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An ethnographic investigation into the development and trialing of more accessible text materials for second language teaching and learning in Physical Science.

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Abstract

This dissertation discusses the development of alternative science curriculum materials for a secondary schooling context where English, the medium of instruction, is a second language for both teachers and students.

The research is located in an interpretative ethnographic framework and the data gathered during the classroom-based trialing of the materials highlights the vital role of language in the teaching and learning of school science.

An interactive reading model coupled with a discourse approach to text analysis explores some of the language difficulties which black students experience with their science textbooks. That many students fail to develop adequate reading strategies is identified as lying at the heart of many learning problems. It is suggested that the key to comprehension is instruction from a base of more accessible text materials.

Furthermore, although science practical work does not automatically advance students' knowledge and understanding, relevant and contextualised learning activities do equip students to become more self-directed and reflective learners of science.

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Lastly, and most importantly, this dissertation is dedicated to my Standard 8 science students of 1991 who participated so willing and enthusiastically in what was for all of us a voyage of discovery.

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Chapter 1
Introduction

Within the broader educational crisis in South Africa, there exists another crisis - that which surrounds the state of science education. Students in black secondary schools often find Physical Science a difficult subject to master - it is widely regarded by both teachers and students as a "failing subject" and one to be avoided. This is reflected in the fact that in the Department of Education and Training (DET) only one in five black students took Physical Science in Standard 10 in 1991. In the 1991 DET Standard 10 examinations, nearly two thirds of the students entered on the Higher Grade and the pass rate was a mere 14%.

The reasons for the difficulties students experience in science are complex, and are in part caused by the nature of the science curriculum itself, which is largely concept-driven, academic and removed from the everyday reality of the majority of the students (Gray 1992b).

A principal argument of this research project is that one of the other main obstacles faced by black students is that of having to study science through the medium of a second language (hereafter referred to as L2). In support of this contention, chapter 2 is devoted to exploring the idea that teaching and learning in science, specifically in contexts where instruction is through the medium of a second language, is an extremely complicated affair. Various aspects of L2 learning in science are examined. For example the role of metaphorical language in concept learning and the "distance" of English from the learner's mother tongue are considered in some detail. An attempt is made to locate this discussion in the context of black South African classrooms where, because of the historical development of apartheid education, the issue of medium of instruction is a highly contested terrain. Some of the challenges facing English in this role in black education are discussed. In particular, the issue of bilingualism in L2 classrooms is considered in relation to Cummins (1979) "Linguistic interdependence hypothesis".

In chapter 3 it is suggested that education is largely a text-based activity, and that the textbook in all subjects is the primary resource for teaching and learning. The inappropriateness of existing science texts for the linguistic situation of L2 users is presented as one of the main causes of difficulty in learning science at the secondary school level. Instead of conventional readability measures, an interactive view of reading will be proposed as being most suitable for probing the comprehension difficulties L2 students experience with science texts. It will be shown how a discourse analysis approach can provide guidelines on how to write, from a linguistic perspective, more accessible texts for L2 readers. To this end a large part of chapter 3 is devoted to a discussion of the major factors which affect the readability and comprehensibility of science texts.

Given the concerns raised in chapters 2 and 3, it may come as a surprise that a literature survey has indicated that relatively little work in this country has focused directly on the problems which L2 users experience with secondary school science texts. This then provided me with the focus and justification for my research project - to produce a trial text for L2 users which takes specific account of the various text-based factors which affect the readability and comprehensibility of science texts. An important component of this project was to expose this text to a period of classroom based trialing; it was expected that this exercise would allow me to probe further the specific difficulties students experience when reading L2 science texts.

Yet during the formative stage of this research project it became increasingly clear to me that I could not simply produce a science text without considering the broader curriculum issues which confront science education in South

Africa. It appears as if in the past there has been a tendency (supported perhaps by the dominance of empirical research methodologies), to view the science classroom in isolation from its broader school and societal context. In any event this dissertation has been undertaken during a time of fundamental political change in this country. We must surely be entering a period in which there will be a rethink not only in terms of the science curriculum, but also the ways in which teachers can become more actively involved in the curriculum development process.

Whether by accident or design, my attempts to develop more accessible science text materials amounted to an excursion with fairly limited objectives into the curriculum development process. As such I was conscious of breaking new ground in terms of my own expertise, since at the start of this research I had six years experience of teaching in rural and urban black secondary schools but little in the way of the skills which I imagined were needed for engaging in curriculum development. An immediate challenge facing me before I started writing any text material was to sit back and reflect on my own stance on teaching and learning in science.

To this end chapter 4 explores some of the issues facing science curriculum development; a critique of "discovery learning" develops into support for a view of "science as a craft activity". It will be argued that selective use of a process approach provides a framework that can help structure student activity in science. Thereafter the implications of a constructivist position on teaching and learning in science are carefully considered.

As suggested above, school science does not take place in a vacuum, for there is in any classroom a social and cultural context which will have a significant impact on the teaching and learning of the subject. In this respect a further section of chapter 4 considers some current issues relating to the cultural context of science education in Africa and in particular, the crucial debate surrounding the question of "relevance" in science education.

Finally in order to contextualise my own attempt at materials development the last section of chapter 4 is devoted to a brief consideration of some aspects of the existing science curriculum in South Africa.

I chose to work at the level of Standard 8 Physical Science, and to concentrate on developing materials for a specific section of the chemistry syllabus entitled "Acids, bases and salts". The reasons for this choice of focus are dealt with in chapter 5, where the actual process of developing a package of trial text material and supporting practical kits is documented in some detail. The challenge lay in producing and then trialing at the classroom level text material and supporting resources which could justifiably be said to be usable within an L2 context. As a criterion in legitimate research this might seem to be stating the obvious, but the words of Prophet (1990) sound a cautionary note at all times:

> The reality of the teaching-learning situation experienced in science lessons in individual classrooms is very different from the intentions of the curriculum developers. (1990:18)

As a practising teacher engaged in part-time research, I employed a strategy of identifying and then using existing resources as far as possible. The three main sources, "Salters' Science Programme", "Science by Investigation in Botswana", and the local "Science Education Project" (SEP) are described in turn. Basically, a pragmatic approach was adopted towards innovation; in the "acids and alkalis" trial text material, similar conceptual territory is covered as in the existing syllabus, but in this instance an attempt is made to reverse the present approach to syllabus construction. When developing the trial text material the Salters' chemistry "applications-led" approach with its emphasis on more relevant, accessible science offers real possibilities for providing students with activities which lead towards more meaningful learning.

To this end group practical work is seen to be of central importance, the trial text being built around a series of practical worksheets. In an attempt to encourage more self-directed learning a group investigation was included as an integral part of the handout. A deliberate attempt was also made to enable students to consider the impact and implications of science for society (e.g. the information sheet and comprehension exercise on acid rain). Finally, a commitment to the concept of language across the curriculum (LAC) is made in the trial text material through the inclusion of a number of comprehension type exercises.

Having produced a package of text and supporting practical kits, my next step was to subject them to actual classroom-based trialing exercises with my two Standard 8 classes (each with over 40 students). In order to evaluate its effectiveness I had to observe as critically as possible the students' interaction with the new material over what would be in each class at least a four week trial period. I needed to obtain as authentic as possible an account of classroom interaction over this time. To this end I decided to locate my research in an interpretative ethnographic framework. The rationale behind this choice is dealt with in chapter 6 where the various ethnographic data collecting techniques are described in full.

Aspects of the two trialing exercises are documented in chapter 7, and the various forms of data which were collected are used in both chapters 7 and 8 to explore a wide range of issues. By design both chapters adopt a narrative style, and quote extensively from the students and from my own reflections of the day to day events.

The significance of this dissertation can most clearly be picked up in these two chapters. Chapter 7 represents a critical reflection on different aspects of the trialing exercises. It seeks to determine the success or otherwise of the group practical work, the suitability of the text material for L2 users, the findings of the pretest and the attitudinal questionnaire etc. The chapter also analyses the context in which the project took place by recording teacher attendance in 8A and the attitudes of students towards school stayaways and boycotts. These are included in order to illustrate the complexity of the research context of black schooling in South Africa. Furthermore they add a critical dimension which both enriches and enlivens the research work and uncovers some fascinating and perhaps provocative findings. Examples are also given of where the students were able to contribute significantly to the evaluation of the trial text material, and in so doing play a crucial role in the ongoing process of developing the text material. Throughout chapters 7 and 8 extensive use is made of the student interviews, a form of data which contributed significantly to this project.

The purpose of chapter 8 is to illustrate by example how some of the different forms of data which were gathered during the course of the two trialing exercises can be used as a diagnostic tool to probe the various language difficulties experienced by the students as they interact with their textbook and with the trial text material. The attitudinal questionnaire, an analysis of the "acid rain" comprehension and the letter writing exercise, and the various student interviews form the basis for most of the discussion.

Finally, besides the conclusions and recommendations for future research contained in chapter 9, the trial text is included as Appendix 1. It is hoped that this handout together with the practical kit (see the photographs in Figure 5.1) will provide a basis for other practising teachers to engage in the development of alternative science curriculum materials which are specifically intended for the L2 context of black schooling.

Chapter 2

Learning Science Through a Second Language

2.1 Language and Learning

Since the 1960s there has been a movement away from viewing language simply as a communicative tool, towards its being seen as the means whereby children also learn and understand. As Barnes (1969) suggests, language should be viewed as "language for learning".

This concept achieved official recognition and sanction in 1975 when the highly influential Bullock report, "A Language for Life", pointed out the need for a more searching examination of the role of language in education.

One of the central notions of the Bullock report was that all teachers, irrespective of the subjects they teach, are teachers of language. One of the recommendations is worth quoting in full:

> 138. In the secondary school, all subject teachers need to be aware of:
> (i) the linguistic processes by which their pupils acquire information and understanding, and the implications for the teacher's own use of language;
> (ii) the reading demands of their own subjects, and ways in which pupils can be helped to meet them.
> (1975:529)

A major priority, then, for every teacher is to heighten his/her own awareness of the complexities and subtleties of language and the particular demands that their subject makes on the language skills of students (Rice 1982). As Austin (1991:9) puts it, what needs to be done is to build up an awareness of the importance of language not as part of the subject English but as a fundamental part of each content subject which is essential to the actual understanding of that content.

2.2 Language and Learning in Science

Increasing attention has been given to the role of language in the learning of science and a considerable body of research now exists in this field. Ranging in focus from studies on the uses of reading and writing in the development of scientific understanding (see Carre 1981; Sutton 1981), the role of language in science examinations (Johnstone & Cassels 1978), Sutton's work (1974;1980;1989) focusing on the language used by learners in their struggle to comprehend science, to those specific problems (given the nature of scientific discourse itself) presented by the language(s) of scientific texts (to be discussed in the following chapter).

Curtis and Millar (1988) sum it up well when stating that

> language plays a crucial role in the child's ability to construct meaning; the learning of abstract scientific concepts therefore depends both on the child's ability to use language to explore his/her existing conceptions and on the richness of the word- and the idea-associations which the child has with the particular scientific ideas involved. (1988:62)

Clearly the call is for science teachers to put more emphasis on the use of language in science lessons. For the language difficulties experienced by students can only be addressed more explicitly through an increased emphasis on classroom and homework tasks which involve the use of written and spoken language. These tasks will encourage familiarity with new terminology and ideas and serve to reinforce concept learning (Sutton op cit; Davies and Greene 1984).

Whatever difficulties L1 users experience because of the language of the science lesson, it is reasonable to assume that these problems are exacerbated for black students when having to study science through an L2. Prophet (1990) identifies L2 learning problems in science as one of the main obstacles faced by Motswana students in Botswana.

Wilkinson, Reuter and Kriel (1987), in a study of the problems of teaching and learning science in parts of South Africa, identify one of the most important ones as being "pupils experiencing difficulties expressing themselves in English". Secondly, they find that the difficulty black students have in coping with scientific language is one of the most significant reasons why students do not take science as a subject beyond Standard 7.

This is reflected in the numbers of students who sit for this subject in the final matric examinations. In 1991, of the total of 306 480 DET candidates, only 16 259 had entered for Physical Science and, of these, only 3 205 students passed on either the Higher or Standard grade (Edusource 1992:4).

The reasons for this high failure rate are extremely complex and extend beyond whatever problems arise from the medium of instruction. Yet, as described in the introduction to this dissertation, eight years of teaching science in both rural and township black high schools alerted me to the immense difficulties my students specifically experienced through having to learn science through the medium of English as a second language.

