we do after this?
Sandra: What's meant to happen? etc.

My notes on the lesson introduction give further light on the experiments:

Data 8.2a Robert, Sandra & Sarah (K1301,2,3) June 16 1981

Teacher: We've been looking at ways of extracting minerals from their ores.
Last time we ... (there is an interruption by another teacher) ...
What we'll do today is lead ore to get lead.
(He gives instructions and draws diagrams on the board).
Take a pestle and mortar, and lead ore and charcoal.
(Robert is chatting to Sarah).
Crush the two together and transfer to asbestos paper.
Use tongs and heat for about five minutes.
(All three are copying from diagrams on the board).
Then tip it on to a mat and look for silvery globules of metal. If not, re-heat.

Cont/

(Robert is the first in the class to fetch a bunsen burner and tripod. He lights the bunsen. Sandra stands up as if to join in, sits down and carries on copying. The bunsen won't light. He tries the tap. 'It's working now' (exasperated). 'I know what's wrong, it's blocked,the tube.' He fetches another and tries it. 'That's better.' All this several minutes before the next person moves).

Even though the teacher has spelled out the purpose, as he thought, clearly, the attention of the pupils is diverted for several reasons.

a) The unavoidable intervention of the other teacher at the critical introduction stage.

b) The fact that several things are going on at once: the teacher's instructions, his drawings on the board, and the pupils' copying into their books. This reduces the amount of attention the pupils can give to listening to the purpose.

They are more interested in what they will have to do rather than with what they need to achieve and why.

Robert's: 'Keep the rest in case we have to do it again.'
and Sarah's: 'We can have another go.' indicate that the emphasis is on the practical aspects of the experiment.

Their comments:

Sarah: We've got to heat it for five minutes.

Robert: One more minute.
One more minute, then we can stop.
That's what MR - told me to use. all further indicate a pre-occupation with the teacher's directions on experimental detail. To their credit, as the pupils themselves would probably protest, they are keen to get it 'right', but their obsession with the practical detail, even to heating for the exact minute, has shifted their gaze from the purpose of the experiment.

c) As well as copying while the instructions are being given, the pupils are chattering. So they do not hear the teacher's crucial nuances of instruction which give clues to his intended 'critical scientific design features.'

'..... heat for about five minutes.'
'..... look for ... if not, re-heat.'

These three short examples of pupils engaged in project work and practical science seem to suggest that pupils invent their own purposes for experiments and are pre-occupied by 'how', not 'why', when working.

Does the bulk of the data support this view?

In order to discover the extent to which this may be happening it is necessary to scan the whole of the data. Since the accumulated observational notes on the 26 pupils are too bulky to include I have selected one pupil's field notes and put them as an appendix (See Appendix A). I have used the first part of these notes as the basis for further probing into this important aspect of pupils' approach to science.

8.3 A further look at project work; notes about the observation of a primary school pupil aged 11 years

The notes given as Appendix A are about Stuart (D1103) when he was working on a topic sheet entitled 'Using your eyes'. Much of Stuart's science work derives from worksheets. Each pupil is supposed to work on his or her own, and the pupils' occasional remarks show that they are fully aware of it.

eg. A1/25 M: No, no, I don't want (you to give me) the answer.

A1/89 E, slightly jealous, says: He should be doing his own work.

In the lesson described in section A1 Stuart keeps to the prescribed course at first, following the worksheet to complete three practical tests; the pinhole camera, the pencil experiment and shadow profiles. Then he is distracted as he notices the model of the brain - line A1/19.

He returns to his own work (A1/26) but promptly becomes involved in the other boys' work about reflection. At A1/47,9 he side-tracks by mentioning a TV programme and his dad's camp. In each case the trigger producing this is the shiny property of reflecting materials and 'Diamonds' - the name of the television programme. All the time (A1/68,73) he is slowly fulfilling his own obligation as spelled out by the worksheet. There are examples too of how he is fairly slavishly controlled in his learning by the 'how'.

A1/1 Where's the question on this?
4 Oh, I've lost it now.
27 I've done that bit (a), now (b).
76 He searches for a pen, because experiment B_1 says 'pencil' but B_2 says 'pen'.

For Stuart the purpose is an inflexible programme of obeying instructions, getting the right answers and copying them down, Correct spelling is of paramount importance. Nevertheless Stuart is learning and indeed has a very good general knowledge, as the interview data A2 clearly shows.

Data from the first phase of my research, at both primary and the more pointedly 'scientific' secondary levels, seemed to give sufficient evidence to justify testing of a more controlled nature. I was anxious to find out from the pupils themselves what it was that they thought they were doing; what the purpose of science lessons was, from their point of view.

8.4 Closely controlled testing of a class of 14 year old pupils, over a period of seven months, to study their response to a deliberately declared purpose for each lesson.

I therefore decided to test a whole class of third year chemistry pupils (Q1401-27) on several different occasions during 1983-4. Each practical lesson would be carefully structured, the purpose of the lesson being very clearly spelled out at the beginning. At the end of the lesson, or the following week, the pupils would be asked to write down a sentence describing what they were trying to do.

Their responses would then be categorised using techniques similar to those of Brook, Briggs & Bell(1983), that is, allocating them to one of four groups, as described below.

The above workers had transferred responses by % to pie charts. I decided to use also a numerical scheme, as described later.

The four sessions chosen, with their purposes, were:

1. 30 September 1983 (tested 7 Oct)

   'To prepare the silver halides and to say how they are similar and different.'

2. 2 December 1983 (tested the same day)

   'To show how metals can be made.'

3. 20 January 1984 (tested 27 Jan)

   'Using acid to drive carbon dioxide out of a carbonate, and testing carbon dioxide with lime water.'

4. 16 March 1984 (tested the same day)

   'To show that ammonium chloride can be split into two gases, and to show that these gases can travel at different speeds.'

At the beginning of each lesson these purposes were made clear to the class. It will be seen that a variety of straightforward and more complex purposes were introduced to see if it was possible to differentiate between the ways pupils coped with each.

The lesson of December 2 1983 was of particular interest because it was exactly the same as that seen and reported as Data 4.12c.

The precise instructions given to the class on this occasion are reproduced here.

Data 8.4a

The purpose of this lesson is to show how metals can be made.

You will heat a mixture of lead oxide and the element carbon. If the carbon is more reactive than the lead it will take the oxygen away from the lead oxide, leaving metallic lead.

How will you recognise the metal lead?

In previous lessons we have seen that metals react with acids at different speeds. From these experiments we were able to make a reactivity series of the metals, a league table with the most reactive at the top and the least reactive at the bottom.

From this afternoon's work we should be able to fit carbon into the list, as far as lead is concerned.

The purpose of this lesson then is to show how metals can be made.

Take the tube with a mixture of lead oxide and carbon, and heat it gently at first, then more strongly. All the time study the tube carefully to see what is happening.

Write down in your books

1. A title for the work.
2. A description of what you did.
3. What you saw happen.
4. A conclusion.

A diagram was then drawn on the board and the last four instructions written down as a reference for them.

At the end of the lesson, or the following week, I asked the pupils to write a sentence or two about their ideas of the purpose of the lesson. I later sorted their responses. allocating them to one or other of the four categories below. With each of the categories I have given an example from the pupils' responses.

<u>Category 1</u> Those responses which included all or substantially all of the intended purpose

<u>Q1423</u> <u>I think the main reason was to see if we could make a metal.</u>

<u>Category 2</u> Those responses which included purposes related to the intended purpose.

<u>Q1406</u> <u>The purpose of this afternoon's lesson is to (find) what is the most active carbon or lead.</u>

<u>Category 3</u> Those responses which included some scientific purpose not directly related to the intended purpose.

<u>Q1410</u> <u>To get solid from an oxide.</u>

<u>Category 4</u> Those responses with non-committal, confused or nonsensical purposes.

<u>Q1425</u> <u>The purpose was to combine the substances together and remove the air.</u>

The results of the categorisation are shown in Table 8.4a, these figures being presented also in Chart 8.4a. The %'s for each experiment and a composite are given in Chart 8.4b.

A number of interesting points emerge.

Table 8.4a shows that no pupil is consistently able to state the intended purpose fo the lessons. Q1409, 1423 and 1426 are nearly perfect; Q1415 and 1419 are poor, but the rest are totally variable.

Pupil	Categories of response			
	30/9/83	2/12/83	20/1/84	16/3/84
Q1401	1	2	2	1
1402	4	2	1	1
1403	4	2	-	2
1404	2	1	2	3
1405	1	1	2	4
1406	2	2	-	-
1407	-	-	1	1
1408	-	-	1	1
1409	1	1	1	2
1410	2	3	2	-
1411	-	1	-	-
1412	2	3	1	1
1413	1	3	-	1
1414	-	2	1	1
1415	4	2	4	1
1416	4	1	3	1
1417	-	-	2	-
1418	3	1	1	1
1419	2	4	4	1
1420	2	2	3	1
1421	2	2	-	1
1422	2	2	1	3
1423	2	1	1	1
1424	2	2	-	2
1425	-	-	2	1
1426	1	2	1	1
1427	-	1	1	3
1428	2	4	3	1
TOTAL	46	47	40	36
	$\frac{46}{21} = 2.19$	$\frac{47}{24} = 1.96$	$\frac{40}{22} = 1.8$	$\frac{36}{24} = 1.5$

Table 8.4a Pupils' ideas of the purpose of four lessons

Class Q1401-28

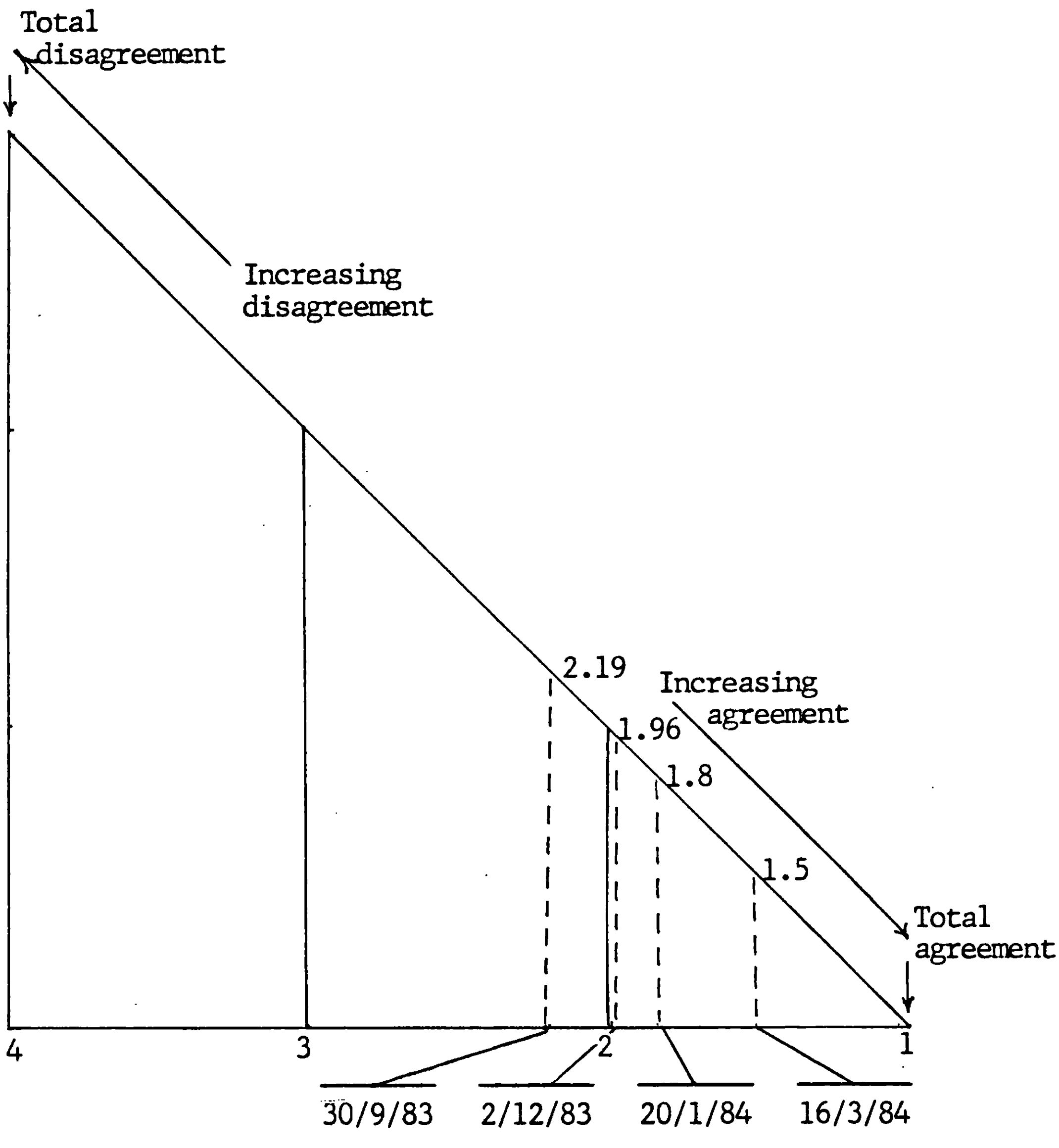
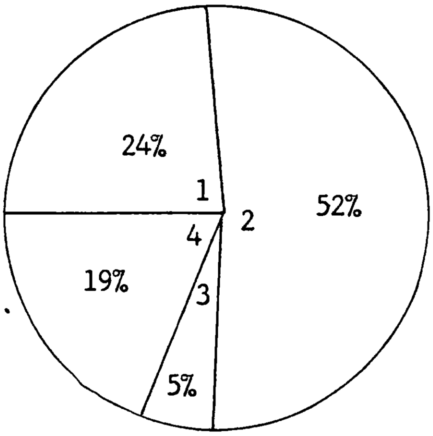
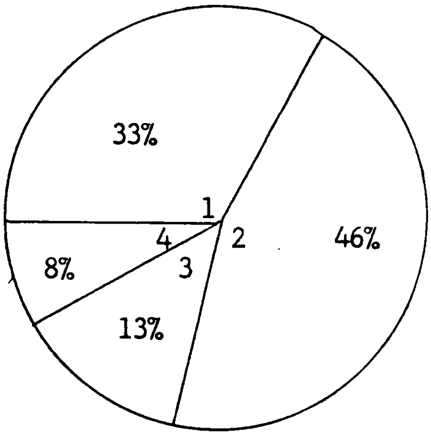


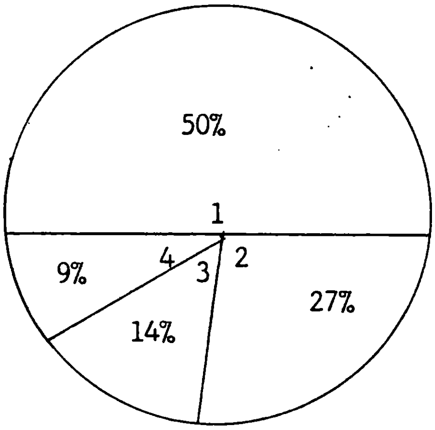
Chart 8.4a Diagram of Teacher-Pupils agreement about the purpose of experiments. As the class average approaches unity the pupils increasingly agree with the teacher's intended purpose for the lesson.



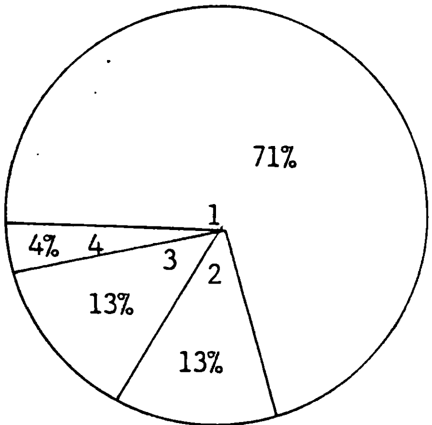
Lesson 1 (30/9/83)



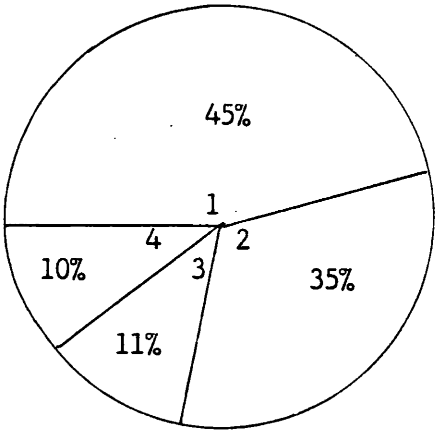
Lesson 2 (2/12/83)



Lesson 3 (20/1/84)



Lesson 4 (16/3/84)



Composite

Categories:	1 = all or most of the intended purpose
	2 = some of the intended purpose
	3 = scientific purpose unrelated to that intended
	4 = spurious purpose

CHART 8.4b % understanding of the purpose of experiments (Pupils Q1401-28)

Chart 8.4b shows that the pupils' ability to state the purpose of the lesson increases steadily from Lesson 1 to Lesson 4. Also, the number of hazy or spurious purposes decreases steadily. The pupils are apparently becoming used to the format:

Beginning: Listen carefully. This is the purpose ...

End: Write down the purpose of the lesson.

If these results, using this technique, can be replicated with larger numbers and a range of abilities, it could suggest

1) That earlier research results that pupils invent purposes of their own are due to lack of teaching precision in clearly stating the purpose behind the work.
2) That pupils will learn to focus on the teacher's intended purpose if it is clearly stated and often referred to.

Chart 8.4a is another way of showing the results numerically and visually. The total of the categorised responses is divided by the number of pupils to give a class average as a ratio. The ratio will approach unity for a total agreement between class and teacher about the intended purpose of the lesson. The ratio will approach 4 for totally inadequate invented purposes throughout the class.

It can be seen that, for this class, the initial average is 2.19 (which is less than 50% = 2.5) and progression is to the right, that is, towards increasing agreement between teacher intention and pupil perception.

Another important feature of these experiments impinges on the questions being asked in this chapter. In experiment 2 for example (2/12/83) the pupils had been asked to write down

a) A title of their own devising.
b) What they did.
c) What they saw happening.
d) A conclusion.

When the titles which they invented were studied it was found that they fell into two distinct areas. There were those pupils who followed the stated purpose and gave such titles as

Q1409 To find out how lead is formed.

And there were those pupils who deviated from the stated aim but followed an inherent theme. Titles of this type included

Q1406 Where does carbon fit into the reaction series?

Where did this type of title come from? It came from the pupils' linkage of ideas. In the lesson introduction I had specifically stated: 'From this afternoon's experiment we should be able to fit carbon into the (reactivity) list.'

During the previous few weeks we had been studying metal reactivity and compiling the reactivity series, this in turn deriving from a study of the elements which had stressed pattern, similarity and trends. The pupils' expectation had been that each lesson would be built on by the next. At the end of the previous lesson I had mentioned that we would be using carbon to extract lead and thus fitting it into the reactivity series.

It is this continuity that the latter group of pupils is focussing on. In their minds the making of the metal is secondary to the fact that, since carbon can force lead out of its compound, it must be more reactive and therefore higher up the league table. The importance of this lies in its pertinence to questions already posed:

Are pupils motivated to learn as meaning increases?
What does increased meaning mean to pupils?

These pupils quite clearly are motivated to learn, as a study of their observations and conclusions shows (see Data 8.4b,c over)

Data 8.4b Q1410 2/12/83

Title: Making a metal oxide a metal

What we did: We put the metal oxide (lead oxide) and carbon into a test tube and heated it slowly until it turned to a silvery solid. We emptied the powder out leaving the lead behind.

What happened: At first there was no reaction, but after a minute the metal oxide started to gas and rise.

Conclusion: To get a metal solid from a powdered metal oxide you have to add carbon to the oxide and heat it.

Data 8.4c Q1419 2/12/83

Title: Making lead.

The method we used: We put a non-metal and a metal powder together in a small tube. We heated the tube on a bunsen burner. When the powder has heated a metal should have appeared.

What I saw: I saw the powder turning into a liquid state (hot). Then underneath the hot liquid appeared a silvery metal which is called 'lead'. When I tipped it out there was a black metal with silver bits in it.

Conclusion: My result was successful a metal came called lead.

These and the other scripts show that for these pupils increased meaning means finding more elements to fit into their accumulating understanding of reactivity, using tried techniques of more-versus-less reactive elements in actual competitive experiments.

CHAPTER SUMMARY

This chapter has reported three specific examples in the close observation of individuals and groups of pupils, and the results of a more specific enquiry with a whole class.

From these it emerges, in line with Tasker's findings, that pupils often confuse the purpose of a science lesson with the mundane completion of tasks, and that they are often concerned with what to do rather than with what they should be achieving and why. This is equally true with individual written work as with group practical experiments.

The study suggests that this pre-occupation with the organisation of work is rooted in their prior experience and that, more importantly, this prior experience tends to condition their whole approach to the study of science.

The results throw further light on pupils' perceptions of the purpose of their work. It shows that, despite the pupils' concentration on organising their work, they do often doggedly adhere to underlying purposes which are spelled out by the teacher or are implicit in work programmes.

Evidence exists that where pupils invent their own purposes for work these are linked with earlier experience in a deliberate attempt to make their learning more meaningful. Whereas Tasker's results imply that pupils' purposes, where they are at variance with the teacher's intended purpose, are of an inferior nature, this study has revealed examples of pupils diverging from the teacher's intentions in a positive and potentially beneficial way.

The study suggests that any haziness that the pupils have about the purpose of their lessons could be due to lack of precision in stating that purpose. Where the purpose is clearly indicated pupils do learn to fix on that purpose.

CHAPTER NINE

CHAPTER 9 SOME EFFECTS OF CONTEXT UPON MEANING

9.1 Observation and interviews with eleven pupils aged 9 - 11 years, and four pupils aged 12 years, as an initial attempt to find evidence of context-influenced understanding

9.2 Close questioning of a class of twenty-six 12 year old pupils about their ideas of MASS and VOLUME prior and subsequent to a teaching sequence

9.3 Interviews with two 16 year old pupils about the answers they gave in a questionnaire on ACIDS

Chapter Introduction

Earlier research (for example, Donaldson, 1978) has indicated that the meaning of a word is influenced by the context in which the word is heard or used. If this is so, the pupils' understanding of (ie. their interpretation of the meaning of) science words is affected by the context in which those words are placed.

It follows that the quality of their learning is dependent upon the clarity of the context in which science words are first encountered. I decided to investigate this.

The data in this chapter is presented in two sections; that from the initial phase of the research, and that from the closer probing into the question of context.

The data from the first phase gives examples from the work of three pupils, plus written answers from a further eight pupils and two interviews. Examples of synonyms and sentences follow, from four boys aged 12 years, and during the subsequent discussion further data from two pupils is introduced.

The data from the closer study includes

1) A class of 22 pupils aged 12 years, questioned about their concept of MASS prior to instruction, and

2) the same class questioned one year later, the results presented in tabular form and burr-type diagrams. (Reported also in Chapter 7 (Section 7.2))

3) Interviews with two pupils aged 16 years about their concept of ACID. (Other results from this class of 19 pupils have been given in Chapter 7 (Section 7.4))

9.1 Observation and interviews with eleven pupils aged 9-11 years, and four pupils aged 12 years, as an initial attempt to find evidence of context-influenced understanding

During the initial observational part of the research I used informal questioning while the pupils were working to try to discover their understanding of what they were doing. In one school pupils aged 9 - 11 years worked chiefly from worksheets on comprehension exercises. By talking to the pupils I tried to discover the ways in which they made sense of the questions which they had to answer, how much and in what ways they used prior experience or were influenced by it, and to what extent they understood the words they incorporated in their answers.

Some examples follow.

Data 9.1a Clare D0901 13 May 1981

Clare had written: When the light is on the iris closes up and shields the pupil.

Res: What does shield mean?

Clare: It guards it, helps it not to get damaged. People used to use shields made of steel and metal.

Res: Have you seen shields used today?

Clare: Royal Insurance shields you.

Data 9.1b Clare D0901 13 May 1981

Clare had also written: The ship has to contend with water friction.

Res: What does contend with mean?

Clare: To ride on.

Res: What does water friction do to the ship?

Clare: Make it lighter.

Cont/

Res: What is friction?

Clare: I don't know.

Res: Where have you heard the word before?

Clare: I've not.

(We discuss this a little and I mention the fact that rubbing can cause heat)

Clare: Yes, like your hands get hot when you slide down a rope.

Res: Yes. Has that happened to you?

Clare: No. A friend told me about it.

Data 9.1c Alan D1002 13 May 1981

Res: When you did question two where did you go for the answer?

Alan: The text description.

Res: Why did you go to the description?

Alan: I didn't know from the diagram which the sense organs were.

Res: What did the text say the sense organs looked like?

Alan: Like a large pear; like an eye.

Res: When you wrote down the answers from the text why did you alter the words, their arrangement?

Alan: Because you have to put them in your own words. You can't copy.

Data 9.1d Robert D1102 June 9 1981

Robert has been studying elephant communication.

The sheet says: (It) will spread its ears wide and hold its trunk rigid, after a great deal of snorting and trumpeting.

Robert writes: He will rise it's ears, rigid his trunk and make rude and snorting noises.

Data 9.1e Class of eleven year olds including Stuart D1103
19 May 1981

Some members of this class had visited a theatre to see a play about 'Light'. One dramatic demonstration had been to shine light through a bottle of water, setting fire to a piece of paper. When they got back to school the pupils were asked questions. One was: If sunlight were passed through a curved glass bottle filled with water what happens to the light rays that come out the other side?

The eight pupils who answered this question wrote in their books:

1. If sunlight were passed through a curved glass bottle filled with water the rays would be magnified. (Deborah - see below)
2. The bottle full of water passes through to the other side and is heated. And it can burn paper.
3. The light rays that come out the other side of the curved bottle become magnified. It can also cause flames and make a fire.
4. The light rays that come out the other side would set fire to just about anything that would burn.
5. The light rays that come through a curved glass bottle full of water cause heat, if sunlight were passed through it.
6. The light rays that come through a curved glass bottle can cause heat. The heat can burn things the other side of the paper.
7. If sunlight passes through a curved glass bottle full of water the light that comes out the other side will be directed on one spot and will start burning.
8. The light rays will fall onto the fireplace and light the fire. (Stuart)

When I read these answers several things intrigued me and I dug deeper. Firstly, several pupils referred to the rays being magnified, but only one (No. 7) referred to them being focussed. I asked Deborah:

What does magnified mean?

Deborah: Get larger.

Res: What is the goldfish bowl doing to the rays of light?

Deborah: Don't know.

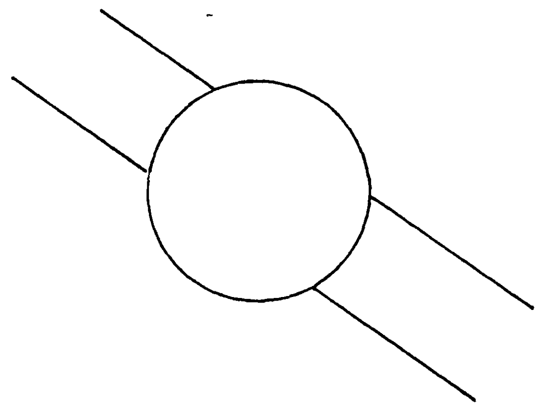
Res: Is it making them go faster?

Deborah: Don't know.

Res: Is it making more of them?

Deborah: Yes.

Res: Can you draw me a picture of the rays going through the goldfish bowl?



Secondly I was interested in the preoccupation of the pupils with the drama of the fire. As Stuart was the only one of the eight pupils whom I was studying in detail I questioned him about his answer.

Data 9.1f

Res: The question asked what happens to the light rays when they come out of the bottle of water. Can you remember what you put?

Stuart: The paper sets on fire.

Res: How are the rays coming out different to those going in?

Stuart: They are hotter.

Res: What has happened to the rays to make them hotter?

Stuart: I don't know. But glass can do it as well. Somebody left a piece of glass near my dad's tyre and it burnt a hole right through.

Data collected from another school during the initial phase of the research is pertinent to the current discussion. On one occasion a class of 26 pupils aged 12 years had been studying wood-lice and the effects of various conditions on the insects. It was a class containing a group of five boys who had been chosen for me by the teacher for extended observation.

They were working with the guidance of a work booklet and I was interested to know whether they understood certain key words in the instructions. I withdrew the group from the class and asked the pupils to write down a synonym for each key word (give another word of similar meaning to ...). I then asked them to write down a sentence explaining the meaning of the word.

The group was particularly useful for scrutiny because two boys (K1201/2) were intellectually bright (K1201 especially so), two being fairly average (K1203/4). The fifth member of the group had great difficulty reading and spelling, and his written responses were sometimes indecipherable. It was found to be more profitable to rely on his oral contributions either in interview or during class discussion and other activity.

The key words chosen were:

observe
record
settled
besides
investigate
lightness
damp
slope
darkness
findings

Their responses are given in Data tables 9.1g and 9.1h overleaf.

Data Table
9.1g 29 April 1981

Key words	K1201	K1202
observe	to look at closely	to look
record	remember	write down
settled	stable	staying
besides	close to	otherwise
investigate	find out	look into
lightness	bright	to see
damp	moist	wet
slope	gradient	not level
darkness	damp	could not see
findings	receiving	things to find out

Key words	K1203	K1204
observe	watch	look, watch
record	tape	reminder on paper
settled	quietened down	comfey
besides	anyway	another
investigate	-	looking ~~for someone~~
lightness	light	day bright
damp	wet, soggy	wet, soaking
slope	hill	tilt
darkness	night	black
findings	found	discovered

Data table
9.1h 29 April 1981

Key words	Pupil	A sentence to show the meaning
Observe	K1201	To look at carefully and take note of what happens
	K1202	Looking and remember what you see
	K1203	Watch and don't go away
	K1204	Watch and don't do anything else
Record	K1201	To write down the results of your work
	K1202	Write down (make notes) of what you discover
	K1203	Write down what is happening
	K1204	Record in your book what the crawlers are doing
Settled	K1201	To not move, when the object/ animal has become stationary and won't move easily
	K1202	Stay there/ without moving for a while
	K1203	Stopped or where it has stopped
	K1204	Means when you are used to your surroundings
Besides	K1201	Apart from anything else but colour, ie dampness, moistness
	K1202	Other than something
	K1203	As well
	K1204	Means on the other hand or something else
Investigate	K1201	To look out and search out a reason for the animal's preference to either condition
	K1202	Find out by do(ing) other experiements
	K1203	-
	K1204	Means investigate why the crawler has stopped

cont/

/cont

Lightness	K1201	Light conditions
	K1202	Light - you can easily see
	K1203	-
	K1204	Means light, day or something like that
Damp	K1201	Moistness, not dry
	K1202	Moist, slightly wet
	K1203	-
	K1204	Because it smells rotten
Slope	K1201	A degree of rise, a horizontal line either up or down
	K1202	Uphill or downhill, not level
	K1203	To move one side up or down
	K1204	Means slant, or a road going up or down
Darkness	K1201	Conditions where it is darker and cooler
	K1202	Not being able to see fully, slightly dark, no light
	K1203	Where it is not light
	K1204	Means black dark night
Findings	K1201	Results that have been found from an experiment
	K1202	What we have found out when doing the experiment
	K1203	What we have found
	K1204	Means like you've found some things

These varied and seemingly disparate examples from the initial phase of the research highlight the subtle effect of context on the pupils' understanding of words.