Before considering in more detail a number of specific aspects of L2 learning in science, it is necessary to pause in order to locate such a discussion within the actual context of my study; namely a South African classroom in which English L2 is the medium of instruction.

2.3 English as Medium of Instruction

It seems generally accepted (Young 1986; Austin 1991; among others) that the standard of English at all levels in black schools is disturbingly low. The inability of students to attain satisfactory levels of competence, particularly in spoken English, has major implications in the classroom:

> Lacking oral competence, the pupils dare not open their mouths in class for fear of the mockery of their peers and the ire of the teacher. Teacher-pupil interaction is, therefore, stifled, classroom talk teacher-initiated and maintained, and the joint venture of teacher and pupil in the formulation of knowledge rendered impossible. (Rangaka 1982:27)

According to Weimann (1986) the dominance of rote learning in black rural high schools in the Ciskei is a response by the students to their failure to grasp and understand what they have been taught through the medium of their second language English.

As Gudschinsky (1977) puts it, for second language (L2) learners such a "manipulation of word tokens without meaning" is certainly part of their attempts to solve the whole problem of lack of understanding (the dominance of rote learning is further discussed in Chapter 3).

The use of English as a second language as medium of instruction in black schools is faced with numerous challenges. Mawasha (1979; 1983; 1984; 1987), for example, has dealt extensively with many of the issues involved.

One set of problems relates to the teachers' own lack of competence in English. MacDonald (1990) explains how the apartheid system has ensured that most teachers do not speak English with confidence or fluency and consequently struggle to use it effectively as a medium of instruction in the classroom.

In particular, Ridge (1990) points out that most

English teachers at the secondary school level are underqualified to teach English; Mawasha (1979) reports that 70% of a sample of English second language teachers were inadequately qualified to teach English as a second language.

However the problem runs deeper than even figures such as these suggest, for it concerns in part the kind of training to which many language teachers are exposed in the colleges and the kind of teaching which is practised in schools. In both situations it is dominated by methodologies which still tend to focus on developing grammatical rather than communicative competence. Buthelezi (1984) concludes that the English taught at the school level in particular is primarily literary in content and does not equip students to communicate effectively.

The situation seems worse in the content subjects, where teachers experiénce major obstacles to teaching the language dimension of their subjects. Not only do teachers lack training in how to identify the language demands of their subjects, but they also do not know how to meet these demands.

Another problem which has been identified (by Mawasha 1986 amongst others) is that the environment in which students live (outside the school) is not always supportive of English as a medium of instruction. Another consequence of apartheid is that social interchange with English-speaking people is minimal and exposure to English is limited to the school classroom or college campus.

I wish to pick up on one further issue which has a critical effect on school performance at all levels; namely that of "switch-of-medium" from mother tongue to English in primary schooling.

2.4 Bilingualism in L2 Classrooms

In recent years the medium of instruction issue has been a prominent one in South Africa among educationists and educational authorities alike. Young (Ed) (1987) deals with various aspects of this topic as it relates to the broader issues of language planning.

In an analysis of the direction of language medium policies in a post-apartheid South Africa, Heugh (1987) concludes that English is likely to perform the role of the lingua franca (for purposes of national unity) and continue as the chief medium of instruction in schooling.

Yet there is one area in which there is continual debate particularly in the light of recent State initiatives in this regard. This relates to when and how to go about making the crucial shift in medium of instruction from mother tongue to English.

At present black students study all subjects except the first language (Xhosa, Zulu, Tswana etc) and the third language (Afrikaans), through the medium of English from the Standard 3 level upwards. Consequently, all textbooks and all examinations in all content subjects are written in English.

Weimann (1986:13) cautiously argues, on the basis of his personal experience over a period of five years contact with classroom practice in the Ciskei, that a teaching approach which could be included under the descriptive title of "Bilingual Education" is more widespread than is generally realised. His recordings of classroom teaching (Standard 8 Geography) indicate the extent to which both English and Xhosa were used as medium of instruction.

My own experience over the past eight years sharing laboratory facilities with colleagues for whom English was an L2 confirms this. The reality of most science lessons, particularly at the junior secondary level, is that besides the specific terms and expressions of science for which there is a lack of equivalent terminology in mother tongue, lessons are given almost exclusively in the mother tongue.

The reasons for this are in turn complex but relate in part to broader issues of the teachers' own competencies to teach their subject through the medium of English (as discussed earlier). Furthermore, it clearly indicates how little English the students can actually understand and comfortably use.

It must be stressed, though, that nowhere am I arguing that in such a context must teachers use only English in the classroom. Research work in Kenya reported by Cleghorn (1992), suggests that at the primary level important concepts in science were more easily conveyed when teachers did <u>not</u> (her emphasis) adhere strictly to the English-only language of instruction policy. She argues convincingly that more effective explanations of culturally foreign concepts in science can be given along with concrete, familiar examples through a complex pattern of code switching, including the near exclusive use of the local language.

It is reasonable to assume that there are similar advantages to using mother tongue in science in the secondary school. Yet at this level there is a clear danger that an over-reliance on mother-tongue will seriously hinder attempts by students to develop their English language skills - a necessity, given that both textbooks and examinations will be written in this medium. The crucial point seems to be this: the mother tongue should be used not as a crutch but as an aid to learning, for it has an important role to play in attempts by both student and teacher to negotiate meaning out of the complex and often highly abstract concepts presented in school science.

The whole area of bilingualism in education has been covered at length by Cummins (1979). One specific aspect of recent research into language acquisition in bilingual children suggests that the development of cognitive academic language proficiency (CALP) in the first language (L1), is vital if it is to develop in the second language (L2).

In his "Linguistic interdependence hypothesis", Cummins suggests that the level of competence a student reaches in an L2 learned in school is a function of certain competencies reached in his/her L1. One significant implication of this hypothesis is that if effective early learning of the student's L1 fails to occur, then not only will the student struggle to reach acceptable levels of competence in the L2 but will <u>also</u> face impeded development of the L1.

As Weimann (1986) points out, if such an hypothesis were true, it might hold out a partial explanation as to why black students (and teachers) have such language problems at school. Dawe (1983), in a study of the ability of bilingual children in Britain to reason deductively in English as an L2, concludes that, irrespective of the medium of instruction, mathematical reasoning in a deductive sense was closely related to the ability to use language as a tool of thought. Dawe emphasises that for bilingual children this involved competence in <u>both</u> languages.

The impact of this "interdependence hypothesis" on bilingual education theory has been felt in this country, the Molteno project accepts as one of their starting points that any programme to increase student proficiency in English as an L2 is rooted in a solid foundation of L1 proficiency. It is also reflected in one crucial area of focus in the recent HSRC Threshold Project reports (see Macdonald 1990): the future options for managing the switch from mother tongue to English medium instruction in black primary schooling.

2.5 <u>Problems of L2 Learning and Teaching in Science</u>

A large body of work now exists on the problems associated with the learning and teaching of science through a foreign language (Harrison 1973; Strevens 1976;1980; Acuna and Guzman 1987, to name a few).

Strevens (1976) cites an unpublished paper of Halliday (no date given) in a comprehensive article on the problems of teaching and learning science through a foreign language and creates a useful framework for identifying and explaining sources of language difficulty. He identifies sources of difficulty to be either linguistic or sociolinguistic in origin; his summary is worth quoting in full:

1. **Linguistic difficulties**: these may be of three kinds

   a) **Meanings** - "semantic difficulties". The learner must learn the appropriate meanings of science and how they are expressed in English.
   They are of two main types.

   i) arguments - the "rhetoric" of scientific communication

   ii) single items - e.g. terminology, logical operators etc

   b) **Words and Structures** - "lexico-grammar". In order to understand and express the meanings of science the learner must acquire command of the three kinds of language rules for doing so;

   i) sentence and phrase structures - "syntax", the rules for constructing and comprehending sentences;

   ii) words - "vocabulary", the items (with meanings) which string together in phrases and sentences;

   iii) word structures - "morphology", the rules for constructing words in English, which includes the large stock of words borrowed from Greek and Latin.

   c) **Symbols** - the learner must be aware of the degree and kind of correspondence, and be able to handle the rules for conversion between writing and speech, of chemical formulae, mathematical notation and other scientific symbolizations.

> **Sociolinguistic difficulties**: these will be principally determined by two kinds of variables:
>
> a) **The functional status of English** when used as medium of science education:
>
> i) **in general** - how widely is English used in the society in question?
>
> ii) **special** - how familiar in the local society is the English of science?
>
> b) **"Distance" of English from the learner's mother tongue**
>
> i) **in status** - the learner's expectations and achievements are much affected by whether English, as a language, is valued low or highly in his community;
>
> ii) **in world view and meaning styles** - particularly, whether Western science, logic and reasoning systems are familiar;
>
> iii) **in internal structure** - the more closely English approximates to the learner's mother tongue, in syntax, vocabulary, word-structure, sound systems and writing systems, the smaller will be the language barrier in general, and the smaller will be the impediment to learning science through English.
>
> (Strevens 1976:60)

Many of the difficulties raised by Strevens, particularly as they relate to the formal, written language of science, will be considered in the following chapter which focuses on the role of the textbook in science lessons.

The following brief discussion is intended to highlight the complexity of the interaction between language, culture and cognition, specifically in contexts where English as an L2 is used as a medium of instruction.

2.6 Language, Culture and Cognition

We must start by stating an important presumption, that the major concepts of science, especially those ideas that children find difficult, are abstract. Given their abstract nature, it is only through the medium of language that these concepts can be approached (Maskill 1988:486). Thus there is a close relationship between language and concept learning.

In the section on constructivism in chapter 4, some general issues relating to concept learning in science will be considered. Indeed, one focus of constructivist research has been the investigation of language and concept development. Methods include: concept mapping (Champagne et al 1981), the construction of concept "trees" (Matthews et al 1984), definition writing (Schaefer 1979) and word-association (Ross and Sutton 1982).

Vygotsky (1962;1978) views language as very important in defining the shape of thought. He claims that words both form concepts and later come to symbolise concepts, and defines concept formation itself as:

> the intellectual operation in which all the elementary mental functions participate in a specific combination. This operation is guided by the use of words as a means of actively centring attention, abstracting certain traits, synthesising them and symbolising them by a sign. (1962:304)

For Vygotsky, advanced concept formation depends on the use of words in abstract synthesis which can be used as the instruments of abstract, decontextualised thought. This amounts to an assertion that there is a dialectical relationship between thought and word: "thought is not expressed merely in words, it comes into existence through them" (1962:186). The role of the language used in instruction is therefore critical, for it becomes the mediator of cognitive growth.

In contrast to Vygotsky, Chomsky and Piaget seem to assume that language and thought are autonomously structured. According to Hakuta (1986), Chomsky understands the mind to consist of a set of unique capabilities, one of which is language. Piaget in turn has devised a developmental model of cognition based on formal logic, in which general forms of knowledge are the source of all domains of cognition, including language. The work of these two psychologists seems to imply that language has minimal influence on thought - the linguistic and cognitive functions are viewed as being quite separate by Chomsky, while Piaget assumes that they are derived from a common logical base.

Clearly the relation of language to thought in the study of science (as elsewhere) is a very complex issue and one that is essentially unresolved (Wilson 1981). Fortunately, as suggested in the preceding sections to this chapter, there is a growing awareness that many of the problems in the teaching and learning of science, particularly when learning is through the medium of an L2, are linguistic in origin. A number of these will now be discussed.

2.6.1 Metaphorical Language and Concept Learning

Metaphor, using the word in its widest sense, to include similes, personifications and other figurative speech, clearly permeates all language. Given the increased attention to the role of language in the learning of science, there has been growing interest in the role of metaphor in knowledge creation. As Sutton (1981) puts it:

> metaphorical language, and the imagery behind it, is a major cognitive aid, a means by which new thoughts are begun. (1981:219)

It can be expected, given the problems associated with learning through the medium of an L2, that students will experience specific difficulties with the metaphorical use of language in science. Metaphor is found in scientific theorising, in the evolution of language, in children's attempts to interpret new experiences, and in teachers' efforts to help them do so (Sutton 1981).

Scientific models are themselves elaborations of metaphors: for example, over the years various atomic models have been proposed - from Dalton's "billiard ball model", Thomson's "plum-pudding model" and Bohr's "planetary model". Each model, just like the metaphor from which it is derived, provides for a while a powerful interpretative framework.