Two distinctly different contextual influences either reinforce or attenuate each other as pupils strive to understand ideas in science. There is the immediate context within which the word arises, and there is the more powerful remembered context in which relevant knowledge was previously gained. The effects of these contexts on each other are clearly seen in some of the data quoted. In 9.1a Clare understands the word shield well. She remembers the shields of history and, when I tried to prompt her to quote the present day use of riot-police shields, quotes a pertinent TV advertisement. Here Clare's remembered context reinforces the immediate context, and understanding results.

In 9.1b however Clare has never heard of friction and her attempt at deriving meaning from the immediate context, having no reinforcement from experience, fails. The context of the 'water friction' leads her to think that it is something slippery which makes the ship's movement easy by helping to buoy it up. The immediate context employs the tacit assumption that friction is either known about or can be easily understoood from that context, but the friction effect of so slippery a thing as water can only be understood in this case if the concept 'contend with' is fully grasped.

There is nothing in this immediate context to trigger Clare's - albeit by proxy - experience of friction, and thus reinforce understanding.

9.1e shows quite clearly the dominant effect of remembered context. In an attempt to extend the pupils' understanding of light refraction the teacher frames a question in a scientific way. A goldfish bowl thus becomes a curved glass bottle. The answer she expects is that the rays are brought to a focus. However the pupils remember the dramatic effect of the goldfish bowl in causing a fire, and are compelled to mention this. They try to explain it by talking of the rays being magnified - made hotter and fiercer - as Deborah's answers confirm. She knows that magnifies means gets larger, but can only assume that the number of rays is being somehow increased, in number rather than concentration.

Stuart is also fascinated by the fire. His pre-occupation is further reinforced by an earlier experience of the sun's rays causing a fire, and can explain the behaviour of the emerging rays only in terms of their 'hotness'.

In some cases then the immediate and remembered contexts reinforce each other and learning occurs. In other cases the more powerful remembered context is dominant and any learning which the teacher had hoped for may be destroyed. This has happened in the last examples. The teacher expected the pupils to remember that the context of the topic work was light, and treat the demonstration as rays of light being brought to a focus. However the children concentrate only on the fire - a vivid event - and can explain magnification only in terms of the increase of rays. Deborah's drawing shows that she has no inkling at all that rays are being altered in direction, although one pupil does mention this.

(7) '... the light that comes out the other side will be directed on one spot ...'

The context in which science words are placed can have another sort of influence, especially in the comprehension type instances quoted earlier. In data 9.1a,b,c and d, the pupils are being required to answer questions based on descriptive passages which include labelled diagrams. They are not allowed to copy. This leads to several problems.

Data 9.1h Stuart (D1103) June 30 1981

Stuart: (To me) Question 2 says: How do larger animals detect their surroundings compared to small animals, eg amoeba? I don't know. I can't work it out.
(He talks to Richard his friend but is still diffident about committing himself in writing).

(Again to me) What does that say? Senses ....?.... on head?

Res: Positioned.

Richard finds the answer for him, reading from the sheet.

Stuart flicks back through his book to where the teacher has written: 'More care over details' and reads it aloud.

Richard: You'll get into trouble if you copy it. You've got to use your own words. (He fetches his old book and shows Stuart a reprimand for copying).

Two further brief notes support the slavish adherence to context and the difficulties it poses for pupils.

Data 9.1j Cheryl (D1101) May 12 1981

Cheryl is working with the Sense of Touch worksheet.

Cheryl: The sense organs - they're like a pear (looking at the diagram).

She reads the passage about it. The text says that the sense organs are onion shaped. She looks confused because the masses of circles on the diagram are irregular in shape.

She gets question 2 - what the touch organs look like - wrong.

Data 9.1k Stuart (D1103) May 12 1981

Stuart is looking for what the sense organs look like.

Stuart: That looks like a pear - like a doughnut. He has great difficulty extracting the answer from the context.

9.1h and 9.1c illustrate graphically the constraining, even imprisoning effect of restricting the pupils to the context. 9.1d illustrates the farcical effect this can have. The pupils study the diagrams to help them understand, but they are forced to go to the text in order to frame the answer. Sometimes there is a conflict between the information they derive from the diagram and that from the text. Instead of the descriptive passages liberating the pupils' minds and enlarging their experience they become a puzzle which the pupils try to rearrange in order to escape from.

Under these conditions the context in which a word or concept is found becomes a confusing rather than an elucidating and enlarging experience. The pupils are often confused and unhappy with this, and they try to break free and contribute their own remembered contexts to such situations, as the following example shows.

Data 9.11 Stuart (D1103) June 30 1981

Stuart spends a long time finding and fitting a cartridge in his pen.

Stuart: Cats and mice sense organs - eyes (jumping to his own conclusion without reading the passage).

Res: Read the third paragraph - the answer's there.

Stuart dashes away and asks the teacher.

Res: Why did you go and ask the teacher?

Stuart: It's a waste of time looking.

Res: You didn't draw any pictures here. Why not?

Stuart: I couldn't be bothered.

Why is the sense of smell important to many animals?

(Social chat about bungalows versus houses. Richard puts forward various suggestions, none based on the passage).

Stuart, who cannot be bothered to unravel the text to discover that cats and mice rely on a keen sense of smell, substitutes an ego-centric answer - eyes. When, in the next question, the sense of smell is referred to, his mind is already closed and he fails to spot this clue to the previous answer.

The term 'contextual meaning', as applied to passages of writing, has little meaning for younger pupils, since the two words are mutually dependent. Those children of about ten years of age, whose work I studied carefully, seemed to make no connection at all between the context in which a word was placed and its meaning. In the cases of Clare and Stuart above they impose their own meaning by selecting from the context only those words which they understand, and use them to try to make sense of the questions they are asked.

Thus Clare (9.1b) does not derive meaning for the term 'contend with' from the context of water friction. Rather, seeing the familiar words 'water' and 'ship' she generates her own reasonable idea that the word means 'ride on'.

Stuart (9.1h and 1) cannot connect the ideas of sense organs with animals (amoeba, cat, mouse) and ignores the context in which the words 'sense organs' are placed. My notes at the time recorded that he was jumping to his own conclusions. He took the words completely out of context, thought of his own keenest sense, and said 'eyes'. Although I tried to steer him back to the context he was not interested and he and Richard continued guessing.

These younger pupils seem to make facile connections and manipulate context. The meanings they build are often ego-centric, subjective and anthropomorphic. They also seem to treat context experientially, not intellectually, testing out the mass of words toe-in-water, only being prepared to plunge in further towards the meaning where such aids as subjectively remembered experiences are available.

Teachers cannot therefore make the assumption that context either encapsulates or will determine meaning. Context has the ability to fix meaning only where there is meaning in the context. I do not think it is extreme to suggest that in the case of younger pupils context has no influence at all on meaning, except to frustrate meaning, unless other powerful influences such as prior and direct experience are available to illuminate it.

It would be interesting to know at what age or under what precise circumstances pupils can begin to infer meaning from context. Certainly it follows the stage at which pupils realise that the same word can have different meanings. Thus, when Christine (see Table 9.2a later) reveals her awareness of two distinct meanings for mass, she would presumably also be able to deduce which meaning for the word was being used in a particular context.

Since the task of inferring meaning from context - the comprehension exercise - is so widespread in all aspects of science learning a great deal of research remains, both to establish its value and pertinence, especially for younger pupils, and to suggest ways by which pupils can increase their awareness of the growth of meanings of words and concepts, and how this growth is linked with contextual use.

Data 9.1f contributes further to this discussion. A study of the synonyms the pupils use shows that they sometimes pluck them anywhere from experience, even though the key words have specific immediate contextual meanings.

For example,

K1203 (settled) = <u>quietened down.</u> Is this pupil hearing the teacher bringing him to order?

K1204 (settled) = comfey. Is this pupil imagining himself at home in a comfortable arm-chair?

K1203 (record) = tape. Is this pupil linking recording with tape recording?

K1204 (investigate) = looking ~~for someone~~. He crosses out 'for someone' as if he has checked in his mental stride, having spotted an inappropriate context.

However, apart from these significant examples, the synonyms they suggest are largely derived from the immediate context, that is the experiments they had been doing with woodlice. The sentences they compose to show the meanings (9.1c) are almost without exception linked closely with their experimental work.

K1203 who suggested 'quietened down' as a synonym for settled, gives the sentence

'Stopped or where it has stopped.' 'It' is the woodlouse.

K1204, whose synonym 'comfey' indicated an ego-centric, experiential response, moves away only slightly from this remembered context.

'Means when you are used to your surroundings.'

His response seems to be halfway between the child's tendency to interpret meanings in self-centred terms, and the scientist's ability to link meaning with context, in this case the woodlouse study. Other sentences show that he is developing the latter ability. His responses to the words 'record' and 'investigate' are

'Record in your book what the crawlers are doing.'

'Means investigate why the crawler has stopped.'

The difference in maturity between K1201 and K1204 is marked, as their responses to the word 'darkness' illustrate.

The sentence offered by K1201

'Conditions where it is darker and cooler.' shows clear links with the experiment in which they discovered the woodlouse's preference for cool as well as dark places, and that the dark places were also cool.

But K1204 does not link the meaning of darkness with the context, but with any very dark night.

'Means black dark night.'

These pupils are significantly older than Clare, Stuart and the rest. They are at secondary school and are doing genuinely controlled experiments under laboratory conditions. Their ability to interpret meaning within the scientific context is noteably greater (but see Brian, Chapter 7, Table 7.2a and comments). Perhaps a fairer comparison between these and younger children would have been to conduct similar testing with primary pupils engaged in laboratory-based primary science experiments.

9.2 Close questioning of a class of twenty six 12 year old pupils about their ideas of mass prior and subsequent to a teaching sequence.

I decided to generate further data using more closely controlled techniques, and used questioning methods which have been reported in Chapter 7, that is, asking specific questions about science words or concepts. Class Q1201-26 was about to study MASS and at the beginning of the first lesson I asked them four direct questions.

1. Have you ever heard the word MASS?
2. If so, where did you hear it first (at primary school, at home, on TV, etc)?
3. What do you think the word means?
4. Give another word, of similar meaning.

The results of questions 3 and 4 are given in full in Table 9.2a. Although only 4 of the pupils admitted to having heard of the word before 19 attempted an answer as to its meaning, and 14 volunteered a synonym.

A study of their answers shows that they not only derive meanings from many areas of previous experience, but that they are making serious attempts at both visualising and describing something about which they have only a tenuous grasp. Even though they have not heard the word before they are trying to make sense of an almost incomprehensible word. This being so, it supports the contention that pupils who have already met a concept will both have and be continually developing conceptual ideas as they seek to extend their grasp of that concept. This was discussed earlier in the section on alternative frameworks, Section 7.3, Chapter 7.

Name of pupil	Question 3 - What do you think the word MASS means?	Qu.4. Give a word of similar meaning
Mark	I think it is a birthmark	-
Paul	My guess is that mass is a sort of a liquid	massive, large thing or quantity
Roy	Guess - I think it is acid	-
Thomas	-	-
Michael B	-	-
Michael W	I think mass is a piece of land, as a land mass	-
Pauline	Guess. I think it is a form of a solid	-
Alison	Guess - I think it is a form of solid	-
Glen	I think mass is something to do with a mass of space	A big space
Stephen	Guess. Mass is a lot of things together	Expand
Gary	Mass is a lot of something	Something big
Nicky	A mass of people	A lot of
John	A mixing of chemicals	A crowd of something
Marie	-	-
Rachel	Something to do with maths	Weight
Jane	I think it is some liquid	Mess
Amanda	A word in church when people start a service	More people
Jackie	A religion for catholics to go to church	Something about your body
Juliette	A mass is a catholic service	Service
Christine	Mass is a sort of word to do with weighing and has a totally different meaning in church	Weight
Kerry	It is to do with weighing	Weighing
Lorna	It is a service at church	Service

TABLE 9.2a Pupils Q1201 - 1226 28 Sept 1982

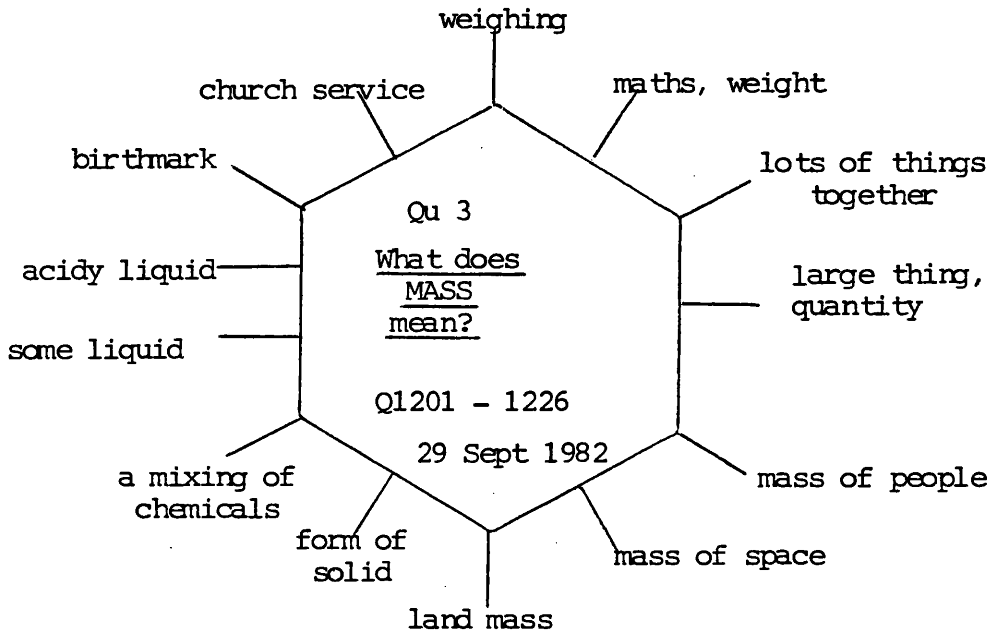
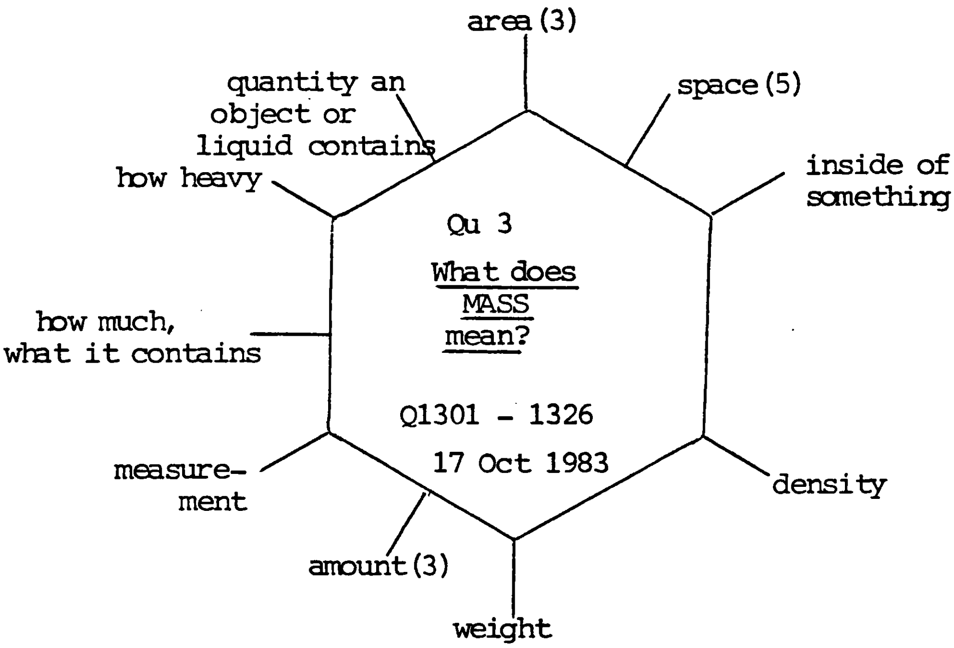


CHART 9.2a Burr-type representations of pupils' responses



Name of pupil	Question 3 - What do you think the word MASS means?	Qu 4 - Give a word of similar meaning
Mark	-	Watch
Paul	-	-
Roy	It means the area and the space	Space
Thomas	The inside of something	Volume
Michael B	-	-
Michael W	How much density something has	Volume
Pauline	Mass is the meaning of weight	Weight
Alison	-	-
Glen	The weight and space an object takes up	Volume
Stephen	The weight of something. The whole thing	Volume
Gary	The area of a box or something else	-
Nicky	The amount of space that is taken up	Volume
John	Amount is what mass means	Volume
Marie	Measurement of something	Centimetre
Rachel	Mass is how much is there and what it contains	Quantity
Jane	The measurements round an object	Volume
Amanda	Area of space, and how heavy the object is	Volume
Jackie	-	-
Juliette	Mass means weight	Weight
Christine	Weight of something	Weight
Kerry	Mass is the quantity an object or liquid contains	Greatness
Lorna	Mass is an amount of space occupied	-

TABLE 9.2b Pupils Q1301 - 1326 17 Oct 1983

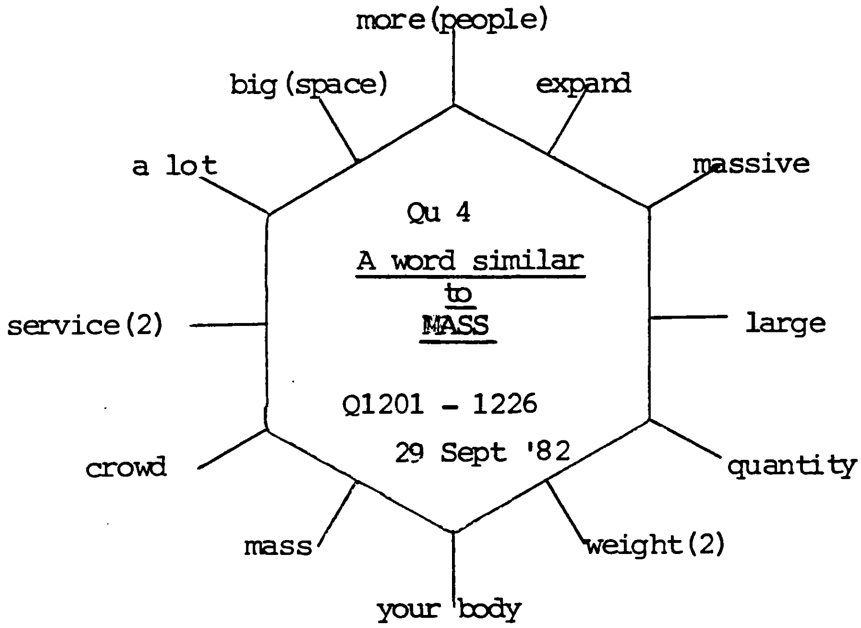
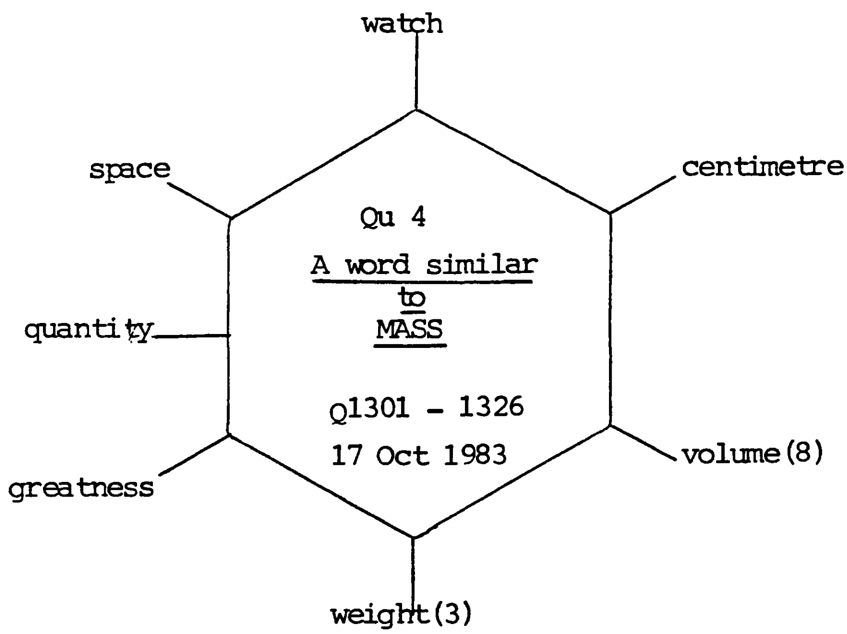


CHART 9.2b Burr-type representations of pupils' responses



According to this class, mass includes this variety of meanings:

.......it is a birthmark......an acidy liquid......a land mass......a mass of space......a mixing of chemicals......to do with weighing...service at a church......

If it is true that these remembered contexts are destined to have a powerful influence upon the pupils' subsequent learning of the concept mass, it will be interesting to see the extent to which the pupils' ideas of mass approach satisfaction when their learning of the topic is complete.

About a year later the same pupils were asked the same four questions. Their responses are given in entirety in Table 9.2b. Their responses on the two occasions to questions 3 and 4 are given for comparison in the burr-type charts 9.2a and b).

Their responses are now entirely different from those broached the previous year. On that occasion they had no immediate contextual experience to draw on and their responses were derived from a wide spectrum of remembered contexts, or more accurately from quasi-relevant experience as they supposed. Now they try to respond in the scientific idiom - they know it is expected of them and their answers derive from a narrow remembered context. A year after the event their understanding of the concept mass is very hazy. They had no warning of my questions, and thus no chance to revise, but the questions are fair in that they elicited the pupils' knowledge under conditions similar to those pertaining when topics are re-introduced in order to reinforce or extend them.

Thus, measurement of length will be re-introduced in preparation for the idea of volume, volume itself being revised before mass is studied, volume and mass before density, and so on. The pupils' responses about the meaning of mass tend to derive from these introductory or previous-experience concepts, the words they use being nearly all connected with linear measurement.

......area......space......amount......measurement......

Even though the words 'weight' and 'heavy' figure in their responses they are in a minority, and the synonyms - which have the words 'volume' : 'weight' in the ratio 8 : 3 - include 'watch' (measurement of time?), 'centimetre' and 'greatness'.

This latter response gives a further clue to the pupils' latent concept of mass. Their earlier responses had hinted at the 'massiveness' of mass: (Table 9.2a)

Michael W	...a piece of land, as a land mass.
Glen	...a mass of space.
Stephen	Mass is a lot of things together.
Gary	Mass is a lot of something.
Nicky	A mass of people.

Their new concept of mass, tempered by the elapsing of a year, still includes this idea of being massive, and the word volume which is a well-understood concept from the primary school context, more nearly describes something big than the more nebulous word weight.

It seems then that the pupils' understanding of concepts is one step behind, a point made at earlier parts of this thesis. They begin to feel at ease with work they did the time before last and tend to use this in grappling with new ideas rather than work they have most recently done and which is not yet a reliable basis for further venture. It is as if, on the steep cliff of learning, their feet have found a solid grip but their hands are still struggling to establish a firm hold.

How does this finding link with earlier comments? I have previously drawn a distinction between younger children who tend to interpret meanings by making facile connections with known and familiar words, disdaining context, and maturer pupils who begin to make definite links between context and the meaning that it requires. The closer study reported here seems to indicate a half-way position where pupils, asked to give meanings for words in a situation which lacks immediate context, fix on the nearest sensible word or concept which they understand.

If it can be established that pupils refer back in their minds to earlier contexts when trying to cope with new work, it would suggest that teachers should introduce new ideas by linking them not only with work just completed but with pupils' earlier learning experiences.

One of the most interesting responses above is that of Christine (Table 9.2a).

> Mass is a sort of word to do with weighing and has a totally different meaning in church.

Christine is the only pupil to mention two different contexts in which the same word hold different meanings. This is a mature insight. It relates to Ausubel's ideas of superordinate learning, the strengthening and broadening of concepts and forming new associations between concepts. In this case - that of the church mass and the science mass - the two concepts are worlds apart in utility and there would be little value at elementary school level in pursuing any associations; yet the ability and opportunity in science to generate different contextual meanings for words and to explore their associations should generally lead to a deepening awareness of the richness of concepts. It is an essential ingredient in much of science. For example, if a pupil is to continue to develop his or her ideas of acid, he or she must progress by what Ausubel calls obliterative subsumption through the sequence:

acid = sour ... acid = red litmus ... acid = low pH ... acid = proton donor ... etc.

9.3 Interviews with two 16 year old pupils about the answers they gave in a questionnaire on acids

In Chapter 7, Section 7.4, I reported the results of questions put to pupils to discover their ideas about acids. Two of the 16 year old, 5th year CSE pupils, gave answers which seemed to have been influenced by context, and I interviewed them to find out more.

Data 9.3a Stephen (Q1618) 13/9/83

To the question: Where did you first hear about acids? Stephen had written:

Acids in Biology, 1st years, about fruits and in Metalwork.

His answers to later questions stressed the reactive burning nature of acids.

Res: In your answers three weeks ago you said you first heard about acids in Biology. What do you remember about fruits and acids?

Cont/

Stephen: Not much really. All about citric acids in fruits ... ants ... and nettles.

Res: What did you do about acids in metalwork?

Stephen: Oh, in the first year, I just asked the teacher what it was doing in the bucket and he said: To clean metals up.

Res: Have you ever done anything about acids in metalwork?

Stephen: Yes, in the second year, in brazing. The acid in the bucket was clear blue ... the teacher said just dip the metal in, then rinse the acid off.

Res: What picture do you have now about acids?

Stephen: Something burning if you put something ... (ponders) ... not burning ... fizzes in it ... dissolves.

Res: Why not burning?

Stephen: Not bursting into flames and that.

(These last observations of Stephen's impinge on important studies of the concept of burning by, for example, Ross & Sutton(1982))

Data 9.3b Mandy (1609) 13/9/83

Mandy's response to the question: Where did you first hear about acids? had been:

Acid sweets.

This also seemed a long way from Mandy's later answers about acid being a burning substance.

Res: In your answers three weeks ago you mentioned acids as being both sweets to eat and reactive enough to burn. How is it possible to have two very different views about acids?

Mandy: (Startled at the question, almost scoffing) 'Cos you can get weak and strong acids.

Res: How did you come to learn that acids could burn and be dangerous?

Mandy: By chemistry ... just by doing experiments ... putting metals into acids and things, and there was one which spun round and disintegrated.

Res: In your earlier answers you said that acid can burn. What do you mean, burn?

Mandy: It reacts, dissolves.

Cont/

Res: When you heard that acids could burn, how did that affect your ideas about acid sweets?

Mandy: It didn't. It's just two separate kinds of acids, used in two different ways ... dilute and that.

Stephen's earlier picture of acid was

'A piece of metal fizzing in a beaker with acid in it.'

The picture he sees during this interview is context determined. Having been re-living his experiences of seeing the metal dipped in the acid, a dramatic event at 11 years of age with its possible acid-bath imaginations, he begins to 'see' the burning character of acids. (This makes an interesting comparison with the pictures of acids of Abigail, Robert and Alison, Section 7.5, Chapter 7). His later experiences however are already blurring that simplistic view:

'Fizzes in it ...' (the physical view of the reaction)

'Dissolves.' (the conceptual view)

This illustrates too the value of teaching techniques which allow pupils to talk through their ideas. The development in Stephen's verbal explanation of his ideas comes through the challenge of articulation.

Mandy is a brighter pupil. She adequately holds both ideas of acids in her mind, and can use them. The interview reveals some possible weaknesses in her grasp of ideas which would need to be further tested. Is she confusing 'weak and strong' with 'dilute and that'? and 'putting metals into acids' with putting reactive metals into water? However, her answers show a clearer grasp of ideas than the similar responses of Wendy (Data 7.6a, Chapter 7) which are shrouded in haziness

A lump of metal that's got steam coming from it and it sizzles with it.

Apart from the differences in age and ability, which it may not be fair to discount, I would suggest that Mandy's superior grasp of acids and her facility in distinguishing the different properties of different acids, stems from her superior contextual experiences.

When I asked Wendy about her experiences of acids she was vague, quoting proxy experiences only. She had written:

> Suzy said in chemstry acid was a liquid but I didn't believe her.

Res: Can you remember, or picture in your mind, an event, a happening when you saw this lump of metal with steam coming from it, and fizzing?

Wendy: No.

But Mandy is far more assertive, far more specific.

Res: How did you come to learn that acids could burn and be dangerous?

Mandy: By chemistry ... just by doing experiments ... putting metals into acids and things,...

Mandy is very clear about the meaning of 'burn' in this context, vis-a-vis acid/metal. Res: What do you mean, burn?

Mandy: It reacts, dissolves.

It is easy therefore for her to explain the sweet and burning character of acids:

Mandy: It's just two separate kinds of acids, used in two different ways ....

I wonder if Wendy was one of those many pupils who, fearing acids, shirked any practical experiments, clinging to old conceptions rooted in remembered or folklore contexts. The above indicates the force of personal practical experience in formulating deeper conceptions of scientific phenomena.