At the level of individual words, each has both a denotative meaning (how we might wish to define it) and connotative meaning (all the things it implies to us). It is characteristic of language development in science that the connotative meanings of words are played down (Sutton 1980). As he goes on to suggest, in the world of science the meaning of terms is thought to be fixed and determined, the idea that meaning varies from person to person and changes over time is relatively unfamiliar.

One consequence of this is the mistaken belief that meaning resides in the actual words of the definitions so beloved of school science texts. For example, consider the following typical statement taken from a Standard 8 textbook in common use in L2 classrooms in South Africa:

> A **compound** is a pure substance that can be broken into simpler substances (eg elements) by means of chemical methods. (Pienaar et al 1985:154)

It could be argued that in order for a student to make any kind of sense of this definition of a compound, he/she has to deal with the contextual use of a number of abstract concepts ("pure substance"; "element"; "chemical methods" etc). A failure to understand any (or all) these concepts will cripple a student's attempts to create meaning for him/herself. And in response, as a coping strategy, the student will be forced to resort to rote memorisation (the "manipulation of word tokens without meaning" referred to earlier).

One aspect of the problem is that, for a child particularly, the meaning of a word is <u>not</u> its definition. It is better thought of as the sum of all connections to other things he/she knows (Sutton 1980:51). So in the wider context words are not "fixed" labels for things or phenomena; they change their meaning - sometimes through small shifts of usage, sometimes through large scale reapplication into different contexts. In this way metaphors die and words acquire new meanings.

This way many words used in science have acquired meanings which have grown out of the metaphorical extensions of older meanings (see Sutton 1980 for some interesting examples of the way in which scientific vocabulary has evolved through the metaphorical reapplication of existing words).

On another level, as learning in science often involves encounters with new experiences, ideas and explanations, the science teacher continually uses metaphorical thinking in that students are asked to think of the new in terms of the familiar, and both similes and analogies are frequently used in the search for simple ways of introducing an abstract or complex idea.

Analogies in particular are a powerful descriptive tool (Shortland and Gregory 1991) yet their use (in science texts for example) may present L2 learners with added problems of comprehension. Suggesting that "the atom is like the solar system" assumes that the student has a reasonable grasp of what the solar system is; without this background knowledge the analogy will clearly fail to facilitate understanding.

Furthermore, if it is accepted that all metaphors are grounded in experience (Lakoff and Johnson 1981), it is possible that those which are deeply embedded in cultural beliefs may play a role in concept formation. In a fascinating study, Hewson and Hamlyn (1984) explored conceptions concerning "heat" amongst the Sotho people of Southern Africa. Their findings show how existing knowledge concerning heat is influenced by the presence of a powerful heat metaphor which dominates the intellectual environment of Sotho people. This prevalent cultural metaphor has clearly arisen out of the hot, arid environment in which the Sotho live.

Hewson and Hamlyn conclude that in this instance, Sotho students may in fact find it easier to acquire the contemporary scientific view of heat, because their existing knowledge has been so strongly influenced by the heat metaphor.

Given the above considerations, metaphorical thinking will play, either by accident or design, a central role in the classroom. And as Bowers and Cooper (1986) suggest, an understanding of the metaphorical nature of language and thought can add substantially to the teacher's awareness of the dynamics of the learning process.

2.6.2 "Distance" of English from the Learner's Mother Tongue

> The conventional belief that language is a neutral technology ... is now giving way to the recognition that language helps to organise the thought process in accordance with the conceptual categories and assumptions that make up the world view of the cultural group. Whereas the old view held that the speaker uses language, the new and more complex understanding is that the individual both uses and is used by language. (Bowers and Cooper 1986:3)

Berry (1985) chooses to focus on aspects of teaching and learning in which the "distance" between the mother tongue of the learner and the medium of instruction plays a role. Using an extremely informal and intuitive concept of linguistic distance (see Dawe 1983 for a more detailed discussion of this concept), he suggests that it is likely to be easier for a student to function effectively in an L2 which is semantically and culturally close to his mother tongue than in one which is remote.

Learning problems are compounded when the student's mother-tongue, whether used as the medium of instruction or not, is the language of what Wilson (1981) refers to as a pre-scientific culture. Such languages have only limited scientific registers; they may lack the terms, words, expressions and so on for communicating about science.

In this regard Strevens (1976) gives, among others, the following specific areas of difficulty:

i) an absence in the mother tongue of words or expressions equivalent to ones in English eg "electricity", "expansion";

ii) an absence in the mother tongue or culture of certain concepts, e.g., "gravity", "infinity", "zero".

iii) interference from non-decimal counting systems.

He has this to say about the lack of equivalents in mother tongue for the scientific concepts presented in the science classroom:

> When a learner of science is a native speaker of a language not yet adapted to the purposes of science, his learning through English entails very special, additional difficulties of cognition and understanding. He cannot appeal to translation into his mother tongue for the resolution of doubt or the dissipation of ignorance. (1976:58)

The lack of an adequate existing scientific register to support mother-tongue instruction has led in some instances to its forced development through the invention of new technical vocabulary or its incorporation from other languages. Not surprisingly this process presents major challenges and in turn has created difficulties for many of the countries concerned (see Haddad 1971; Tan 1991).

However seeing that many countries, particularly in Africa, continue to pursue a policy of using English as a medium of instruction, the problems of teaching and learning science through an L2 remain.

Acuna and Guzman (1987), in describing the problems that science students in the Philippines face when using English as an L2, compares Philipino (one of the eight major Filipino dialects) with English as a medium for communication and shows how unclear to the students are the meanings of many English terms they came across in science.

An interesting perspective is provided by research work not directly concerned with science. The difficulties which Zulu students encounter in English literature due to the culture-bound meaning of certain words is highlighted by Pienaar (1989). She cites linguists such as Loveday and Wilkins who allude to the close relationship between the vocabulary of a language and the cultural environment in which it is embedded.

It may be, as suggested by Tomaszczyk (1983), that there are degrees of culture-specificity, with some words being more culture-bound than others. In the previous section mention was made of the possible influence on cognition of a cultural metaphor relating to "heat". This concept, lexicalised in many languages, will reflect a range of culture-bound meanings. Yet as discussed earlier, science attempts to pass off meaning as being fixed and determined. This disregard for the connotative meanings of words goes some way to explaining the language difficulties faced by learners in science.

It can be argued then that an awareness of the culture-bound meaning of words and concepts should become an integral component, particularly for L2 learners, of any programme of instruction in science.

2.6.3 Culture and Cognition

In a cross-cultural study (in England and Nigeria) originally set out to examine the effect that learning in a second language has on concept formation, Ross and Sutton (1982) conclude, somewhat to their surprise, that cultural differences stand out as being more significant than specific language ones.

As noted by George and Glasgow (1988), the difficulties which non-Western students may encounter because of the nature of their language form just one sub-set of the effects of culture on learning in science.

What is implied by culture? As Pienaar (1989) points out, the word has several related senses. Lyons (1981) describes culture as being:

> socially acquired knowledge i.e. ... the knowledge that someone has by virtue of his being a member of a particular society. (1981:302)

A semiotic concept of culture espoused by Geertz (1973) believes that "man is an animal suspended in webs of significance he himself has spun" (1973:5). Culture is taken then to be these webs; people are seen as making sense of the events in their lives through systems of symbols which are constructed historically and maintained through social interaction among individuals.

However, Giroux (1981:26) proposes a more "politicised" concept of culture in which it is defined also as "lived antagonistic relations" situated within a complex of socio-political institutions and social forms that limit as well as enable human actions.

Particularly in a country like South Africa, where one group has enjoyed economic and political dominance over all others for so long, the concepts of power and conflict are central to any consideration of culture (Millroy 1988).

This gives rise to complex issues which lie beyond the scope of this dissertation. However, such a concept of culture does seem to resonate well with attempts to problematise (in the broadest possible way) science teaching and learning, specifically in contexts where, as Maddock (1981) puts it:

> (culture) involves not only a new body of subject matter, with its abstract vocabulary, unrelated to the realm of experiences in the receiving culture, but a whole field of beliefs and attitudes complexly interwoven in the subculture of scientists and science educators... Much more is involved than the mere transmission and learning of "noises" with associated noises representing verbalizations within the donor culture. (1981:11)

Culture and cognition are thus inextricably intertwined. As Bullivant (1975) observes, language, conceptual structures, logics and knowledge are situationally anchored; they are specific to certain cultures and not to others.

Lave (1988) argues strongly against separating the individual from collective, cultural aspects of cognition and has attempted to develop a more adequate model of cognition in a cultural context. This has strong links with the ideas of Vygotsky (1962) whose theory of cognitive development stresses that cognitive functioning occurs first on the social level between people, thereafter it is internalised as individual development.

Elsewhere, Vygotsky (1978) claims that the higher mental functions are socially formed and culturally transmitted. He thus emphasises that learning is a social process and that as such language is an important tool through which society transmits its values and knowledge to the child.

In the discussion on constructivism in chapter 4, it will be suggested that instead of seeing knowledge construction as a personal process, learning theory needs to be located within a sociology of knowledge which acknowledges the importance of socially constructed meaning. This implies that an individual's development cannot be seen in isolation from others with whom he continually interacts and the larger cultural context within which he/she lives.

The growing awareness that science education must take into explicit account the cultural context in which it is located will also be discussed at length in chapter 4. It will be suggested that socio-cultural beliefs tend to exert a mediating influence as students interact with the formal ideas and concepts presented in school science. This view is regarded as being consistent within a broader constructivist position on teaching and learning in science.

2.6.4 The Interdependence of Language, Culture and Cognition.

One crucial question which has to be asked is whether or not a causal chain links language, culture and cognition. This will be briefly considered seeing that it lies at the heart of the debate over what is known as the Sapir-Whorf hypothesis.

The idea that the structure of a language can influence cognitive processes has been termed the Sapir-Whorf or "linguistic-relativity hypothesis". Whorf (1956) notes that the view of the world an individual holds depends on the concepts by which he/she categorises experiences. Since these concepts are channelled through one's target language, speakers of different languages code their experiences into different categories and their thought patterns therefore differ.

Put simply, in what amounts to a claim for linguistic determinism, it is suggested that the nature of the relation between language and thought is one of cause and effect. Such a "linguistic-relativity hypothesis" has been advanced in some cross-cultural studies (see Austin and Howson 1979:168-169 for a discussion of some of these in mathematics) to explain the difficulties which non-Western students have when studying in an L2.

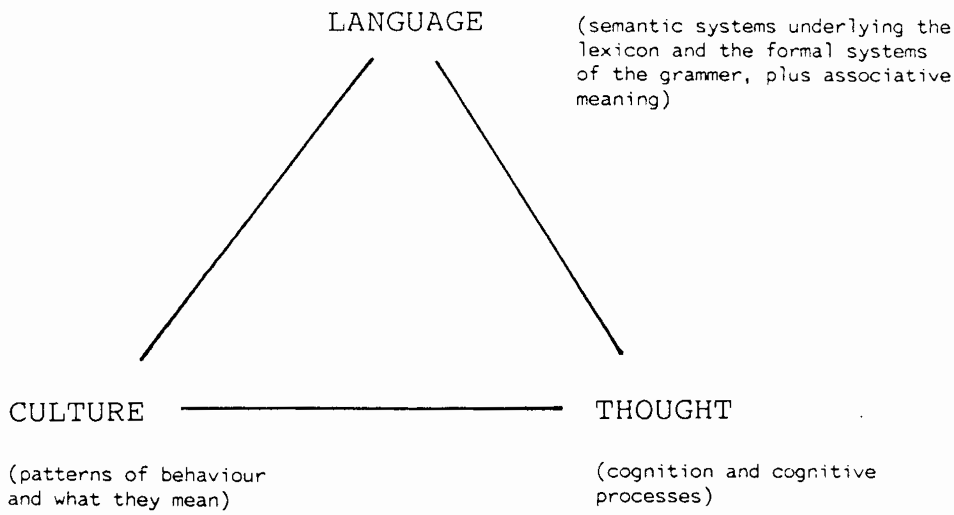
Current research, though, based on field work in different parts of the world, tends to discredit a strong form of the Whorfian hypothesis as a general description of the relation between language and thought (Berry 1985). According to this, we do not perceive things differently by virtue of operating in different linguistic codes.