CHAPTER SUMMARY

Data presented in this chapter was derived from observation, questionnaires and clinical interviews with pupils aged 10-16 years.

The impact of both remembered and immediate contexts has been examined, and evidence suggests that the former has a dominant effect. Understanding occurs best where information from both contexts coalesces.

Examples have been given which indicate that pupils draw on remembered contexts when trying to make sense of new knowledge where the immediate context is confusing. They seem mostly to rely on older firmly established knowledge rather than on more recently acquired and tenuously held concepts in understanding new ideas.

Pupils do develop the ability to reconcile different contextual meanings for concepts in science but doubt remains as to when and how this skill occurs and how it can be encouraged in the science curriculum.

Despite professional disenchantment with those heuristic methods which either allowed the pupils to dabble aimlessly in unstructured practical work, or were so open-ended that pupils could not see the purpose of experiments, the data has reinforced indications from earlier chapters that understanding is rooted in the pupils' involvement in the practical testing of ideas.

The data suggests forcibly that younger children derive little meaning from written context. Since comprehension exercises are widely used from an early age, research needs to be done to establish the conditions under which pupils can gain maximum benefit from comprehension work.

CHAPTER TEN

CHAPTER 10 THE STUDY - ITS FINDINGS AND IMPLICATIONS

Chapter introduction

The data for this investigation was collected during two distinct but complementary phases. The initial phase of twelve weeks involved close observation of and interviews with 26 pupils aged 9 - 14 years, in four schools. The second phase was a more closely controlled study of some 111 pupils aged 11 - 16 years, over a period of three years.

While the main axis of the investigation was the question: 'Does prior knowledge influence learning?' tackling it has revealed a good deal about research conducted by a full-time teacher.

The methods employed in the investigation were chosen because they seemed appropriate for use by a teacher-researcher. The results have highlighted several issues surrounding the use of these methods in this context, The following discussion seeks first (Section 10.1) to isolate these issues and to comment on specific strengths and limitations.

10.1 Implications for teachers as researchers

10.11 The theory base for research.
10.12 The choice of questions to investigate.
10.13 The choice of methods.
10.14 Means of improving reliability and validity.
10.15 The practical opportunities for a teacher.

In the final part of the chapter (Section 10.2) the findings of the study of prior knowledge, and their implications for teachers and further research are discussed.

10.2 Findings and implications - prior knowledge

10.21 Findings.
10.22 Implications for teachers.
10.23 Implications for further research.

10.11 The theory base for research

This thesis has probed possibilities for teachers as researchers. The theory on which it is based and within which it has been developed altered as the investigation progressed, in two ways. First, decisions had to be made quite early on about the general problem area to be studied. A considerable amount of reading had to be done. As a teacher-researcher I was thus conducting the early parts of the investigation whilst assimilating both the general educational theory and the methodological issues which were pertinent to the research field.

Secondly, in a research study which took some four years to develop, results of parallel research projects continually appeared as articles in journals or in books. These were a source of deepening knowledge and of stimulus; they were subtle in their ability to influence the nature and direction of the research effort, an influence which is probably greater on the longer studies of part-time research than on the shorter, more intense, full-time research programme. As an example of the influence on my own study, the emergence of Tasker's(1981) findings that pupils invent their own purposes for science lessons led to the investigation reported in Chapter 8, whilst the methods used by Brook, Briggs & Bell(1983) - see page 31 - contributed to the processing of data which was generated.

This is not to suggest that the teacher-researcher's theory base is unstable (all research projects are subject to the dynamic nature of knowledge evolution) but it is liable to change, and the teacher will need to be aware of ways in which it could influence his studies.

The evolving nature of part-time research and its roots in a multi-faceted methodology can lead to an eclecticism which dissipates energies and diverts attention from an incisive attack on a particular issue. Wide reading is essential, so as to acquaint the teacher-researcher with the latest theory and results in his field of interest. Since educational theory in its broadest sense overlaps philosophy, sociology, psychology, psychiatry, etc., it is tempting to take ideas piecemeal from many workers and theorists. The teacher-researcher may find it valuable to isolate a narrow field of study and be strict in subordinating the selection of theory to that aim.

The theory on which my own thesis developed included the following main elements, though not necessarily emerging in this neat order since a good deal of overlapping of reading and assimilation inevitably occurred. The philosophical ideas of Toulmin(1972) that there are no 'absolute' concepts but that human understanding is based on concepts prevailing at particular moments in history, these concepts evolving with time, were very forceful. They suggested that pupils' ideas and conceptual grasp are probably also in a state of flux and that their learning in science is a constantly refining and enlarging process.

Kelly's(1969) ideas tended to support and extend this theory, arguing that concepts vary from person to person and involve each person's organisation of his experiences; that is, the person actively constructs meaning by interpreting new information in the light of previous happenings.

Piaget's work(1929 onwards) also made large contributions to early developments in the theory base of this thesis. Piaget had been concerned with children's thinking, and how children view and react to their environment; he saw a close relationship between logico-mathematical structures and the progressive emergence of causal reasoning. Despite reservations about the interpretation of his results - see Chapter 3 - his testing techniques and clinical interviews have been extremely useful in eliciting information about how children learn.

The views of Ausubel(1960) and Novak(1976) figure centrally in the thesis: that meaningful learning occurs when new information is linked to existing relevant ideas in the pupil's cognitive structure, and that prior knowledge (containing ideas - preconceptions - which are extremely tenacious) dominates and tends to determine the quality of future learning.

Driver(1978) et al developing the preconceptions idea, envisaged situations in which pupils' understandings, however rudimentary, were autonomous frameworks for conceptualising their experience of phenomena, and called these conceptualisations alternative frameworks.

A final series of important elements in the theory of this thesis include the Generative Learning Model (cf. Osborne & Wittrock - 1982) and the ideas of Hewson(1980) which reinforce the notion of the active participation of the brain in the structuring of ideas, and raise such crucial factors as the learner's selective perception of events/surroundings.

The theory thus developed from the broad idea of the impact of prior knowledge on learning to more specific focusses for study. For example, if what the pupils learn is conditioned by what they already know, it may also determine the perspective on, perception of and purpose for their science lessons, the latter having formed one of the three areas of study.

The impact of perspective and methodology on results. The theory upon which a research investigation is based will strongly influence the results which are eventually produced. Driver & Easley(1978) draw attention to this with respect to Piaget's work. They point out that Piaget had interpreted his data in order to discover evidence of stages of mental development but suggest that, since it is in the detail of the pupils' responses that the main educational value of his work lies, far different results would have been obtained by concentrating on the actual content of the pupils' ideas. One of the three main threads Piaget used in interpreting his data was: that there comes a point in children's development when they begin to argue with themselves in their own mind about the meaning of phenomena, based on their experiences. This most important idea could have formed a useful focus for study in my own investigation.

A teacher embarking on research may well perceive his study from a pragmatic angle, wanting his results to find some practical application in the classroom. Studies of this type have recently developed out of Kellian theory. Kelly(1969) as a practising psychotherapist was anxious not only to discover his patients' problems but to solve them. His theory and clinical interviews have influenced such workers as Watts(1981,1983) - see IAI technique, p36 - Tasker(1981); Bell(1983); Osborne & Wittrock (1983) etc., and it is not surprising that their research seeks not only to find out how children learn but to influence how they are taught.

Qualitative methods of the type employed by these workers, and which figure in my own study, are likely to appeal to the teacher-researcher because they lend themselves to development for classroom research. A danger for the teacher is that he could carry into his research his didactic bias. This could be useful where it is recognised or perhaps intended. Thus, Hewson & Hewson(1983) hoping to find the impact of different teaching strategies on pupils' learning deliberately taught the pupils using different teaching approaches. In investigations of this nature the research objectives require the inclusion of a didactic component.

In most cases however the researcher will be standing well back from the teaching role, simply finding out what is going on and drawing inferences, but in no way disturbing the classroom interaction. The teacher-researcher may benefit from an awareness of those conditions under which he may, and those under which he may not influence the research programme.

An example arising in my thesis is at pages 146 and 151, where I report the results of an investigation into the pupils' purposes for lessons. It can be seen that pupil Q1406 had offered a purpose closely related to the stated purpose of the lesson, a purpose which would normally impress and please a science teacher. However, because it was not the primary purpose it had to be relegated to Category 2.

Other examples, using different methods, are implicit in the thesis. Thus, when I was interviewing pupils to discover more about what they had said in pencil-and-paper tests, I had to be careful not to slip into the teacher role. Interviews can be used as teaching tools, but if a researcher is using them to find out what a pupil knows, he will find it helpful to keep in mind the requirement not to ask leading questions, or give answers, or even nod approval or frown, thus giving the pupil clues about the researcher's 'hoped-for' answers. In the interviews reported on pages 118, 121 and 124, for example, I used the discussions only to discover the pupils' ideas about acids.

There are however some methods which a teacher-researcher may use in which a teaching component is legitimate. Participant observation implies some input of influence but the amount will vary according to the research intent. If a teacher is researching in another teacher's classroom he may assume the role of a pupil, joining in a group experiment in an attempt to identify the crucial learning events from the pupils' point of view. This 'pretending not to be an adult/researcher/inspector etc.,' approach is strongly advocated by such workers as Pines et al(1978) in an attempt to reduce the impact of an outsider on the behaviour of the pupils.

At the other end of the scale a teacher-researcher may assume the role of teacher quite deliberately, recognising that, when the research objectives permit, to teach and study the impact of that teaching is effectively the same as studying the impact of someones else's teaching.

Thus, when I interviewed Alison, pages 68-9, about her ideas of the amount of water and ice, I said:'I know, let's do an experiment to see if your idea's right.' In this sort of situation the researcher acts as teacher and deliberately pushes forward the learning process in order to study it.

The teacher-researcher may find it useful therefore to be aware of the theory he relies on, the constraints it could place on his results and their interpretation, and the need to use methods for the precise purpose intended. (In Section 10.13 below I will discuss more fully the importance of choosing appropriate methods).

The way in which research is conducted is greatly influential in determining the results which are elicited. In the same way that the tone of voice influences a person's reaction to a question (the same words can be either a request or a command) so in research the questions asked, the way they are put, the time allowed for answering, whether prompting is involved, whether written or verbal answers are required, etc., all affect the quality and content of data. Brook, Briggs & Bell(1983) for example, asked the same questions, requiring pupils to give both written and verbal answers, so that a cross-check could be made on the information given.

In my own research, at page 83, I deliberately used the phrase 'the game we were playing' to describe the research method. In a real sense research is a contrived situation which has its artificial, unique structure, with rules which pupils must follow if they are to provide the data which the researcher hopes for. It is an awareness of the ways which the setting up and effecting of the research programme have on the results which a teacher-researcher could find useful to develop.

It may therefore be necessary for a teacher who undertakes research to build into the early part of his reading a time-space in which to ponder and assimilate the above issues, and others which I will now go on to discuss, that is, the questions to address, the methods to choose and the reliability and validity of data. Such early appraisals could prove helpful in seeing more clearly how the research will develop, and help in planning such essential ingredients as repeats, checks, extensions, etc., of data, so as to arrive eventually at definite recommendations.

10.12 The choice of questions to investigate

The teacher-researcher may profit from focussing his attention on a single question. The teacher who tackles research is likely to be aware of the many problems confronting teacher and learner in science; he is also likely to have many worthy ideas about probable solutions to some of these problems.

In this thesis three areas of investigation developed from a single broad question. These three areas could easily have been exploded to ten times that number of issues but the task of arriving at worthwhile solutions would then have been made impossible. Profitably the investigation could have rested on a single issue (for example, the pupils' ideas of the purpose of their science lessons would justify a complete study in itself).

In this particular thesis however I have been considering the over-riding issue of the teacher-as-researcher, and the study of the three related areas both contributes to and complements that issue.

Care would need to be taken to distinguish between questions addressed and questions arising (i.e. generated by the data). The purpose of the thesis will be to offer some partial and definite solutions as well as suggesting further areas of study. By minimising the area of investigation the teacher will be able to contribute to knowledge about a particular issue. Although he will wish to generate ideas for further research he still requires sufficient data on his own study to enable definite conclusions to be reached.

As an example, following the 'picture' questions (see page 104) which in themselves might have provided doubtful answers, I interviewed three pupils (page 117 et seq.) the results extending the data and enabling a much sounder postulate to be made. Another example is at page 115. Here I propounded three hypotheses: given time, data could have been derived to test these ideas, and this would normally be the aim of the teacher-researcher.

It would perhaps be most efficient therefore if the research did not pose or generate too many unanswered questions. The teacher-researcher begins by deciding which question he is to address. Thereafter, if subsequent questions arise, he can ask himself: which am I reasonably able to answer, and which should be left for investigation by other workers?

10.13 The choice of methods

As discussed in Chapter 3, the use of several different techniques to derive different kinds of data has accompanied the movement towards qualitative methods of inquiry. Thus, the Ford Teaching Project(1975) used a multiplicity of techniques in order to build up a composite picture of classroom interaction, and also developed the technique of triangulation to cross-check events and their meanings.

By using more than one method advantages accrue, but precautions must be broached. Advantages include the ability to describe whole events, as a detective investigates an incident by questioning several independent witnesses. It also enables cross-checking so as to increase the validity of inferences. The charge of subjectivity is therefore less likely to take hold.

For the teacher-researcher who uses qualitative methods these issues become heightened and he will need to take stringent precautions if he is to defend the validity and generalisability of his results, points which will be discussed more fully later. The chief factor which militates against him is the small size of his research sample. He is likely to be looking, even though at some depth over a longish period of time, at a very small number of pupils. He may feel that the use of several methods will help to compensate for or minimise weaknesses due to the limited area of study. However, a multi-faceted approach to data generation does itself have dangers.

The seven methods I used in the pilot study (see page 41, and cf. Ford Teaching Project's six methods, this thesis page 28) were, in the later more precise attack on the problems, refined to short test questions and interviews. Using many methods does not reduce subjectivity per se. Instead it can produce so many variables that the data becomes hopelessly complex. The teacher could profitably select his methods, few or many, on the basis of specific usefulness. What job does he intend each to do? What type of information does he hope to derive and which method(s) will most economically and precisely elicit it? What value does any single method have; what complementary values do two or more methods contribute?

For example, one might wonder: If I ask pupils to give me their 'picture' of acid (see page 104) will that really tell me very much about their concept of acid? If there is some doubt, one can then ask: If I interview them about their answers, will that provide me with a fuller understanding of their ideas? The two methods in this case do not simply provide more information about the pupils' thoughts, they are a check on each other. If there is evidence that such complementary techniques are yielding reliable and useful data, the results of their use with several pupils can be scrutinised to gauge the extent of their usefulness. A pilot study can be used as a means of testing and rejecting some methods.

In the table below (Table 10.1) I have listed the seven methods which I used in the pilot study. The three methods used in the closer investigation are either subsumed within this (eg. unstructured interviews) or are discussed after the table. The lists of strengths and weaknesses of the methods include observations about their general usefulness as well as particular observations about their usefulness in my own study.