Hakuta (1986) suggests that there is sufficient evidence for maintaining the weak form of the Whorfian hypothesis, i.e. there is a tendency for thought to operate along the lines defined by language, but it remains an open question whether there are real differences at the levels of memory and higher mental processes.

Lanham (1980), in a studied appraisal of the Whorfian hypothesis, rejects the assertion that any particular causal relation exists between language and thought. He argues instead that there are complex dependency relationships between thought, language and behaviour and that these are interactive and interdependent in terms of mental function.

He proposes a more useful model (figure 2.1 on the following page) to provide the terms for exploring these dependency relations:

Figure 2.1



(Lanham 1980:9)

In his discussion Lanham in no way attempts to dispute the notion that deep-seated differences exist between cultures in the manner in which they interpret and hence think about and manipulate, the world of their experience. But, as also suggested by Cole et al (1971), cultural differences in cognition reside more in the situation in which cognitive processes are applied, rather than in the existence of a particular process specific to a particular group. It is accepted that there are differences in language-stimulated behaviour, but as Lanham points out, this does not imply cognitive inflexibility, for language-determined mental structures can surely be modified.

The findings of research in Kenya reported by Seddon and Waweru (1987) seem to support this view. They take as their starting point the fact that many scientific concepts, which are constructs of Western cultures, and which are not part of traditional African cultures, are difficult if not impossible to translate (in this case from English) and teach or test using the vernacular.

They show that in fact this barrier to transfer from English to both Swahili and Kikuyu, and between both Swahili and Kikuyu can be broken down. And interestingly enough, for all three languages of teaching, the resulting performance in both vernacular languages is indistinguishable from that in English.

To sum up, teaching and learning in science, specifically in contexts where instruction is through the medium of a second language, is an extremely complicated affair.

In particular, language (be it medium of instruction or the learners mother tongue) cannot be seen in isolation; it must be considered in relation to the culture in which it is located. This implies that an analysis of the language difficulties which L2 students experience when learning school science must be undertaken within a framework which acknowledges the complex web of linguistic and sociolinguistic factors at play.

Furthermore, on a broader level language, culture and cognition are considered to be inextricably interwoven into complex dependency relationships that are interactive and interdependent in terms of mental function.

In conclusion, it is suggested that an awareness of the above issues can add substantially to a teacher's understanding of the learning process and in turn aid his/her attempts to generate more effective learning in school science.

Chapter 3

"Brother, can you spare me a book I can understand?"

3.1 Introduction

In a classroom students are exposed to discourse in a variety of ways, but a major part of educational input is through the medium of written texts. Education is largely a text based activity (Pillay 1988:104) and this is certainly the case here in South Africa. In the context of L2 black schooling Young (1986) has this to say:

> Textbooks... invariably are the pretext and text for most lessons, especially at (the) secondary level. (1986:47)

Why is this? For a start, black students are exposed throughout their schooling to a great deal of transmission teaching (Austin 1991). There are various reasons for this; Ellis (1987) and Macdonald (1987) suggest that the practice has deep cultural roots and that the implicit views of knowledge held by both students and teachers predispose towards it.

Another significant reason for the dominance of rote learning, is suggested, as discussed in the previous chapter, by Weimann (1986) who believes that in an L2 context it is by and large a response to the students' lack of competence in English. Lanham (1986) argues that it is the poorly constructed texts themselves which are a significant contributor to black children's present tendency to rely on rote learning.

This is a view supported by Macdonald (1986) who, in her study of General Science textbooks, found that the quality of texts themselves are likely to be a cause of learning difficulty. Similar attention has focused on other content textbooks. Langhan (1990) gives a useful overview of research, both here and overseas, into textbook-reader mismatch mostly at the primary school level.

It could also be argued that transmission teaching is a legitimate response to the highly prescriptive and restrictive syllabi which typify education in this country (see figure 4.1 on page 86).

Young and Nuttall (1989:224) make the point that, in particular, strong learner dependencies on textbooks are created because of the extremely close correspondence between official syllabi/work schemes and the content of such texts. This is certainly the case in Physical Science, where an abridged version of the "official" work programme can be found printed in the front of some textbooks (see for example the "Science in Action" series by Brink et al 1985).

As Young (1986) put it:

> Textbooks encapsulate the syllabus and flesh out its skeleton. Learners are captive and vulnerable, therefore, to the way in which language is used to transmit subject content. (1986:47)

At the secondary school level, Pillay (1988) concludes that the majority of Standard 6 L2 students are unable to cope with the demands of the Geography texts in use. Weimann (1986) finds similar problems in the same subject in Standard 8.

However, relatively little work in this country has focused directly on the problems which L2 users experience with science texts. Wegerhoff (1981) shows that many science textbooks are encoded in language way beyond the comprehension levels of the first language users for whom they are intended. These self-same textbooks are to be found in black schools; so texts which L1 students have difficulty in comprehending end up as the primary resource for teaching and learning science in black secondary schools.

Previous research (Clark 1987), applies similar readability measures to the texts I was using in my own L2 Standard 8 and 9 science classes. In the light of the above it is hardly surprising that nearly all the students tested found these texts unreadable, and that the majority of students in both Standards were frustration-level readers of their science textbooks. A disturbing conclusion made at the time was that there was no appreciable difference in reading ability between Standards 8 and 9.

Related issues are taken up in an analysis of the textbook attitudinal survey which formed part of the field work for this dissertation. This survey gave students the opportunity to articulate their own feelings towards their science textbook. For a discussion of the findings see chapter 8.

The impact on student performance of such "unreadable" texts is impossible to quantify in precise terms, but it is surely profound. I would contend that the inappropriateness of existing textbooks is certainly one of the major causes of difficulty in learning science at the secondary school level.

It must be accepted that in an academic subject like science, textbooks will play a central role, for as Wright (1982) points out, much science content knowledge must be gained through reading. Furthermore, it remains my contention that the textbook, however unreadable, however unpalatable to readers it now appears, will remain the primary resource for teaching and learning science in black secondary schools.

Given the above concerns, it is vital that attempts are made to write expository science texts which are more accessible to L2 learners than those commonly produced in this country. For this to be successful, text production must be rooted in an approach which looks beyond the traditional concerns of science text writers, hence the rest of this chapter.

3.2 Reading in a Second Language

3.2.1 Reading: A Psycholinguistic Guessing game

Up to the late 1960s reading theory and practice was strongly influenced by the audiolingual method, in which reading and teaching reading was understood essentially as being a mechanical process.

Silberstein (1987) quotes Goodman's article of 1967, "Reading: A Psychological Guessing Game" as being a seminal one which caused the demise of the audiolingual method and brought reading theory under the influence of psycholinguistics. This marked the introduction of a completely new approach to reading which continues to inform thinking to the present day.

Goodman (1972) insists that reading is not an accurate process, but depends rather on what meaning structures the reader brings to the text, hence his description of reading as a "psycholinguistic guessing game" which involves the "systematic reduction of uncertainty".

He stresses that meaning (as opposed to word recognition) is the goal of all reading, and that this can be derived from the understanding of clauses, grammatical and syntactical structure rather than words. Goodman proposes a model of reading in which meaning moves from the author's deep structure to surface graphic display and back to the inferred deep structures of the reader.

The importance of this theory is that it introduces the notion to both first and second language reading, that the reader is an active participant in the reading process, and that reading is essentially a linguistic process, constrained by the linguistic structure of text in interaction with the linguistic competence of the reader. As Donald (1992:4) puts it, Goodman's model is an attempt to come to terms not only with the degree to which linguistic constraints determine the process of reading but also with how the reader synthesises information from a variety of sources to construct the meaning of the text.

However, a major limitation in this model is its focus on the processing of information in the text; for meaning is taken as being fully present in the text to be decoded by the reader when responding to the linguistic cues offered in the text (Langhan 1990:17).

In an attempt to focus more specifically on the role of the reader in the reading process, subsequent developments in reading theory have tended to elaborate on Goodman's basic model.

3.2.2 The Interactive Reading Model and Schema Theory

Coady (1979) suggests a model in which the reader's background knowledge interacts with process strategies and conceptual abilities to produce comprehension. In particular, what the reader brings to the reading task is seen as being of crucial importance: "more information is contributed by the reader than by the print on the page..." (Clarke and Silberstein 1977:136).

The role played by readers' prior knowledge in allowing them to interpret and understand a text is one of the major themes in research on reading comprehension, and it has been formalised in what has come to be known as "schema theory" (Rumelhart and Ortony 1977).

A fundamental tenet of this theory is that any text, either spoken or written, does not by itself carry meaning. Rather, a text only provides directions for readers as to how they should retrieve or construct meaning from their own, previously acquired knowledge. This is what Adams and Collins (1979) called the reader's "background knowledge". All the previously acquired knowledge is packed in the brain as units or knowledge structures called "schemata".

Thus, according to schema theory, comprehending a text is an interactive process between the reader's background knowledge and the text, and efficient comprehension requires the ability to relate the textual material to one's own knowledge (Carrell and Eisterhold 1988). In this regard, Carrell (1983) draws a particular distinction between "formal schemata" (background knowledge of the formal, organisational structures of different types of texts) and "content schemata" (background knowledge of the content area of a text).

Central to schema theory are two basic modes of information processing, referred to as bottom-up and top-down processing. Bottom-up processing occurs when information from the text is mapped against the reader's schemata, which are then modified accordingly. Top-down processing occurs as prior knowledge is used by the reader to make predictions about the data which will be found in the text and the text is then checked to confirm or refute those predictions.

The crucial feature of the interactive model is that for the skilled reader bottom-up and top-down processing occur simultaneously and interact with each other (Adams and Collins 1979; Silberstein 1987; Carrell and Eisterhold 1988).

In other words, for a satisfactory interpretation of the text to occur, incoming information being processed through bottom-up processing and the conceptual predictions being made through top-down processing must be compatible.

The emphasis, then, is clearly on the role of the reader as an active participant in the reading process, and the centrality of the reader and his/her background knowledge has in turn crucial implications particularly for L2 readers of texts, for as Silberstein (1987) puts it:

> no text can be considered generically difficult or easy simply on the basis of linguistic features such as syntactic complexity or word frequencies...texts become easier if they correspond to the students' prior knowledge of language, rhetorical conventions and of the world. (1987:31)

Carrell (1988) proposes five causes for the breakdown of the reading process (see also Silberstein 1987), located at both the level of linguistic deficiency and at the level of cognitive schemata and cognitive style.

For example, a growing body of empirical research (see Carrell and Eisterhold 1988) attests to the role of both content and formal schemata in L2 reading comprehension and to the potential cultural specificity of both types of schemata.

Carrell (1987) finds that they both have a significant effect, but that content schemata are more important i.e. unfamiliar content poses more difficulties for L2 readers than unfamiliar form.

Carrell and Eisterhold (1988:562) note that reading problems may result because firstly, the background knowledge that L2 readers bring to a text is often culture-specific and secondly, implicit cultural knowledge is often presupposed by a text.

In this regard the content of a text can only be understood in its context and the socio-cultural context of the writer may alienate the reader and create a barrier to comprehension. Alderson (1984 in Blunt 1989:5) states:

> Cross-cultural experimentation demonstrates that reading comprehension is a function of cultural background knowledge. If readers possess the schemata assumed by the writer, they understand what is stated and effortlessly make the inference intended. If they do not, they distort meaning as they attempt to accommodate even explicitly stated propositions to their own pre-existing knowledge structures.

The extent to which reading is successful clearly depends on a range of reader and text-related factors; the implications for L2 reading instruction include the need to emphasise both cognitive processes and textual decoding - e.g. the pre-teaching of background knowledge, related terms and vocabulary.

The problem of the implementation of the interactive model of reading in the classroom was addressed by Harri-Augstein et al (1982). They stress that the reader should interrogate the text for meaning and that the text should give the clues; reading should be taught then as a conversation between the reader and the text. This implies that readers need to hold both a process and content conversation with the text.

3.2.3 Cognitive Reading Strategies

In recent years the focus of reading research has shifted from the classification and description of reading skills to an interest in the cognitive strategies that are part of the process of reading (Langhan 1990:30).

While the term "reading strategies" is an all-embracing concept (Pillay 1988); Lanham (1986;1990)) suggests that there are four main cognitive strategies in competent reading. These are:

1. Fitting information present in the text into a background of previous experience.
2. Setting up equivalences between forms of English and the mother-tongue.
3. Anticipating what is to come on the basis of probabilities arising from what has already been read.
4. Constructing for oneself the coherence of the text.

Lanham's work was developed in the context of black primary schools in this country, and consequently relates directly to young L2 readers' competence and the difficulties they may be expected to encounter. However, it is felt that the above four strategies, consistent as they are with schema theory and the interactive approach to the reading process, could serve as a useful framework for considering L2 reading in general.

In conclusion, the role of the reader in the reading process is summed up by Langhan (1990) as follows:

> the reader using cognitive strategies (consciously or unconsciously), is seen to be actively engaged in constructing meaning by interacting with the text, which makes cognitive demands of its own. The cognitively prepared, active reader is therefore as important for the reading process as the text. (1990:35)

How then, in the context of the issues raised in the previous two sections, can school science texts be made more comprehensible for L2 readers?

Before describing how a "text as discourse" approach can be used to analyze the readability and comprehensibility of L2 science texts, we must consider the conventional readability measures which are frequently used in the present assessment of such texts.

3.3 Readability

What is meant by the "readability" of a textbook? There are numerous definitions. Johnson (1979) for example, sees it as being all the factors that affect success in reading and understanding a text.

While Klare (1963 in Young and Nuttall 1989:225) defines it as: "ease of understanding or comprehension due to the style of writing."

Gilliland (1972:83), after considering many definitions of readability, isolates three main areas. He sees readability as involving ease of reading, interest or compellingness and ease of understanding.

The history of readability is exhaustive; according to Chall (1988) readability research grew out of a desire to find "objective" means to determine whether textbooks were suitable for those using them. It was essentially then atheoretical research and, in focusing on the use of text characteristics to predict the reading level at which an average reader would comprehend the text, assumed that the reader had the necessary resources for comprehension.

At this stage it is worth noting that since readability formulas do not set out to define the sources of difficulty in texts, they are not meant to be used as guidelines for writing. Instead they are meant to judge the difficulty of text after it has been written.

Although virtually all readability formulas were developed for use in assessing L1 texts they have been in the past the most widely accepted methods of assessing both L1 and L2 texts. Well known examples are the Flesch Reading Ease Formula, the Gunning Fog Index and the Fry Readability Graph. Like other formulas they basically involve the general use of two text properties, average sentence length and average word complexity.

In general they are regarded as giving reliable estimates of the relative difficulty of texts (Gould 1977). Fry (1988) has this to say about them:

> Despite criticisms of readability formulas, their use has never been more popular. The formulas have had a profound influence on the textbook publishing industry in the past 10 years. (1988:77)

One particular criticism acknowledged by proponents of readability measures is that there is a tendency for writers to use them mechanically. This is done through substituting easier for harder words and shorter for longer sentences. Davison (1988) accepts that by simplifying vocabulary and shortening sentences comprehensibility is not improved.

In an attempt to shift the focus away from only surface structures of text (the semantic and syntactic factors mentioned above), broader aspects of text structure such as organisation, coherence and cohesion have been incorporated into readability measures. Even so Fry (1988) acknowledges that there are kinds of sentence complexity (like nominalisations and kernel theory) that readability formulas cannot pick up.

Given the limitations of conventional readability formulas, a further measure of readability felt by many researchers to reflect more adequately the total language ability of a reader is the Cloze Procedure. The basic Cloze Procedure involves the deleting of words in text at stated intervals (usually every fifth word) which the reader is asked to fill in correctly.

According to Klare (1988) it can provide a good index of comprehensibility. As far as Gilliland (1972) is concerned, the Cloze Procedure is able to measure the ability of a reader to use a variety of contextual inter-relationships to complete gaps left in a text. It measures understanding of, and response to, the language structure of the text. As Rye (1982) puts it, "it measures a personal response to linguistic difficulties".

However, conventional readability measures (whether they be formulas or Cloze Procedures) tend to view the text in isolation. This is because their focus is on the text as product, rather than on the text as a communicative act in which meaning has to be negotiated between the writer and reader using the rules of discourse (Young and Nuttall 1989:229).

Young and Nuttall (1989) go on to discuss another major problem with readability measures, namely that they inaccurately infer that readability is synonymous with comprehensibility (for example see Klare's earlier comment about the Cloze Procedure).

If one accepts that readability is text-focused, comprehensibility is better thought of as an indication of how effectively a reader is able to extract full meaning and understanding from a text, and is as such clearly reader focused. Furthermore, if one adheres to an interactive view of reading, then readability cannot be considered a property of texts alone, but one of text-reader interaction (Kintsch and van Dyk 1978). This is consistent with a schema theory view of reading, in which both decoding ability and text topic familiarity are seen to influence reading comprehension performance. As Zakaluk and Samuels (1988:122) point out, readability formulas in concentrating only on text characteristics, totally neglect how the cognitive processing factors of the reader influence the comprehensibility of text.

To sum up, the significance of the current criticisms levelled at readability measures is this: because of their focus on the text itself they lose sight of a number of important readability factors; in particular, they tend to neglect the one crucial component in any interactive reading model - namely the reader him/herself.

3.4 Text as Discourse

A central focus of this dissertation is my attempt to write a portion of science text which would prove, from a linguistic perspective, to be more accessible to my L2 students.

In line with current interactive views of reading there have been attempts to develop models for textual analysis which assess readability in terms of both text and reader factors. Yet it is unlikely that any single model can take full account of all possible factors in the complex interaction between reader, writer and text (Langhan 1990).

Discourse analysis is itself an extremely complex field, so what I was interested in was a set of guidelines, shaped by the major factors that affect the readability and comprehensibility of science textbooks, which could be reasonably taken into account when writing text materials.

To this end from a theoretical perspective, the work of Halliday and Hasan (1976); Van Dijk (1981); Kintsch and Van Dijk (1978) and Widdowson (1978) was useful. And for more practical applications extensive use was made of Swales (1971), Williams (1985) and Young and Nuttall (1989).

To start with, a view of "text as discourse" was adopted in which texts are seen

> ...as an instance of discourse production - a complex socio-psychological process of communicative interaction between writer and reader which draws on both local (textual) and global (world) knowledge to enable understanding of the text. (Young and Nuttall 1989:230)

3.4.1 Scientific Language

> "Provisionally, let it suffice that some substances form more than one type of oxide..." (General Science in Action 7, Horn et al 1985:106).

When we begin to talk about the language of science we should rather talk of the languages of science, because there are a number of modes of discourse associated with scientific work. Flower (1966) suggests at least five types, one of which is of interest to us here - the supposedly "neutral" (my emphasis) language used in expository science texts.

It is possible to typify the language of such texts; in general most scientific texts adopt a stiff and formal style, restricted to mainly passive, roundabout and impersonal constructions and use complex and abstract language embedded in what Turk and Kirkman (1982:100) despairingly call "the heavy soil of scientific prose". Of an array of features displayed by scientific writing, Strevens (1976) singles out the following:

1. long and complicated noun-phrases
2. a high proportion of passive constructions
3. frequent use of logical connectives
4. a high proportion of items of specialized vocabulary

Sutton (1982:2896) in turn describes a number of features which he believes may create particular difficulties in understanding; three of them are:

1. suppression of the peripheral aspects of word meanings
2. insistence on clearly defined terms
3. the adoption of an impersonal style of reporting

In chapter 2 (section 2.6.1) it is suggested that playing down the connotative meanings of words is a feature of language development in science. Indeed the trend towards precision in language use, particularly in the important area of scientific theorising, is clearly intentional and has as its stated aim the reduction of ambiguity of meaning. To this end authors of science texts attempt to reduce ambiguity of meaning through a scientific style which is in their terms simple, clear and precise.

Yet if one accepts an interactive view of reading, the text itself only has "meaning potential". As Widdowson (1978) and others have persuasively argued, successful reading is an act of creation rather than an act of discovery - for it is the reader who <u>creates</u> meaning through interaction with a text.

Herein lies a problem: scientists assume that scientific concepts will mediate themselves irrespective of language use, that language is somehow neutral or transparent in relation to subject matter (Harrison 1973). This is clearly a false assumption, as Sutton (1980) so succinctly puts it:

> To make a scientific statement meaningful is probably no less difficult or time-consuming than the literature teacher's job in assisting pupils to explore meaning from a line of poetry. The meaning of 'volume is inversely proportional to the pressure' is no more obvious, on first inspection, than that of 'all the world's a stage', and it deserves no less care and time in its interpretation. (1980:50)

The following discussion will focus on the various text-based factors which present reading difficulties for L2 readers of science texts. In what is not intended as an exhaustive review, these factors will be considered under the following general headings: vocabulary, sentence length and complexity, cohesion and coherence.

3.4.2 Vocabulary

All reading models recognise the importance of vocabulary, for it is the aspect of reading most regularly identified by readers as being difficult (Campbell 1987). According to the interactive model for L2 readers, automatic word recognition is more important to fluent processing of text than contextual clues.

Schema theory has shed light on the complex inter-relationship between schemata, context and vocabulary knowledge (Carrell 1983). Words are acknowledged as having a variety of meanings around a "prototypical core" and it is these meanings which interact with context and background knowledge during the reading process. Thus knowledge of individual word meanings is strongly associated with conceptual knowledge; as Carrell (1988:243) puts it "learning vocabulary is also learning the conceptual knowledge associated with the word."

This has important implications for the way in which we view the vocabulary problems L2 readers experience. As

Carrell (1988) goes on to suggest, merely presenting a list of new or unfamiliar vocabulary items in a text (even with appropriate definitions to their use in that text) does not guarantee improved reading comprehension of the text passage.

As even a cursory study of a school science textbook will show, scientific writing tends to be loaded with technical terms and definitions which are likely to be associated with key concept words (e.g. **solid; substance; solution**). Often it is assumed, particularly when these appear frequently, that readers have a clear understanding of these key concept words. Yet these words have complex meanings which represent semantic hierarchies and classifications of notions (Lynch et al 1985).

For example, throughout the secondary school science syllabi assumptions are made that students will have an understanding of the difference between, say, an atom and a molecule. Without this understanding, a student will not understand a text in which these two fundamental chemistry concepts are encountered.

In previously reported research I concluded that L2 readers appear to acquire new technical/conceptual terms without too much difficulty. This does not mean that the terms and concepts are clearly understood, but rather that they are readily learned, the memorising of such words being seen as a necessary part of negotiating the subject matter (Clark 1987:5).

The problem seems to lie more with the non-technical vocabulary of scientific texts. As Barnes (1969) concludes from analyzing the language used in a number of science lessons, it is the general vocabulary words with a scientific bias which actually constitute the language of science communication.

Even though Barnes' work is of limited value in that it does not pursue its investigation beyond the level of the sentence, his three categories of language of instruction are worth noting:

1. Specialist language presented: the technical/conceptual terms specific to the subject e.g. diffraction, mole, force.
2. Specialist language not presented: the specific terminology of the subject e.g. suspension, particle, diagram.
3. Language register of secondary education: the language of the textbook e.g. similar, compare, determine.

Wegerhoff (1981) suggests that for L1 readers, it is the words falling into the second and third registers which primarily create comprehension problems. The same difficulties, albeit on a broader scale, are experienced by L2 users of the same science textbooks (Clark 1987).

Clearly one of the problems which L2 readers face is that familiar words and phrases become invested with new technical meaning. "Naked" as in "the baby is naked" will be understood, but its same use embedded in a particular scientific context "a candle has a naked flame" does not hold for an L2 reader anything like as obvious a meaning. Johnstone and Cassels (1978) make the point that if students are struggling to acquire new vocabulary, in order to avoid confusion the multiple meanings of words must be dealt with as they arise.

They give the example of the word "fused" which when correctly used in science means "melted"; in everyday speech it is applied to electric lights or appliances which are not functioning. It is not surprising then that referring to "fused salts" in chemistry proves puzzling to students.

Furthermore, as Sutton (1980) notes, poor readers (and here we would have to include most L2 readers) struggle to use for themselves the "thinking words" which mobilise the technical terms, and also, when faced with unfamiliar words in a text, find it difficult to use contextual clues to deduce meaning.

Science texts, particularly those dealing with topics in physics, contain various forms of mathematical symbolism. This symbolism, in its now internationally accepted form, is a shorthand of symbols and terminology, the bulk of which, as Austin and Howson (1979) point out, has been devised by speakers of a few closely related languages. Not surprisingly then, as with the formal language codes of science, L2 students face a range of related problems when attempting to interpret and manipulate the syntax and specialised vocabulary of mathematics.