STRENGTHS	WEAKNESSES
1. Observation of pupils in the classroom, without a specific observation schedule but with general questions in mind	
Useful at pilot study phase to acclimatize researcher to the learning milieu Useful as an early means of isolating areas of study An unobtrusive technique of special value in detecting behaviour, attitudes, movement, relationships, etc	As selective perception is critical to the data derived this technique becomes useful only when specific and narrow questions have been crystallized prior to observation Much data could be recorded which is eventually not used
2. Initial structured interview of pupils	
Can provide first view insight into pupils' ideas Pupils' answers at this early stage are more likely to be unconditioned by the research process	All structured interviews require strict framing so as to rule out ambiguity Little or no opportunity either for the pupil to say what he feels in a free-flowing or expansive way, or for the researcher to follow up interesting information which arises As a source of usable data this method may be of little value on its own (it leads to more precise inquiries)
3. Structured tasks given to pupils - pencil-and-paper and practical work	
Increases the contact with the pupil and hence improves relationships Provides further specific data about conceptual grasp, if well designed Can provide an extra dimension to the results to act as a validating device	Can be contrived. Perhaps best if arising naturally from pupils' learning or suggested by pupils .... but this is not easy, and may lead away from a central issue which the researcher was concentrating on Could have too much of the ideas of the researcher in them, thus blurring the research focus

cont/

Table 10.1 A comparison of the strengths and weaknesses of research methods used in this thesis

strengths	weaknesses
4. Unstructured interviews with pupils and/or teachers	
Pupils' impromptu answers may best describe what they are thinking - they do not have time to frame more sophisticated responses which they may suppose to be more acceptable but which are often less instructive to the researcher May provide unusual and unprompted 'innocent' information, ie. less likelihood of the pupils' answers being determined by the researcher Allows the researcher to negotiate around 'don't know' answers in an effort to encourage unresponsive pupils Allows the pupils freedom to suggest the continued line of the interview - what is important for them	Pupils may be caught out, giving truncated answers which yield little information about their actual ideas or understanding. 'Satisfactory' answers (ie. both to pupil and researcher) may require a good deal of deliberation, a structured interview or other questioning technique which gives the pupil better opportunity to develop his thoughts. The 'loose' nature of the interview may provide little useful information since the pupils' answers will vary widely in content, style, length, etc. Researcher may slip into his natural didactic role
5. Scrutiny of resource material used in the classroom	
Provided a checklist or schedule is used, resource material can give insights into the aims of the curriculum, discrepancies between stated aims and actual course content, etc. Provides access to quantifiable data, eg. what proportion of worksheets overtly express the purpose of the work? what proportion invite pupils to write their own conclusions, etc.	There is no direct pupil interaction, thus of limited value in inferring its impact The information the resource contains is not the same as how the pupil uses it - the dynamic of learning is missing

Table 10.1(cont)

cont/

strengths	weaknesses
6. Written questionnaire to parents	
Can provide complementary and/ or confirmatory data about pupils and their learning Gives access to important influences on learning, eg. out-of-school social and environmental climate Parents may supply more detailed or sophisticated information than, eg. small or inarticulate pupils; this widens the scope of inquiries by including pupils who might otherwise be left out	The responses by parents may be subjectively biased Little opportunity to check on the content and objectivity of the parents' answers Needs careful framing as parents may not be familiar with current educational terminology or be able to interpret nuances of meaning There may be a poor return rate of completed questionnaires
7. Final structured interviews with pupils	
Provides a useful comparison with data from initial and subsequent interviews Gives an opportunity to 'tie up loose ends', checking data	Its formality and the attempt to make a neat termination of the observational part of the study may render its results prosaic and of limited value

Table 10.1 (cont)

My views of the methods now In retrospect the most useful methods were the structured tasks, the unstructured interviews, and the combined initial and final structured interviews.

The structured tasks, which were a combination of pencil-and-paper and practical experiments, seem to provide a very useful means of enquiry. If properly designed they can yield much information about pupils' ideas and understanding of concepts, about the way they tackle problems, etc. They are extremely valuable in validating data derived from other sources, for example from oral questioning or paper tests.

Their chief weakness seems to lie in the structuring process, as hinted in Table 10.1, since tasks not thought out carefully could include leading questions, the incorporation of the researcher's ideas, and so on. Much useful work waits to be done therefore in devising structured tasks to investigate specific problems in pupils' learning, reporting back on how they worked and suggesting how they can be developed.

The unstructured interviews proved useful. However, I was interviewing partly as a check on pupils' earlier responses, and partly to develop further insight into their grasp of specific concepts; the interviews were essentially not without structure therefore since I knew beforehand the content matter I was probing and the sorts of questions I would be asking. Semi-structured interviews of this type could usefully be developed further since they could contribute the qualities of the structured interview (providing relatively uniform, reliable data) and the qualities of the unstructured interview (allowing access to new ideas and new areas for study). Teachers wanting to use such a technique may probably benefit from earlier experience in conducting the extremes of interview.

The chief contribution of the final structured interview to the pilot study was to provide a check on pupils' earlier responses and act as a validating method. Such before-and-after interviews seem to be valuable and necessary in this type of study.

Other methods which I used were either of limited value or had to be used cautiously because the results they generated could prove to be imprecise unless weighed against those from other methods. Classroom observation is a powerful device under appropriate conditions, but the observer's perspective is vital. What is he looking at, or for? Is he looking at the teacher and/or pupils? at teacher-pupil or pupil-pupil interaction? at social flux? at the impact of resources? at individual or group autonomy in learning? at humour as a weapon in teaching? for verbal skills or articulation of ideas? etc. Even if the observer has no precise schedule he will need to formulate a precise perspective beforehand; without a sharp focus the data recorded will be unwieldy and destructive of effort.

The questioning of pupils is both fruitful and hazardous. Young children need to be asked simple, straightforward questions; but such questions may not be easy to answer. Two contrasting questions which I asked were:

> 'If you can remember, try to say where you first heard the word _______.'
>
> 'When you hear the word ______ what picture comes to your mind?'

The answer to the first is simple enough, a matter of fact. The second however requires either the articulation/description of a concept or the need to describe something which they know little or nothing about. The latter can be a particularly galling exercise for pupils of limited experience. Even if they do have some idea about the concept in question it is easy to over-estimate the ability of pupils to conceptualise on the spot. Such questioning therefore needs checking devices, such as interviews, but in any case needs developing because it appears to be a useful technique. For example, the questions could be asked ad hoc; then the pupils could be given warning that the same questions were to be asked. The answers given after this gestation time would be checked against the earlier responses.

This thesis has provided examples and further data in the area of prior knowledge. However the need still remains to develop techniques to quantify data. Questions and interviewing on an extended scale would provide fuller data, but methods are required for condensing information without destroying its content. Concept mapping (cf. Pines, Novak et al - 1978) and Finley's(1984)* propositional analyses go some way towards this.

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* Finley, F N(1984) Using propositions from clinical interviews as variables to compare student knowledge, Journal of Research in Science Teaching, 21(8), 809-818.

10.14 Means of improving reliability and validity

The methods used by a teacher-researcher will be valid if they produce the information they are being employed to produce. I needed to keep constantly in mind: Am I, by using this method, finding out more about the pupils' prior experience and its impact upon learning?

For this reason such methods as observation and initial structured interview were not employed after the pilot study; they would have revealed little about the dynamic content of the pupils' ideas.

Another test of the validity of methods is that they should produce results compatible with and pertinent to the context of the research. Although my study was confined to particular classes in a particular local authority's schools, the results should have general applicability in and bear comparison with similar situations in other areas. Some very localised studies may not be able to make generalisations on the massive scale, but their validity would not be reduced.

The reliability of data can be maintained if, for example, questions do not produce ambiguity of response; the results must be real (ie. not fanciful, playful, etc., on the part of pupils); the results are reproducible; different methods produce compatible results. Results may not be exactly reproducible (ie. not entirely reliable) but this does not render the method invalid. For example, such a device as concept mapping where the original construction of the map is significantly personalised; hence any teaching or testing based on the map will also be somewhat arbitrary, yet the differences do not make the device unworkable.

Techniques for improving validity and reliability include triangulation, using a second observer, using a second analyser of data, and making a second analysis of data at a later date by the same researcher.

Triangulation (see Section 10.13 above) builds composite pictures of events and checks the reliability of data from several sources. Second views of events are important. In an earlier work (see Ennis - 1976) a second observer recorded significant classroom events as a check on my own notes. Second analysers of such data processes as categorisation of responses (see page 146) are useful and my own study, in retrospect, would have benefitted from such a validation in this area, since who is to say whether responses have been allocated to the appropriate category? This highlights a possible source of weakness in an individually based study; members of a research team can constantly vet, and challenge, each other's work in a constructive way. It could be argued though that if there is good agreement on data processing it could as easily signify two identically prejudiced minds as validate the allocations. A sceptic of the research effort would therefore be preferable to an ally (or team member).

A second analysis of data, preferably with a good length of time between analyses, would be useful. When intensive research is sustained over a long period it is easy to become immersed in the data and an objective view becomes difficult.

A way of testing the reliability of, for example, the above categorisations would be to process the data as it is obtained and then to sequester it completely for some months, to repeat the categorisation, and to compare the two.

<u>Cautions for teacher-researchers</u> A teacher-researcher is likely to be much less objective than an outside, independent, non-teaching researcher. Research has shown (see Ford Teaching Project, 1975) that a teacher is as influenced by a researcher in the classroom as are the pupils, ie. put under stress with regard to his own success as a teacher. Work needs to be done to discover how subjective/objective teachers-as-researchers can be, but it is a reasonable hypothesis that they will tend to be more rather than less optimistic about the objectivity, validity, reliability and usefulness of their data, and more importantly that they will tend to see classroom events more often from a teacher perspective than from a pupil or 'disinterested outsider' perspective.

A teacher-researcher can practise objectivity, perhaps using some of the methods mentioned above, and enlisting the help of colleagues and/or professional researchers.

The teacher as researcher may also be less perceptive than an outside worker, simply because he has been trained and has developed expertise as a teacher, not as a researcher. The more professionally adept he is as a teacher (getting involved in learning) the less he may possess the perceptive attributes (standing back and quietly observing, for instance).

The more competent he becomes as a teacher the less he may be aware of his limitations in allied fields. It could be damaging to his research if the teacher supposed that because he 'knows' more than anyone else about his classroom he is therefore the best qualified to see and assess what is happening there.

There are ways by which a teacher can develop the necessary perceptive skills. A pilot study is useful both for assessing research possibilities and for acclimatizing the teacher to the research processes. Pines et al(1978) have stressed the need for training in using research methods. They have suggested some months of training in interview techniques before a researcher begins to interview and collect data from interview. A good deal of expertise can be taught and would be more readily acquired by the teacher from professional workers than from trial and error in the field. Teachers can then easily acquire such skills as that highlighted on page 119 where I do not take 'no' for an answer and keep probing patiently until a positive response is elicited.

When the teacher has gained confidence in the use of different methods he can use them to check his own objectiveness and perceptiveness, and hence the validity of his results.

As mentioned above (Section 10.1) the teacher-researcher will benefit from a full awareness of the conditions under which direct teaching is legitimate, and where it is not.

Despite the above cautions the teacher can make a good contribution to research, and in Table 10.2 (below) I have listed strengths which they can offer, compared with those of a non-teacher. As already noted, educational research has shifted towards methods apprehendable by teachers. Research projects have enlisted the help of teachers because one of the outcomes of research - to make science teaching more effective- demands the advice, the insight and the participation of practising teachers.

What teachers think, and could discover, is therefore very important.

There would seem to be a need to combine the strengths of trained teacher-researchers with those of professional research teams in a substantial programme of qualitative science education research.

10.15 The practical opportunities for a teacher

Teachers are well placed to contribute to research in particular ways. They have scope, for example, for extended studies of pupils' learning. Research programmes have included much before-and-after testing (for example, to study contrasting teaching methods) but the teacher could continue his testing year upon year. In this thesis I have included tests over about three years, but even longer programmes are possible, and would yield invaluable results. For instance, studying the primary science - secondary science continuum, or the secondary science years 1-5, or even 1-7, have probably never been attempted in a continuously monitored way.

Teachers also have the opportunity to conduct pilot studies, extended case studies and continuous monitoring of pupils' progress, trying out testing techniques as part of the normal curriculum, extending and modifying the tests as necessary. Their studies could combine the monitoring of learning and the research of learning, the continuous testing acting both to check data and validate results. As mentioned earlier they have the opportunity to process data and then put it aside sine die for later validation processing.

Teachers also gain by having access to supplementary data and enquiries. Because they are always in the classroom they do not have to set up research programmes by seeking permission as a professional team would, arranging visits, taking data away, re-arranging visits if the data is incomplete or inconclusive, etc. The teacher can set up his tests, check his data, arrange further testing, conduct on-the-spot interviews, study textbooks, worksheets, exercise books, homeworks, and so on, in a developing and uninterrupted series of studies.

Another opportunity a teacher has available is that of being able to pick up extraneous, chance and unexpected data. Research often develops as new ideas arise spontaneously in the classroom, sometimes as the result of what pupils say or do. Even if the teacher is not engaged in structured testing he can keep a notebook of interesting events and so be able to tap any potentially fruitful ideas which arise.

A teacher could do the following better than a non-teacher	A non-teacher could do the following better than a teacher
1. Conduct extended studies	1. Wider view of theory and methodology
2. Try out testing techniques as part of the normal curriculum	2. Take a more objective view
3. Repeat tests *ad lib* to ensure the reliability of data	3. Have better perception of events
4. Conduct *ad hoc* interviews to extend or check data	4. More easily identify pupil perspective
5. Conduct deliberately-delayed data re-processing as a validating check	5. Have no didactic bias
6. Have access to supplementary data and enquiries	6. Not susceptible to pragmatic outcomes of the research
7. Have access to extraeous, chance and unexpected data	7. Have access to quantitative methods, as part of a team
	8. Test a much larger sample

Table 10.2

10.2 Findings and implications - prior knowledge

10.21 Findings Evidence from the investigation suggests that pupils try both to anticipate and explain subsequent observations by constructing tentative predictions from prior experience. Results indicate that pupils organise their view of experiences in personal preferred ways, and that this imposes severe constraints on their ability to cope with new information.

The order in which they are introduced to ideas becomes a critical feature of the learning process for children.

Evidence was found that indicates that pupils use alternative interpretations in trying to grasp new ideas, but the rigid postulation of alternative frameworks is cautioned since evidence indicates that their conceptions contain insights into the accepted scientific meaning for the concept being studied. The term approximate concept is offered as a means of reducing difficulties which arise from the alternative frameworks view of learning.

The pupils' written answers to questions, reinforced in interviews, show that they quickly revert to folklore views of concepts unless there is deliberate, continuous reinforcement of the scientific view, adding weight to the theory of Ausubel about the powerful influence of prior knowledge. Examples of the pupils' tendency to pull out from their past and link together their personal graphic experiences of phenomena tend to support generative learning theory.

A study of pupils' ideas about the purpose of their science lessons suggested, in line with Tasker, that their perception focusses largely on the completion of tasks rather than on the teachers' scientific purpose(s). The study showed that these inferior aims rise from their earlier experience of science. Contrary to findings from other workers however, this study produced evidence that pupils do invent their own purposeful aims for lessons and that these reflect their attempts at making their learning more meaningful.