Chemistry itself has its own system of symbolism. The primary purpose of chemistry is the description and explanation of chemical changes (Hesse and Anderson 1992). Such chemical changes are expressed in the form of an equation. When writing and balancing these equations students have to learn to manipulate a variety of symbols including coefficients and subscripts. Here it has been found (see Yarroch 1985) that students' problems lie not so much with the mechanical manipulation of symbols but with the conceptual understanding of chemical changes implied by those equations.

Langhan (1990), in an overview of recent literature on vocabulary in content area textbooks, highlights a number of significant aspects which are likely to affect the readability of textbooks prescribed for young L2 students. Many of these factors are also mentioned by Williams (1985) and Young and Nuttall (1989) as general causes of readability problems for L2 readers of expository texts.

The following aspects of vocabulary have to be borne in mind when writing science texts for L2 readers:

1. Words of high frequency and/or familiarity will contribute to more readable writing.

> e.g. "Today handy appliances <u>enable</u> you to prepare your own soda drinks at home". "Enable" could be replaced by "allow".

2. Concrete vs Abstract terms.

Concrete words are more readable than abstract words. Williams (1985) makes the point that for the L2 reader abstract words are a particular problem when they are used in quick succession. A feature of scientific writing is its use of verbs of Latin origin rather than phrasal verbs.

e.g.	consume	use up
	place	put
	invert	turn upside down

3. Shorter words are usually of higher frequency, and are therefore usually more familiar.

e.g.	about	approximate
	look	appearance
	often	frequently

4. Active vs Passive verbs

Strevens (1976) notes that scientific English displays a high proportion of passive constructions. Turk and Kirkman (1982:120) suggest that nominalisation is encouraged by the traditions of scientific and technical reporting which seem to require impersonality.

However Young and Nuttall (1989:244) argue that because active verbs are shorter, more familiar, and promote stronger mental images, they are in fact more readable than passive verbs.

> e.g. "acid acting on zinc produces hydrogen gas" is clearer than "hydrogen is produced by the action of acid on zinc".

5. The use of modals in scientific statements

These are words which are used with the base form of the verb to give extra meaning to the sentence. They are frequently used to make statements of possibility and probability ("the jar may break when dropped"); written warnings and instructions ("students should be careful when using acids") and predictions. The modal "will" may (!) present L2 readers with particular difficulties because it changes a statement into a prediction.

e.g. "the acid reacts with the alkali" is a statement. "the acid will react with the alkali" is a prediction.

6. The use of compared nouns, qualified comparative statements and qualified time statements.

"Benzene does not have as high a boiling point as water" is not as easily understood as "water has a higher boiling point than benzene".

Assumptions are made in a statement like "a meter is slightly longer than a yard" that the reader shares a similar perception to the author as to how much is meant by "slightly longer".

Statements of time can be "qualified" by using approximately, over, under, about. To avoid confusion students have to be clear of the way in which these "qualifiers" are used.

e.g. Is it clear to the reader what is intended by "heat the test tube for approximately one minute"?

7. Idioms and idiomatic expressions can cause great difficulty for L2 readers. The role of metaphorical language has already been discussed in the previous chapter. In the example used above, "Today handy appliances..." assumes that the student understands the idiomatic use of the word "handy".

8. Noun compounds.

Long and complicated noun-phrases are identified by Strevens (1976) and Williams (1985) as a common feature of scientific texts. When they also contain ellipsis (the practice of omitting words whose inclusion may cause unnecessary repetition), they can cause problems for L2 readers (Young and Nuttall 1989:245).

> e.g. "paired valence electrons lead to ..." could be rewritten "valence electrons which are paired lead to...".

9. Abuse of terminology equals jargon and makes the reader's task that much more difficult (Williams 1985:18). An added problem is that some scientific words have different meanings in different sciences.

> e.g. the word "nucleus" found in both science and biology texts, has a specific meaning in each.

There can be unexpected difficulties with certain specialist words.

> e.g. In Standard 8 science a study is made of some of the properties of waves. Two of these, "refraction" and "reflection", are often confused, in fact many students talk and write about "reflaction" of waves.

On introducing new words and specialist terminology

Given the nature of scientific writing, the L2 reader continually comes up against new words in a textbook. Not only the specialist terminology of the subject but also numerous items of non-technical vocabulary may cause reading difficulties. The way in which new vocabulary items are introduced is therefore of crucial importance.

Young and Nuttall (1989) note five basic ways in which help is given to the reader:

1. Definitions - without careful explanation these may prove extremely problematic.
2. Familiarisation strategies - these include restatement in more comprehensible terms.
3. Explanation through analogy, synonym, etc...
4. Support from the surrounding context.
5. Glossing - the inclusion of a glossary either at the end of each chapter or at the end of the book is not a common feature of school science textbooks in this country. The workbooks produced by the Science Education Project (SEP) include at the beginning of each book a glossary of terms and definitions which will be encountered in the text.

Williams (1985) suggests that there are a number of readability aspects to glossing which have to be borne in mind, including:

- The Standard dictionary format is not always suitable.
- Care has to be taken not to include too many abstract words which will further hamper understanding.
- A gloss should not contain a syntactic structure which would not be used in the text itself.
- Examples in glosses are almost always helpful.
- A gloss should not contain words that are more difficult than the word being glossed.

3.4.3 Sentence Length and Complexity

1. Overlong sentences are difficult to read

> If an orbital could contain three electrons instead of two, as ascertained by Pauli, and all other assumptions and information regarding the modern electron structure remain the same, which elements would have been the first and the second noble gases? (Brink et al 1985:165)

One does not need a readability formula or any other form of analysis to predict that this sentence will prove difficult to read it is simply far too long. This is in large part due to the way in which we read. Our short-term memory is only able to hold a limited number of words at any one time. Long sentences overfill the short-term memory and meaning is lost.

Generally speaking, shorter sentences are easier to read. However it is important to note that too many short sentences will disrupt the flow of information. What is needed are sentences of variable length. Turk and Kirkman (1982) suggest that it is the complexity of the information being presented in a text which should determine the comfortable sentence length.

Besides sentence length, a variety of other factors has to be taken into account, including the following:

2. Extended subjects

Extended subjects make it difficult for the L2 reader to identify what Williams (1985) refers to as the "sentence skeleton" and this seems to be a particular problem in scientific texts. The readability problems associated with extended subjects are that firstly, the main verb occurs too late in the sentence and secondly, the main verb is too far away from its co-referent noun phrase.

3. Passive Voice

Passive structures are a typical feature of scientific texts. They provide emphasis, by bringing to the head of the sentence the thing acted upon, rather than the thing doing the action. Although this is a useful grammatical device, Turk and Kirkman (1982) point out that many scientific texts contain an unusually high percentage of passive constructions (they mention one study which found a total of 32% compared to 6% in samples of descriptive texts).

Alvarez (1980:51) suggests that the anonymity produced by the passive voice appeals to scientists who wish to remove the human element from scientific writing to reflect what they regard as the objectivity of scientific observation. Yet, as discussed elsewhere (see Chapter 4), the notion of objectivity in science, as in everything else, is relative and for this reason alone the excessive use of passive constructions is questionable.

What ever their stated aim, passive structures can unfortunately lengthen and elaborate sentences unnecessarily and in so doing create an additional comprehension burden for L2 readers. Indeed, their added complexity can be the "straw which breaks the back of the reader's comprehension" (Turk and Kirkman 1982:121).

Nowhere is it suggested that there be a complete ban on the use of passives in scientific writing, rather that their unnecessary use be avoided as far as possible.

4. The cumulative effect of syntactic complexity

The reading of school texts is seldom a case of reading isolated or individual sentences, and any individual syntactically complex sentence does not in itself create a readability problem (Young and Nuttall 1989:255). According to Williams (1985) the really important point is that the impact of syntactic structure on readability is cumulative. He illustrates this as follows:

?	A familiar structure in isolation will not be a problem.
??	But the less familiar a structure in isolation, the greater the readability problem,
???	Particularly if accompanied by unfamiliar words.
????	Furthermore, the effect of a sequence of structures that are difficult to process will add to the problem.
?????	A structure embodies not only grammar, but also meaning. Therefore, if unfamiliar structure additionally presents a newly-introduced item of content, then the problem grows,
??????	moreso, if a sequence of items of new content is introduced in quick succession.
???????	If all this is accompanied by unhelpful, cosmetic artwork, poor paragraphing, inadequate cohesion, misleading punctuation, etc., then the reader is in deep trouble. (1985:39-40)

3.4.4 Cohesion

Young and Nuttall (1989) define cohesion as follows:

> Cohesion in a text refers to the relationships that exist within and principally between sentences, and which make a text an integrated unit rather than a collection of unconnected independent sentences. (1989:256)

According to Halliday and Hasan (1976) there are two broad categories of cohesive devices found in texts; namely lexical and grammatical cohesive devices. Important lexical devices include the use of collocations and reiteration; while grammatical devices include substitution, ellipsis, reference and conjunctions.

It is important to locate this discussion within a framework which is consistent with an interactive view of reading. A serious limitation of Halliday and Hasan's cohesion theory is that it is text-bound in the sense that it gives a systematic account of a text's structure, while failing to take into account the contribution of the reader in constructing textual meaning (Langhan 1990).

In the light of a schema-theoretical view of reading, Widdowson (1978) views text as discourse, which involves the writer, text and reader in working out meaning. He offers a perspective on cohesion which extends beyond the lexical and grammatical items described by Halliday and Hasan and perceives it to be the "overt relationship between propositions expressed in sentences". As he puts it:

> The notion of cohesion, then, refers to the way sentences and parts of sentences combine so as to ensure that there is propositional development. (1978:26)

For Widdowson, sentences are appropriate in form to the extent that they allow for effective propositional development. From this perspective, cohesion is less important than coherence for meaning, and a text may be coherent without being cohesive.

We will now briefly consider how an awareness of cohesion can affect the readability of science texts for L2 readers.

1. Substitution and lexical reiteration

These can be considered together, and refer to situations where one item (be it a word or phrase) within the text is replaced by another. According to Williams (1985) substitution does not have a major impact on readability, although he does suggest that certain categories of lexical reiteration should be made more explicit. In particular Young and Nuttall (1989) warn that problems may arise when a general noun is used to replace a phrase or clause.

2. Ellipsis

Ellipsis and substitution are essentially the same process. Because ellipsis involves replacing the item by nothing, it has been referred to by Halliday and Hasan (1976) as "substitution by zero". Although it is a common cohesion device in English, it has been identified by Lanham (1990) as posing a problem for young L2 readers, one of the reasons being that it has little or no equivalence in African languages. Williams (1985) suggests that ellipsis may pose a potential problem as a result of separation from its co-referent.

3. Reference

When one item in the text refers to another, either in the text or outside it, this is termed reference. Reference devices have been divided by Halliday and Hasan (1976) into two main categories: exophoric (outside the text) and endophoric (within the text) reference. The two types of endophoric reference are identified by Williams (1985) as having an impact on readability:

a) Anaphoric reference - occurs when certain words in a text "link back" to preceding, co-referent more explicit words or phrases. If the anaphoric item and co-referent are separated by too great a distance there is a danger that the linkage between them is lost.
b) Cataphoric reference - occurs in a text when words "link-forward" to co-referent, more explicit words, phrases, or even sentences. Similar problems may arise if there is considerable separation between the cataphoric item and its co-referent.

4. Conjunctions

The function of conjunctions (or "discourse markers") is to indicate to the reader the general relationship between he has just read, and what he is about to read. Conjunctions are words or phrases which serve to link sentences, occuring between prepositions in a sentence, or between a preposition and a concept. Examples are: also, because, therefore, that is, if...then, and so on.

Conjunctions constitute a very important element of cohesion which has been specifically identified as causing comprehension difficulties for L2 readers of science texts (Strevens 1976). In this regard the work of Gardner (1980) into what he refers to as "logical connectives" is particularly important.

In the course of his research Gardner identifies 200 logical connectives which occur relatively frequently in secondary school science textbooks. He finds that L1 learners experience problems in the use and understanding of certain of these logical connectives. In particular words like "conversely" and "moreover" are considered to be extremely difficult.

Recent research undertaken by McNaught (1989) and Cumming (1991) has broadened this work into a black L2 context. Working among Swazi students in KaNgwane in South Africa, Cumming (1991:65) concludes that L2 learners also experience similar difficulties with logical connectives. Moreover, these difficulties are compounded because English, the language of the textbook, is not their mother tongue.