The investigation showed that pupils are influenced by both remembered and immediate contexts in their understanding of new ideas. The remembered context has a primary influence and is used by pupils to explain situations where the immediate context in which a new word or concept resides is unintelligible. For the same reason pupils prefer to use older, firmly established knowledge in coping with new ideas, rather than to rely on recent shakier learning. Results suggest strongly that younger pupils derive little meaning from written context, and the methods of application of comprehension exercises are questioned.

10.22 <u>Implications for teachers</u> This thesis has shown some ways in which prior knowledge powerfully influences learning. The results suggest that when new work is being introduced, teachers may benefit from:

a) trying to discover what pupils already know about the subject/concept being considered,

b) trying to predict how that knowledge will help or hinder subsequent learning,

c) allowing pupils to generate and test their own hypotheses,

d) giving the pupils' own ideas about concepts or phenomena high esteem, and encouraging the pupils to share and develop them,

e) giving thought when constructing teaching sequences from syllabuses to the order, juxtaposition and timing of the introduction of new concepts,

f) because new concepts are often tenuously grasped and there is considerable delay before pupils can confidently incorporate them into their existing knowledge, planning for regular and systematic re-introductions at appropriate points in the future,

g) being careful to explain to pupils the purpose of their work so that they can learn meaningfully,

h) trying to discover the pupils' thoughts about ideas and encouraging them to become more aware of how they are learning; the links they are making with earlier knowledge. This is probably best achieved through deliberate and serious discussion of pupils' ideas.

The current practice of using both mass and weight in the early stages of secondary education seems to cause difficulties because, apart from the inherent problems of the concepts themselves, their use seems to require pupils to use the terms (almost) synonymously and at the same time to distinguish between them.

I suggest that if the concepts volume and density were explored by employing heavy and light criteria, which pupils understand enough to use confidently, then such properties as space, amount, capacity, volume, density, heaviness and weight would lead easily into a study of forces, gravity and mass.

Results from this study argue for a re-building, or at least a critical re-appraisal, of both the order and content of learning experiences related to conceptual grasp. Yet I suspect that the view of science learning as being the study of concepts has come so recently and so fast that there is no structure in existence to re-build. There has been a strong movement towards rationalising knowledge by the integration of subjects. Does science teaching need concept integration, so as to make the introduction of new ideas more logical and coherent?

There seems to be a need to continue to look at the way pupils are introduced to certain ideas which, though thought to be both basic and simple by teachers, have been shown by this study to cause considerable difficulty.

10.23 <u>Implications for further research</u> Research could usefully be carried out in the following area: to discover more about pupils' ideas of the purpose of science learning.

Specific areas which this study has touched on and which could be extended are:

a) Investigating the tendency for pupils' prior experience to cause expectations of what science lessons are all about, and how these expectations determine their approach to science lessons.

b) Establishing whether pupils impose their own purposes on science lessons.

c) Finding the conditions under which the difference between the intended purpose of science tasks, and the pupils' perceived purpose, might diminish.

These could be investigated by undertaking identical sequences of work with pairs of parallel ability groups. The first group, acting as a control, would have the lessons introduced in traditional ways. For example:

> 'Today you are going to find out if you can make the metal lead by ....'
>
> Or:
>
> 'During this lesson we will try to compare the strengths of various acids by ....'

The teacher would tell the pupils the sorts of things he wanted them to do, augmented by a written instruction sheet if need be, and would then be available to answer any questions about the route they had to follow.

When they had finished the experiment they would be given a title for the work and asked to write down the method and conclusion. The teacher would be asked to write down a resume of what he himself intended the purpose of the work to be.

The pupils' written work would then be scrutinised for agreements or discrepancies between the title of the work and the conclusion, and ways in which pupils concentrated in their description of the work on organisational aspects of the experiment.

The various pieces of work which the second group undertook would be carefully introduced by referring to the underlying purpose of the experiment. Stress would be laid throughout the teaching on why the pupils were performing tasks, 'investigating' rather than 'doing an experiment'. The pupils would be encouraged at all stages to inquire into the intent and meaning of their work, asking the sorts of questions a scientist would be asking.

The teacher would, from time to time, remind them of the general or specific purpose of the various parts of the study. Their description of the experiment would include inventing their own title to explain what they hoped to achieve, giving details in full of all they did and why, and a few sentences about what they had discovered. Their titles, methods and conclusions would be searched to find evidence of allegiance to the underlying purpose of the work.

Evidence arising from these two approaches could be used to generate hypotheses as to why pupils were working without purpose, inventing their own purposes, or deviating from or converging with the intended purpose of the lesson.

Studies of this type could be backed by carefully framed interview to check and augment the written evidence. They could be extended by using categorisation techniques of the type employed by Brook, Briggs & Bell(1983). Techniques are currently being developed, as mentioned earlier*, to utilise clinical interview data in providing quantitative information. These may prove useful in allowing more generalised hypotheses

* See page 205

to be made in this important area of pupils' learning.

A second area for further research could be to increase knowledge about interviewing techniques.

The structured but informal interview (semi-structured interview) if used skilfully and unobtrusively could form a natural part of science teaching. I should like to see research into this aspect of research/teaching method so that guidance can be given to teachers about the technique of interviewing pupils, about the strengths and weaknesses of interviewing, its usefulness and limitations. As with teaching itself, the art of interviewing can only be acquired by practise, and mistakes made in face-to-face conversation with pupils may never be rectified.

I have included a checklist (see Appendix B) which could act as a basis for further investigation.

A JUSTIFICATION OF METHODS USED IN THIS ENQUIRY

A large amount of data was collected by observation, questionnaire and interview. The use and interpretation of data is fatuous unless it can be trusted.

The reliability of the data in this study resides both in the complementary nature of the techniques used to derive it, and especially in the usefulness of the pupil interviews to check and augment my inferences from pupil observation and from written answers to questions.

The initial observation phase proved useful in enhancing research skill and in providing data from which to crystallise specific research questions. The later phase enabled these questions to be addressed finely with carefully chosen written tests.

General inferences were drawn from the results of the tests but it was an essential part of this study both to focus on individual responses and to make individual inferences. This concentration on the individual response was necessary where there was doubt about the precise meaning of the response or where evidence suggested that an individualistic approach was being made to conceptual understanding.

The role of the interview in this study was crucial. I started with the intention of finding out what pupils were thinking as they tried to understand new ideas. The results showed that if I had relied solely on observation or on the pupils' written responses I would sometimes have been baffled as to their meaning, or have made false inferences.

The methods used in this enquiry were found to be specially suitable for the context in which the study was conducted, for two reasons.

In order to accommodate the research within a busy teaching commitment I had to refine both the problem addressed and the techniques used; the questions asked of the pupils had to be brief, direct and simple, the interviews short and precise. This was not only a useful exercise in itself, it sharpened the focus of the study.

Secondly, by introducing the enquiry as part of the teaching method, it became unobtrusive and focussed on situations as close as possible to normal science learning. As a practising teacher, well-known to and having the uncontrived cooperation of the pupils, I could be confident that I was deriving reliable data. At no time were pupils inhibited or putting on an act, as they might out of insecurity in the presence of a 'stranger'.

For these reasons I believe that the methods used here could be employed and developed by other teachers in other classrooms.

A P P E N D I C E S

APPENDIX A EXAMPLES OF STUDY DATA

Introductory letter to parents - initial observation phase

Motala Close
Corby
Northants NN18 9DT

Telephone
Great Oakley
741657

Head Teacher
John Lord

Northamptonshire **Danesholme Junior School**

Dear Parent,

Please ask for Science Research Our Ref Your Ref Date

During this summer term I am looking at the ways in which children learn science, in three Northamptonshire schools. The children's ages range from 9 - 13.

One of the purposes of the research is to identify difficulties the children are having, so as to improve both the teaching and learning. In each class I have focussed on the work of a few children, chosen at random. ____________ was one of the children chosen.

During the study it has become clear that children use experiences outside of school to make sense of their school work. For example, they may say: "My uncle told me all about engines - he works in a garage."
or: "I saw on television where a piece of broken glass caused a forest fire."

These out-of-school experiences are very important to children and influence their attitude to school, their success or failure. I should like to find out the parents' view of how their child learns, and should be grateful if you could answer the enclosed questions. You will see that there are no questions about the home, nor are any personal or private details required. Please return the question sheet to me, in the enclosed envelope addressed to the Headmaster.

If for any reason you are not able to answer the questions please return the question sheet anyway.

With thanks for your help,

Yours faithfully,

Philip J Ennis.

Example of parental reply

University of Leicester · School of Education

21 University Road, Leicester LE1 7RF · Telephone 0533 551122

Science research - Questions

Name: ALAN HALL School DANESHOLME JUNIOR

Please cross out the parts in brackets which do not apply; and write the answer where there is a line.
It would be best if questions were answered without your child taking part (even though they may want to!).

1. Does ALAN go happily to school ((a) always (b) ~~sometimes~~ (c) ~~rarely~~)?
2. Does ALAN ((a) enjoy (b) ~~dislike~~ (c) ~~never mention~~) his/~~her~~ science work?
3. Would you say that, compared to his/~~her~~ friends ALAN is ((a) ~~not very clever~~ (b) ~~quite clever~~ (c) very clever) ?
4. If you remember ALAN telling you about something he/~~she~~ has learned at school lately, please write it here: HE LEARNT ABOUT ANIMALS AND HOW THEY COMMUNICATE WITH EACH OTHER.
5. If you remember ALAN telling you about something he/~~she~~ learned out-of-school, please write it here: B.A.F. AIRPLANES AND SPACE ARMY OR WAR.

6 When ALAN meets difficulties of any sort does he/~~she~~ ((a) try to sort them out him/~~her~~self? (b) ~~come to you for help~~? (c) ~~go to a relative or friend~~?
If he/~~she~~ always goes to a particular person, please say which: ______

7 Does ALAN use dictionaries or other books at home ((a) ~~often~~ (b) sometimes (c) ~~rarely~~)?

8. Is ALAN a member of the local library? (Yes/~~No~~).

Please return to me in the envelope addressed to the Headmaster. Many thanks. Philip J Ennis. 6/81

Professors of Education: Gerald Bernbaum, Derek Wright

University of Leicester · School of Education
21 University Road, Leicester LE1 7RF · Telephone 0533 551122

Science research - Questions

Name: ALISON MOFFAT School DANESHOLME JUNIOR.

Please cross out the parts in brackets which do not apply; and write the answer where there is a line.
It would be best if questions were answered without your child taking part (even though they may want to!).

1. Does ALISON go happily to school ((a) always (b) ~~sometimes~~ (c) ~~rarely)~~.

2. Does ALISON ((a) enjoy (b) ~~dislike~~ (c) ~~never mention~~) ~~his~~/her science work?

3. Would you say that, compared to ~~his~~/her friends ALISON is ((a) ~~not very clever~~ (b) quite clever (c) ~~very clever)~~ ?

4. If you remember ALISON telling you about something ~~he~~/she has learned at school lately, please write it here: EARS - SUBMARINES - HOW LIGHT TRAVELS - POTTERY

5. If you remember ALISON telling you about something ~~he~~/she learned out-of-school, please write it here: FIRST AID. SCUBA DIVING. How to use a computer Key board.

6 When ALISON meets difficulties of any sort does ~~he~~/she ((a) try to sort them out ~~him~~/herself? ~~(b)~~ then come to you for help? (c) ~~go to a relative or friend?~~

If ~~he~~/she always goes to a particular person, please say which: FATHER OR MOTHER - depending on what type of difficulty.

7 Does ALISON use dictionaries or other books at home ((a) often ~~(b) sometimes~~ ~~(c) rarely)~~?

8. Is ALISON a member of the local library? (Yes/~~No~~).

Please return to me in the envelope addressed to the Headmaster. Many thanks. Philip J Ennis. 6/81

Professors of Education: Gerald Bernbaum, Derek Wright

APPENDIX A_1

Structured interview (used as a preliminary interview)

1. School.

2. Name.

3. D.o.b.

4. Do you enjoy school (a)nearly always,
   (b) sometimes,
   (c) rarely or never?

5. Do you enjoy science(a) nearly always,
   (b) sometimes,
   (c) rarely or never?

6. Which three subjects do you like at school, in order of liking?

7. Would you say you are (a) very clever,
   (b) quite clever,
   (c) not very clever?

8. When you learn new things, where do you mostly hear about them?

9. Suppose you hear a new word, or idea; what do you do to try to understand it?

10. Can you tell me some new things (perhaps in science) that you have learned lately?

    Where did you hear about them?

    What does ...... mean?

11. Have you learned a new thing lately by coming across it entirely by yourself?

    How did you understand it?

    Did you ask anybody's help?

12. When you can't understand something, do you try to learn it by yourself?

    If not, who do you ask? Which person?

13. When you have learned something, do you tell anyone? Who?

14. How do you feel if you understand something?
    How do you feel if you can't understand something?

15. Can you think of something which you understand now, but which you used to find impossible?

    What do you understand by it now? What did you used to think?

APPENDIX A_2

Stuart's answers to the preliminary interview questions.

1.

2. Stuart F....

3. 22.12.69 (11 years).

4. Sometimes.

5. Nearly always.

6. Maths, science, art.

7. Not very clever.

8. At home; at my gran's; at my auntie's.

9. Ask them to say it again. Ask them to say it slower. Use a dictionary.

10. Learning how to ride a horse properly.
    In science, the ballast of ships.

    (What is ballast?) The weight; the level weight.

11. Technical drawing. I'm interested in cars and lorries.
    My grandad helps me.

12. I try it by myself first. Then I go to the teachers, my mum or dad.

13. No, I keep it to myself.

14. Pleased.
    Unhappy.

15. Technical drawing. I didn't know how the engine worked or how the wheels were fixed on or about the brake blocks or oil pipes.

    How does the engine work? By starting the motor. You put the key in and turn it. A little wire goes through and starts the engine.

    How do the brakes work? There's a little steel rim, and inside there's a metal brake block with rubber on the end. You put the wheel on then put the nuts on and then get an electric drill and tighten it up.

APPENDIX A_3

The class teacher's SCHOOL REPORT comment on Stuart

Presentation slightly improved - pen now used. He evades language creative work, or does not finish.

He sits and broods rather than asking, but asks in number work now.

He has completed a lot of number work but sometimes makes careless mistakes.

Little imagination. His reading is improving due to library books.

(The space for Parental Comment was blank)

APPENDIX A_4

Stuart Reelore REPORT BY HIS CLASS TEACHER - JULY 1981

It takes Stuart a long time to produce a fairly good piece of work and sometimes he does not complete it then. He is not very imaginative. In topic work he does not think of interesting way of answering the questions set. He will always copy out the answer word for word from the sheet.

If a piece of work has already been covered, when it comes to recalling that work it takes Stuart a while to remember it. He has to be reminded constantly.

He would rather work on a one to one basis when presented with something he has not come across before and will not use the books, provided to find out any information he needs. I think this is due to the fact that he has a low reading age and is worried about tackling new words.

APPENDIX A_5

Examples of observational notes about Stuart (D1103). These notes were written down long-hand during class observation. They were written up fully as soon as possible after the lesson, but were not added to or commented on at that stage.

A1 May 5 1981 In this lesson Stuart is working with Robert(R), Ellis(E) and Mark(M) doing the worksheet: Using Your Eyes.

The other boys are working on their own sheets; some of these are different from Stuart's but on the same topic. The way they work is to do their own sheet whilst listening to and commenting on the work of others in the group.

1 Stuart sits down and says: Where's the question on this?

He looks, repeats the first question on the sheet out loud.

He is distracted as E asks for a ruler.

4 Stuart: Oh, I've lost it (the place) now.

Reads again. It don't jump at all. (He has followed the instructions and is watching a pencil held close to his eyes).

E: It does. Stick your pencil up, like this.

Stuart does so. It don't jump. It don't. (He is in fact closing one eye to line up the pencil. But it should jump) He tries again, and succeeds.

He answers the question and writes up his method.

He goes and gets a pinhole camera and tests it as instructed by the worksheet, by holding it up near the window.

Stuart: It's upside down. There's no colour. It looks like there's an invasion of flies (the mottled effect of the light through the greaseproof paper). It's the sunlight.

Next he looks at some shadow profiles which have been displayed on the wall. He tells me how they made them, using a projector.

19 He goes over to look at an exploded model of the head which he has noticed. I am going to look at the brain.

He comes back. Horrible that.

He asks me how long I have been at my school.

M mentions vibration and sound waves.

Stuart: I'll tell you.

25 M: No, no. I don't want the answers.

Stuart: (To me) How do you spell inch?

27 I've done that bit (a), now (b).

M: Do vibrations cause sound?

Res: Do sounds cause vibrations?

Stuart: Vibrations cause sounds. It says so in my (exercise) book.

R: What sorts of surfaces reflect light? (The question uses the word 'type').

All four boys give lots of examples:

Polished table
Sun glasses
Glossy paper
Shiny ruler
Kettle

Stuart: That reflects light (he tilts back his plastic calculator).

M takes the calculator, tilts it back and says: That reflects.

R: Nearly everything does.

(More examples given): Rubber
Brass
Cartridge pens

47 Stuart: Did you watch Diamonds last night? (A TV programme).

R: The robbers escaped though. Colditz.

49 Stuart: My dad's camp's like Colditz. He reckons when you get in you can't get out.

(More examples are given)

Eyes reflect
Copper, brass
Silver badge
Lamps reflect light
Blackboard does
No
You go up to it
Varnish. Glassy paper
Varnish. How do you spell varnish?
What else can I put? Two more
Silver. Guillotine
Guillotine. That's a blade
What have you written? (Reels off the list)
What do they do?
Reflect light
Oh, yes. I'd forgotten

68 Stuart is. meanwhile, drawing a diagram of the pencil and interposing such examples as 'bronze.'

Eyes don't reflect.

Yes they do. Look at my eyes.

Oh, yes.

73 Stuart reads: With one eye look through a straw. Bend it.

What do you see? What does this prove?

He writes: Light doesn't bend round

He searches for a pen because Experiment B_1 says 'pencil' but
77 Experiment B_2 says 'pen'.

E reads: Draw some shadows of your own. Ask a friend to identify them.

M: Oh, great. (He thinks, then says): I've got a good one.

Stuart: Use a squash racquet.

Stuart asks me: How do you spell 'easy'? then says immediately: Oh, I'll see if it's in the passage.

He searches and finds the word 'easier' and then asks me again.

I explain happy-and-happier; he spells 'easy'

He makes a mistake on the word 'do' and goes for a rubber

He gives ideas and examples to the others for shadows; continues writing.

89 E, slightly jealous, says: He should be doing his own work.

Stuart finishes his sentence and goes to hand his book in.

A2 May 12 1981

Stuart is looking for information on the sense organs - what they look like. He describes various diagrams as looking like:

a pear
a doughnut

He has great difficulty extracting the written answers from the text of the worksheet

Res: Can you remember some things which reflect light?

Stuart: Diamonds, brass, gold, silver, steel, a shiny table, polished floor, copper, brand new shoes, a piece of glossed paper, eyes, water, a white pan, a milk bottle, iron.

Res: That's an excellent list. Can you say what all of these are: brass, silver, gold, steel, iron?

Stuart: Metals

Res: Can you think of a metal that doesn't shine?

Stuart: Zinc. It doesn't shine. And it's soft when it's heated up.

Res: How do you know that?

Stuart: My grandad told me. He works in a training centre.

Res: Can you remember how you came to be talking about it?

Stuart: It started when - about me reading a book about cars. One page had a car made of all zinc. It said that.

Res: Did it say why it was made of zinc?

Stuart: It's light, and it can pick up speed more than any other car. When it hits things it would spring in and out. But it would crack sometimes.

Res: Let's go back to the work on reflecting. Can you give me another word for reflect?

Stuart: Bounces.

Res: What does that suggest about light?

Stuart: Don't know.

Res: Go back to the word bounce. What does that mean about light?

Stuart: It can't go round bends; goes in a straight line. Just bounces off it.

Res: Yes. Light must be like little bits; like marbles.

Stuart: Molecules.

Res: Can you tell me about what you've just been doing - anything about the senses. The ear, what parts has it got? ......

What are the three bones which carry the sound to the middle ear?

Stuart: The hammer, and stirrup.

Res: What is a stirrup like?

Stuart: A delicate piece of ..... something delicate.

Res: But what is a stirrup? The real thing?

Stuart: Something what you hit horses with to make them go faster, and what you put your foot in.

Res: What does it look like?

Stuart: Like a vase, fat at the bottom with a pole up the middle.

Res: This is called the anvil. Have you ever seen an anvil? Do you know what one is?

Stuart: No.

A3 June 3 1981 Stuart has been working on sunlight. He has written that sunshine is very powerful.

Res: How do you know that sunshine is very powerful?

Stuart: Somebody left a piece of glass near my dad's tyre and it burned a hole right through.

(In answer to the question: What happens to the light rays that come out of the other side when sunlight passes through a curved glass bottle full of water?

Stuart puts: The light rays that come out the other side would set fire to just about anything that would burn.

The teacher expects answers about the focussing of the rays.)

A little later on, Stuart is doing a worksheet on Cameras. He reads out the questions aloud. He is working alongside Matthew and Greg.

Stuart asks me: What happens to the camera shutter when the button is pressed?

Res: What's another word for shutter? A shutter's like ...? What stops light, or lets it in?

Matthew: A curtain.

Stuart: A door. A fridge. A microscope when it's closed.

What controls the amount of light?

The button.

Greg: The speed of the shutter.

Stuart: Say that again Greg. (Copies word for word).

Stuart cannot spell controls. He looks at the sheet and writes:

'contorls.'

A4 June 10 1981 Stuart comes to me and says he's stuck on Question 6

'What recent changes have happened to peppered moths, and why?

Res: How would you normally find the answer?

Stuart: Look for 'recently' on the sheet.

I point this word out to him and he goes off and paraphrases the sentence.

Stuart asks me how to spell 'attempts.' He says: I can't read the teacher's writing.

Another boy asks him how to spell the word. He tells him.

Another boy is using a dictionary to find the word mimic.

Stuart says: It means to copy something.

Do you know what that word (bent) means? It has two meanings.

A boy asks: How do you spell ordinary?

Stuart doesn't know, and asks me.

Stuart, to boy: Rub it all out and start again.

Now to draw a picture.

Write the title: Camouflage. (Copies word from the sheet)

He is looking through the book for illustrations.

Stuart: I'll draw a snake.

I asked Stuart to write a sentence to explain each of the following words, taken from a worksheet he was using:

Vulnerable - means easy to get at.
Evolve - means to develop.
Industrial Revolution - means when the factories came in.
Prey - means hunter's dinner.
Pollution - means bad air.

I asked him: Where had you heard about the Industrial Revolution before? At school?

Stuart: No, at home.

Res: How?

Stuart: I asked how the car started (came into being).

(Later I asked the teacher about this. She said that the Industrial Revolution had been mentioned several times, and that some children had looked up industrial and revolution separately in the dictionary)

A5 June 24 1981 Stuart comes up to me and says:

I've got a magazine at school - a Hot Rod magazine.

He starts work on the Camouflage sheet - Pollution.

Res: Can you think of ways of stopping pollution?

Stuart: Cutting down factories.

Cut down in cars.

Better exhaust fumes.

Res: What's in a car's petrol which could be a pollutant?

Stuart: Hydrogen? Dunno.

In Africa they've stopped pollution. They've built a new engine.

Res: A car?

Stuart: A Ferrari.

Res: What is air in the engine for?

Stuart: For .... help it run, and to feed all the other parts of the engine. Dispose of bad air.

Res: What's the fuel?

Stuart: Petrol.

Res: What does it do?

Stuart: Helps the engine work.

Res: How?

Stuart: You've got a petrol tank. Petrol goes up to parts where it's needed.

Res: What happens to the petrol?

Stuart: It's pured, cleaned. It's being used up by all the parts. Being drunk up.

Res: Then?

Stuart: (Silence)

Res: (Pointing to diagram) What's that part?

Stuart: That's the spark plug.

Res: What does it do? What's a spark?

Stuart: A little piece of light.

Res: What does it do?

Stuart: It gives a shock to the starter motor - to start it.

A6 30 June 1981 Stuart comes to ask me: What is that' (word)?
I say: environment.
He says: surroundings.

He asks me about 'situated'. He looks in 'The Oxford School Dictionary' which says: 'situated - a specified situation'. I direct him to 'A Simplified Dictionary - Schofield & Sims' where it says: 'situate - to find a place for'.

He asks: Question 2 How do larger animals detect their surroundings, ie compared to small, eg amoeba? I don't know. I can't work it out.

There is a long discussion with Richard but Stuart is still diffident and will not commit himself in writing.

Stuart: What does that say: senses (positioned) on head?

Richard finds the answer for him, reading from the sheet. He says: You'll get into trouble if you copy it - you've got to put it in your own words.

Stuart flicks back in his book to where the teacher has written: More care over details, and says it aloud.

Richard fetches his old book and shows Stuart a reprimand for copying.

Stuart spends a long time finding and fitting a cartridge in his pen. Cats and mice sense organs for darkness - Stuart says: eyes - jumping to his own conclusion without reading the passage.

I tell him to read the third paragraph. He dashes away and asks (the teacher). I ask him: why? He says: It's a waste of time looking. Didn't draw any pictures there - I couldn't be bothered.

Stuart reads: Why is the sense of smell important to many animals?

(Social chat about bungalows v houses) Richard puts forward various suggestions, none based on the passage.

APPENDIX B

PUPIL INTERVIEW NOTES

My research has shown the usefulness of interviews in this type of enquiry, and also indicated that they can be a most incisive teaching component. The following notes and recommendations, based on this and earlier research, should prove useful as a check-list for researchers and teachers who are contemplating the use of interviews, and can form the basis for further work in developing the interview as a research and teaching device.

It is important to stress that these notes are based on interviews with primary and secondary pupils aged 9 - 16 years; interview techniques may vary for younger children or for 16+ students.

1. The purpose of the interview. This must be clear in the interviewer's mind, however broad the aim may be. Write the aim(s) down. For example:

   'To find out what the pupils already know about .... so that I can build the work on this base.' Or:

   'To probe the pupils' apparent misconceptions revealed during observation of a class discussion.'

2. The self-confidence of the pupil is a more important factor in guaranteeing a successful interview than age or ability. This confidence must be buttressed or generated by the interviewer

3. Ask the pupil if he or she will be prepared to answer a few questions. State specific and limited aims for the interview and if possible indicate the length of the interview, eg five or ten minutes.

4. Explain carefully the purpose of the interview and what the answers will be used for. Stress, where appropriate, the benefits to the interviewees/the class/the school/education in general, which will derive from the information they give.
5. Arrange a place and time for the interview. Make this within the next 48 hours, preferably out of class time. The place for the interview is important; it must be neither so public that it creates embarrassment, nor so private that it engenders feelings of 'captivity'. If a small room has to be used leave the door wide open, again to relieve any tension in what is an unusual and contrived situation for most school children.
6. Allow the pupil to attend with a friend if desired, or to have the friend close by. (Contrast Watts - 1981) Some pupils relish the attention afforded by interview, but others may feel uncomfortable.
7. In the interview sit opposite the pupil with a desk in between. This gives reassurance that the situation retains the familiar teacher-pupil relationship. (Contrast Watts - 1981)
8. Obtain the pupil's permission for
   a) Note taking, or
   b) Tape recording, and
   c) Further or public use of recorded material.
9. Set the scene by linking the interview with an actual science lesson. Refer to specific class activity or to the pupil's written work or some unusual response during discussion, etc., as appropriate.
10. Keep the questions short and the voice informal, with humour where appropriate. Remember, most pupils have probably never before willingly exposed their weaknesses. They must not be

made to feel that they are being obliged to divulge information they would prefer to keep secret; rather they must feel that the interview will improve their learning of science. (cf. Ford Teaching Project - 1975). This is important, as mentioned in 4 above. The pupil must not fear that he is being 'used' for the sole benefit of the interviewer.

11. Conduct the interview in a steady and relaxed manner. If long-hand notes are being taken give yourself all the time you need in which to put down everything the pupil says. If there is any delay, or silence, explain why this is necessary.
12. Do not be afraid to ask the pupil to repeat anything you could not hear or get down on paper in time.
13. During the interview, persevere if lots of 'don't know' answers arise. Develop the pupil's confidence to articulate his thoughts by referring back to earlier questions and discussing earlier answers, especially where more explanation by the pupil may be needed.
14. Before the interview ends scan your notes so that any further questions can be put before the pupil leaves.
15. Promise to report back, in class or in private, the various developments from or results of the interview. KEEP THE PROMISE.
16. At the end of the interview intimate whether any further questioning will be necessary. Thank the pupil for his cooperation.
17. Write up or transcribe the recording, with full notes, as soon as possible after the interview. (Cf. Ford Teaching Project - 1975 - for dangers in delay).

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LINKAGE BETWEEN PRIOR KNOWLEDGE AND NEW EXPERIENCE IN SOME SCHOOL PUPILS AGED 9 - 16 YEARS

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This study involved close observation of 26 pupils aged 9-14 years in four schools over a period of 12 weeks, and then a further study involving 111 secondary school pupils, carried out over three years.

It investigated the influence of prior knowledge on children's understanding of ideas in science, in three related areas: evidence for and against the contention that pupils formulate 'alternative frameworks' of interpretation; the pupils' understanding of the purpose of their work; and the influence of context upon meaning.

Findings include

(1) a caution against the rigid postulation of alternative frameworks,

(2) indications, nevertheless, that pupils do anticipate and explain observations by constructing tentative predictions from prior experience, and

(3) evidence that pupils often invent their own purposeful aims for lessons.

During the investigation several issues relating to the teacher as researcher emerged, and the thesis chiefly reports this over-riding aspect of the inquiry. The study highlights and appraises implications for teacher-researchers in the following areas: the theory base of the research; the choice of questions to be investigated; the choice of methods; means of improving reliability and validity; and the practical opportunities for teachers.

The thesis suggests ways for teachers to guard against such dangers as eclecticism, subjectivity and lack of perception. It compares the strengths and weaknesses of qualitative methods, includes an interview checklist, and compares the contributions which teachers and non-teachers can make to research. The study also suggests the need to develop semi-structured interviews in classroom research, and argues for a combination of the expertise of teacher-researchers and professional research teams in tackling inquiry into concept development in science.