3.4.5. Coherence

As Steffenson (1981) points out, a number of researchers have objected to Halliday and Hasan's basic premise that coherence is created by cohesion. In the light of schema-theoretical views of reading, Carrell (1982) criticises the concept of cohesion as an index of textual coherence. She is particularly critical of the belief that coherence is located in the text and as such can be defined as a configuration of textual factors.

Because reading is an interactive process between reader and text, the contribution of the reader's background knowledge in "constructing" the coherence of any text has to be taken into account. In this respect Johnson (1981) goes so far to suggest that inaccessible background knowledge is the single most significant factor in reading comprehension.

A further aspect of textual coherence identified by Lanham(1990) as likely to present problems is that of missing propositions. Every text contains missing propositions or information gaps, in which the writer makes assumptions about the kind of background knowledge of the topic available to the reader of that text.

This can be a particular problem in science texts where the world view or life experience of the writer and reader are often so markedly different. As mentioned before, the majority of science texts presently in use in black L2 classrooms in South Africa were written with a white L1 audience in mind. Consequently it can be argued that these books have a distinctly Eurocentric bias which places an additional burden on L2 readers who not only have to cope with the complex and abstract ideas of formal science, but also find them embedded in context-reduced texts far removed from their own life experiences.

To give just one example of an "out-of-context" statement, consider the following:

> Have you ever noticed how the colour of black tea becomes lighter when lemon juice is added? (General Science in Action 7, Horn et al. 1985:99).

How many Standard 7 students sitting in a village classroom (or township one for that matter) would know what to make of that? Clearly writers must take into account the kinds of background knowledge readers bring with them to the text, and one way of avoiding confusion is to make propositional links explicit wherever possible.

In focusing on the text itself, Williams (1985:56) considers a coherent text to be one in which the contents are expressed and sequenced in a logical, natural, systematic manner so that the writer's message is perceived by the reader in exactly the manner intended. He goes on to suggest seven guidelines for making a text more coherent:

1. Headings should be meaningful and predictive.
2. The contents of a heading should be reinforced as soon as possible.
3. Chapters should begin with overviews of their contents, sequence, and interrelationship.
4. Paragraphs should be structured.
5. It is particularly important to sequence information in a natural and consistent manner.
6. Tabulation is often more readable than prose.
7. Readers read artwork as well as prose.

Seeing that almost every page of any school science textbook has an illustration of some kind (be it a graph, table, photograph, diagram etc), the extent to which they help or hinder comprehension is of considerable importance. If we take an interactive view of reading an illustration cannot be considered in isolation; there are two equally important factors, the reader and the visual itself which determine whether or not it is "readable".

Langhan (1990) quotes the work of Benjamin (1989) who concludes that a working knowledge of "visual literacy" is often determined by environment and that depending on the socio-economic conditions, fairly severe problems with visual literacy may be encountered in many black schools, particularly in rural areas. It is not surprising that Langhan (1990:87) goes on to suggest that, as far as illustrations are concerned, the textbooks written and illustrated for white schools are unlikely to be suitable for L2 black students.

Clearly care must be taken to ensure that visual materials do not create additional learning difficulties. Not only must illustrations be carefully integrated into the text, but also methods of reading and interpreting pictures have to be learnt by students.

In conclusion, this chapter began by suggesting that the textbook is in all subjects the primary resource for teaching and learning. This has profound implications in a subject like science where the reader is exposed to forms of written text which create, by virtue of the language used and the material being taught, additional comprehension difficulties. Furthermore these problems are exacerbated for L2 readers when faced with context reduced texts which were clearly not designed for their linguistic situation. The inappropriateness of such texts is regarded as one of the major causes of difficulty in learning science at the secondary school level.

Turning to reading, it is regarded as a process in which meaning is "reconstructed" through a complex interaction between reader, writer and text. Such an interactive view of reading is clearly better able to analyze both text and reader factors than conventional readability measures.

It is suggested that a process of text production in science can draw on a discourse analysis approach for guidelines on how to write, from a linguistic perspective, more accessible texts for L2 readers. To this end the rest of the chapter was devoted to a discussion of the major factors which affect the readability and comprehensibility of science texts.

Chapter 4

Some Issues in Science Education

4.1 Discovery Learning in School Science

It can be argued that over the past few decades science education, particularly in Western countries, has embraced with varying degrees of enthusiasm a number of different orthodoxies, ranging from those with a traditional content driven focus to those which emphasize a discovery-process approach.

The late 1950s marked the end of a long period of stability in the science curriculum (Reid and Hodson 1987). Fensham (1985) argues that since then two distinct societal demands have been placed on science education, firstly the need for specialist manpower and secondly the need to develop a more scientifically literate citizenry. In order to meet these demands science, as it was known in the curriculum of elite secondary schooling, had to be extended to a much wider cross-section of school learners. This necessitated the presentation of the specific conceptual content (or "knowledge-worth-knowing" as Fensham 1985 describes it) in new forms of pedagogy.

In the development of new science curricula emphasis was placed on the process skills of science (observing, classifying, inferring, hypothesizing etc...) as well as, or as a means to, traditional knowledge content. This was linked to a more broadly pedagogical approach that has been described as discovery-, activity- or experienced-based learning.

This "new approach" - discovery, with its catchphrase "being a scientist for a day" (Nuffield Physics, 1966:3), became a major tenet of many school science curricula projects developed in the UK and USA in the 1960s. In turn these influenced the development of science curriculum in other parts of the world. In the 1960s numerous courses like Nuffield Science in the UK, Harvard Project Physics in the

US and the Australian Science Education Project (ASEP) were developed. Recent initiatives like the "Warwick Process Science Project" represent ongoing attempts to develop a "process"-led science curriculum in contrast to the pre-Nuffield "knowledge"-led courses (see Screen 1986).

A characterisation of school science within a "process" approach clearly resonated well with the wider ideology of school science. Science as method - a "process" emphasis - was welcomed as an alternative image to the traditional one of science education being the transmission of the given corpus of accepted knowledge (Millar 1989a). According to Hodson (1986b) the major impetus in the adoption of discovery learning seems to have been the fusion of inductivist ideas about scientific method with more progressive child-centred views which emphasize more direct experience and inquiry.

Within this approach it is taken for granted that science is a practical subject and consequently school science courses place great emphasis on students engaging in practical work. Furthermore, implicit in this approach is the notion that the processes of science education should in some sense mirror the work of scientists.

Millar (1987;1989a), refers to a "standard science education" (SSE) view of scientific method and experimentation:

> The popular image of science is of knowledge discovered in laboratories through experiments which validate the knowledge and guarantee its reliability and trustworthiness. The rhetoric of school science draws on this popular image, justifying the prominence of experimental work by pointing to parallels between the pupils' activity in the classroom and the professional activity of scientists. This image of school science has proved a constant strand in science education writings for the past 20 years and more. (Millar 1987:109)

Discovery learning attained the status of near orthodoxy among some science educators (Harris and Taylor 1983), and science education in Western industrial countries became dominated by an inquiry approach with its emphasis on hands-on, student-centred, discovery learning. As Cawthron and Rowell (1978) put it, "the logic of knowledge and the psychology of knowledge had coalesced under the mesmeric umbrella term 'discovery'" (1978:38).

4.2 Criticisms of "Discovery Learning"

In recent years the effectiveness of this approach to teaching science has been called into doubt and courses with a "process" emphasis and the SSE view of science method in which it is embedded have been criticised for reflecting an inadequate understanding of the nature of scientific knowledge and the processes of science. The following discussion will briefly consider a number of these criticisms.

Some of the limitations and shaky presuppositions of "discovery learning" have been outlined by Wellington (1981); a specific criticism has been that it is modelled on a naive inductivist approach which has since become widely discredited (see also Millar 1989b).

With its emphasis on "hands on" student practical work, Woolnough (1983) describes guided discovery learning as "stage managed heurism" in which experiments are arranged so that students "discover" for themselves some important theory. Not surprisingly students see through this artificial game (which is in any event a caricature of genuine discovery), and in response learn to play it by the teacher's rules. Brandon (1981) goes so far to suggest that discovery teaching encourages a fraudulent game of guessing the "right" answer, a view supported by Driver (1975;1983). As Muller (1987) puts it:

> ...experiments are often raised as a panacea for over-theoretical science syllabi...students are often unclear as to what the results mean... (the discovery approach) is akin to the monkeys and Shakespeare story.
> (1987:73)

Woolnough and Allsop (1985), in summarising their overall criticism of practically-based inquiry methods, suggest that most school practical work is a series of restrictive exercises, closed, convergent and dull and in which "knowing is more important than doing" (1985:3).

4.3 Content versus Process: a False Dichotomy

Science teaching is concerned with both content and processes; on the one hand there is a body of knowledge (the agreed upon important content and concepts of science and their inter-relationships) and on the other, the processes (observation, estimation, measurement, planning, interpretation etc.) which are used by problem-solving scientists in their everyday work. According to Watts and Bell (1985), proponents of "process science" argue that because it actively involves students in learning, it reflects a more "progressive" pedagogy than teaching content which they associate with passive learning.

In a further criticism of the process approach, Millar and Driver (1987) argue that any such dichotomy between content and process is a false one. Drawing on the generative learning model described by Osborne and Wittrock (1983), they argue that any learning of content (in a non-trivial way) involves the learner in an active process of knowledge construction (see the discussion on constructivism which follows).

On another level, the teaching of these two aspects of science often requires different approaches, yet guided discovery learning at times attempts to master both content and process simultaneously, and this may lead instead to an inadequate understanding of both.

In any event, the whole question of what actually constitutes science process skills needs to be very carefully considered. For one, Wellington (1981) suggests that the belief that school science can be made more accessible to a much wider range of ability if it emphasizes the teaching of skills and processes is based not only on the misconception that science proceeds inductively but also that scientific observation, classification and so on, are independent of theory (Wellington 1989).

In particular, the unreliability and the theory-dependence of observation has been stressed by a number of authors; for example Hodson (1986b:385) suggests that what we choose to observe and the way in which we choose to observe are dependent on our knowledge and expectations (see also Driver and Johnston 1989; Hodson 1986a; Norris 1984). Indeed a current view in the philosophy of science is that there is <u>no such thing as scientific method</u> (see Hodson 1982 for an outline of some of the main arguments as they relate to science education). Furthermore, it is now almost universally conceded that there is no algorithm for gaining or validating scientific knowledge (Millar and Driver 1987:40). Maskill (1988) has the following to say about the logic of scientific method:

> the idea that scientists solve problems in a characteristically logical and superior way has been part of the mythology of science for some time. (1988:491)

From such a perspective the idea that separate "scientific processes" are uniquely characteristic of the way in which scientists' work also fails to stand up to scrutiny (Millar 1989a; 1989b). For many of these so-called "processes" are common-sense reasoning and as such have no special link with science; they are simply convenient labels for the general approaches which each of us uses all the time in making sense of the world. In many ways students are scientists in their natural way of working, for everyone is motivated to explore their world and to seek to interpret it for themselves and then make sense of it (Driver 1983).

Mindful of these criticisms of a process approach, I would however agree with Moodie and Rogan (1987:16) who argue that at the very least it provides a framework that can be used to help structure student activity and make it meaningful. An approach which emphasizes process skills (whether they reflect "scientific" or "common-sense" reasoning) can be useful in creating effective interaction between the learner and the content.

4.4 Science as Craft

In the light of the above discussion, what would be a more useful description of science? Gardner and Gauld (1990 cited in Hodson 1992:182) see it as a

> theory-driven, creative endeavour, in which knowledge is negotiated, within the scientific community, by a complex interaction of imagination, observation/experiment, theoretical argument and personal opinion.

Collins(1985) suggests that scientific enquiry cannot be portrayed as rule following but involves the exercise of skill; doing science can be seen then as being more like the skilful exercise of "craft skills" (Polanyi 1958; Ravetz 1971) than the following of an algorithm. This has lead to notions of "science as craft" (for more details see Woolnough 1986; Wellington 1989; Millar 1989b). From such a perspective, "doing science" has much similarity with the realms of music, literature and art - we should recognise that the practice of being a scientist is both an art and a craft (Woolnough and Allsop 1985:35).

Such a view of science has implications for what is taught in this subject at school. Practical work in particular remains of central importance; as Ravetz (1971) notes, one cannot be a craftsman unless one can manipulate one's tools. Clearly, the art and craft of a scientist can only be developed through practical "hands-on" experience. What is at issue is the kind of practical work that is undertaken. Woolnough and Allsop (1985), who deal extensively with this topic, basically argue for separating content from process and for "cutting the Gordian knot", thereby releasing practical work from the restraints of teaching theory. They make the point (1985:38) that many important scientific principles and concepts are elegantly simple, and that too often we hide them by experimental trivia. Furthermore, basic theory can be taught clearly through demonstration and discussion and where science deals with theoretical concepts and their interrelationships, these abstract concepts have at times to be considered in the abstract (and manipulated abstractly as well).

Clearly what is needed is a stance on teaching and learning in science which transcends the conventional dichotomies of content and process. Rather than teaching science as infallible, received knowledge the "rhetorical balance" needs to swing back some way from science as "personal enquiry" towards science as "common knowledge". As Driver and Johnston (1989) put it:

> Learning in science is characterised neither by learning 'content' nor by learning 'process' but a dynamic interaction whereby pupils continually and progressively construct and reconstruct their understanding of the world. (1989:76)

What children learn depends then not only on what they abstract from the learning situation but also on the mental constructions they bring to it (Millar and Driver 1987). In endeavours to recast the nature of the teaching/learning interaction in science classrooms an approach to research in science education has grown rapidly in prominence over the past decade or so. Termed constructivism, this view of science teaching and learning will now be considered.

4.5 Constructivism

Constructivism is not the same as discovery learning (Millar 1989a); it is an umbrella for a range of theories and theorists who share common points of view (Watts 1991).

From a constructivist perspective learning is seen as an active process in which each learner is engaged in constructing his/her own meanings whether it be from text, dialogue or physical experiences (Driver and Bell 1986; Osborne and Wittrock 1983).

From the mid-1970s a considerable body of science education research began to focus on probing learners' understanding of specific topics in science or of specific science concepts. Carmichael et al (1990) in a recent bibliography document almost a thousand papers and listed 12 journals which frequently publish papers in this field.

Much of the research has been unashamedly descriptive (see Driver and Easley 1978; Erikson 1980), the "interview about instances" technique developed by Gilbert and Osborne (1980) being but one example of those developed to identify and elaborate an individual's ideas. Not surprisingly, numerous studies found that learners have firmly held views about many science topics prior to being taught science at school. As Osborne and Wittrock (1983) put it:

> Children develop ideas about their world, develop meanings for words used in science, and develop strategies to obtain explanations for how and why things behave as they do, long before they are formally taught science. (1983:491)

From the range of allied notions used to describe the beliefs which learners hold, variously called "alternative frameworks" (Driver and Easley 1978), "alternative conceptions" (Osborne and Gilbert 1980), "children's science" (Osborne et al 1983) etc, Gilbert and Swift (1985) coined a term for this "invisible college" - the "Alternative Conceptions Movement" (or ACM for short).

According to Watts (1991), the root metaphor for the alternative frameworks which learners hold is Kelly's Theory of Personal Constructs (see also Watts and Pope 1989). Kelly (1955) lays great stress on the uniqueness of each person's construct system; a key assumption within his theory is the "individual corollary" - persons differ from each other in their constructions of events.

A constructivist model of science learning sees concept change as the interaction between existing conceptions and new experiences. Concept learning is understood as a reconstruction of meaning rather than the simple accretion of new ideas (Millar 1989c).

The cognitive psychologist Ausubel in his "Assimilation Theory of Learning" introduces the concept of "meaningful learning" and distinguishes it clearly from rote learning:

> Meaningful learning involves a conscious effort on the part of the learner to relate new knowledge in a substantive, non-arbitrary way to relevant existing concepts or propositions in the learner's cognitive structure. In contrast, rote learning results in arbitrary, verbatim incorporation of new knowledge into cognitive structure. (Novak 1978:4 citing Ausubel 1968)

A model of conceptual exchange - in which a person exchanges an existing conception for a more satisfactory alternative conception is developed by Posner et al 1982. Hewson (1981) extends this model to include conceptual capture - the process whereby a person incorporates a new conception by reconciling it with existing concepts.

Elsewhere, Hewson (1982), suggests and illustrates by example that instructional strategies can be adopted which facilitate conceptual change through explicitly addressing a learner's existing knowledge.

If knowledge construction is seen solely as a personal process Driver (1989) regards this as being similar to what has traditionally been identified with discovery learning. Rather than focusing on the individual's personal construction of meaning, Solomon (1983a;1983b;1983c;1984; 1987), draws on the work of Schutz and Luckmann (1973) and Berger and Luckmann (1967), to locate learning theory within a sociology of knowledge which acknowledges the importance of socially constructed meaning.

As Driver and Johnston (1989) put it, learners do not operate as isolated cognitive beings; they continually try to make sense of any learning experience in both personal and social terms. Not only do individuals make sense of the world through their own personal internalized schemata, but they also seek to integrate their internal models of the world into a socially constructed picture. Reinforced through communication with others and by language itself, these social constructions constitute what Solomon (op cit) refers to as "life-world knowing" and as such have both social value and great persistence.

However during a secondary process of socialisation, such as schooling, other interpretative systems of knowledge may be learnt (Solomon 1983b). The problem lies in that these two coexisting spheres - everyday notions and scientific explanations - are very dissimilar:

> socially acquired meanings are not consistent and logical; they more resemble maxims like 'Too many cooks spoil the broth' - true for soup-making but not for peeling large quantities of potatoes. (Solomon 1983c:227)

That there are clear differences between "real science" and chidren's intuitive views of the world is no surprise, as Hodson (1986a) puts it:

> science utilizes non-observable entities, complex abstract relationships, precise technical language and all-embracing views; children prefer simple, self-centred, direct explanations for specific things.
>
> (1986b:389)

Faced with, for example, the non-rigorous words and meanings of the life-world and also the consistent, defined, but rarely used, concepts of science, learners have to be able to think and operate in two different domains of knowledge and be capable of distinguishing between them (Solomon 1983a). Well documented is the difficulty learners have in crossing over between the two domains of knowledge (Solomon 1987); this impacts strongly on the teaching and learning activities generated in the science classroom. For example, numerous researchers (see Gunstone et al 1981; Osborne and Gilbert 1980; Watts 1982; Osborne and Wittrock 1983; Solomon 1983c; Gauld 1989 and Baxter 1991 to name a few) have shown how tenacious and highly resistant to change learners' ideas are. Not only does socially acquired life-world knowledge constitute at times a barrier to learning, but there is also no guarantee that following instruction learners' ideas will change in the intended direction (see Gilbert, Osborne and Fensham 1982) or that after adopting the orthodox school science view they will not regress to the everyday ways of explanation (Happs 1985).

4.6 Consequences of Constructivism for Teaching

Gilbert, Osborne and Fensham(1982) postulate a series of consequences of children's views of science for science teaching. From the "undisturbed childrens science outcome" to "the unified science outcome" they advance, in the view of Gilbert and Swift (1985), what amounts to a taxonomy for alternative conceptions.

This perspective generates a different view of teaching in the classroom and resonates well with a "sociology of scientific knowledge" perspective (Kuhn 1970). Science teaching is seen as the transmission of a body of consensually accepted knowledge - science as "common knowledge" rather than infallible, received knowledge (Millar 1989a). Learning science is essentially then a process of culturation into the ideas and models of conventional science (Driver 1989). Worth noting are the following features of a constructivist perspective as it impacts on schooling:

1. Learners are not passive; they are purposive and ultimately responsible for their own learning. They bring their prior conceptions to learning situations.
2. Learning involves an active process on the part of the learner, involving the construction of meaning.
3. Knowledge is not 'out there' but is personally and socially constructed.
4. Teachers also bring their prior conceptions to learning situations.
5. Teaching is not the transmission of knowledge, but involves the organisation of classroom situations or design of tasks which will promote scientific learning.
6. Curriculum is not that which is to be learned, but a programme of learning tasks, materials and resources from which students construct their knowledge (Driver and Bell 1986; Driver 1988; Watts 1991).

Driver and Oldham (1986), in an article on the "Children's Learning in Science" project (CLISP), describe what amounts to a constructivist model of instruction (see also Osborne and Wittrock 1983). Briefly, its key features include the following:

1. A need to devise learning materials which take into account students' prior ideas
4. Ways of working which encourage learners to become both individually and collectively active in the learning process
3. Making the implications of adopting a constructivist perspective for classroom practice explicit.

Driver, Guesne and Tiberghien (1985) have suggested that if we understand learners' prior ideas we can better choose which concepts to teach in school science, and then challenge their prior ideas directly by experiences which conflict with expectations, so provoking learners to reconsider their ideas. The science teacher's task then is to arrange appropriate learning experiences for the students in a range of contexts, so that the students are able to build up personal constructs which can lead to increasingly meaningful learning.

Adopting a constructivist view of learning has important implications for curriculum design (Posner et al 1982). From a constructivist perspective curriculum is "the set of learning experiences which enable the learners to develop their understanding" (Driver and Oldham 1986:112)

Curriculum is seen then as a programme of activities from which a body of knowledge or skills can be constructed or acquired. The above mentioned CLISP project and the Salters' programme (discussed further in chapter 5) are just two of a number of recent initiatives which attempt to develop teaching and learning strategies whose aim is to encourage children to change their ideas in useful and intended ways, through activities which encourage them to construct scientific ideas for themselves.

It can be argued that constructivist research may improve the sequencing and pacing of science curricula but impact less in terms of changing teaching styles and approaches. Whatever one's position in this respect, it cannot be doubted that constructivism exerts a powerful influence on current thinking in science education. In particular we must accept that the ideas and interpretations which children have for phenomena in the natural world play an important role in their learning experiences in science (Driver, Guesne and Tiberghien 1985). Earlier it was suggested that socially acquired life-world knowledge may at times constitute a barrier to learning; Solomon (1987) has this to say:

> social influences are pervasive and strong... they spring from a familiar ineradicable style of knowing which can discourage access to the realm of scientific thinking. But the problem cannot be avoided. Our pupils are strongly social beings for whom the teaching of a rigidly insulated science which makes no contact with the everyday context is simply not an option. Social influences of every kind permeate both the learning of science and its application. (1987:79)

School science does not take place in a vacuum, for there is in any classroom a social <u>and</u> cultural context which will have a significant impact on both the teaching and learning of the subject. In this respect, there is a growing awareness among science educators of the need to relate science more closely to the learner's societal or cultural environment (Ogunniyi 1988). For effective science education must take into explicit account the cultural context of the society which provides its setting and whose needs it is supposed to serve (Wilson 1981 see also Biesheuvel 1972; Odhiamba 1972; Ogunniyi 1984). Some current issues relating to the cultural context of science education in Africa form the basis of the following discussion.

4.7 The Cultural Context of Science Education in Africa

> (there are) two fundamental truths about education: education is the same everywhere, but education is always different, because of the context. (Kahn 1990:133)

Over the past 30 years, particularly during what Knamillar (1984) refers to as the "great adoption decade" of the 1970s, there has been a wholesale exporting of syllabi, textbooks, apparatus and examinations from the West to the Third World.

The recent history of science education internationally is the story of the tensions which have arisen from such uncritical transfer. This has lead some educators (see Kelly and Altbach 1978) to refer to the influence which developed countries exert over developing countries in this regard as a form of "academic imperialism".

> It is an incontrovertible fact that the vast majority of education systems in the Dcs (developing countries) are linear descendants of those of the former colonial powers, and not only are they descendants, but that they remain tied to their source. (Kahn 1990:132)

One criticism of the process of importing Western science curricula into African contexts is that it often involves only superficial adaption of the materials for local conditions. As Wilson (1981:27) put it "Lagos for London, cedis for dollars, mangoes for apples". Yet there are, according to Ogunniyi (1986), enough well-informed opinions and research evidence to show that the type of science taught at schools provides at best, ready made knowledge isolated from the black student's cultural background (see also Cole 1975; Ogunniyi 1983). This has led Ingle and Turner (1981) to characterise the majority of African science curricula as "cultural misfits".

Any cultural context is naturally an extremely complex web of factors (linguistic, social, religious etc...) forming a unique amalgam. Some of these factors may be supportive of initiatives in science education, others not. An interesting perspective is provided by Prophet (1990), who argues that although there is, in Western countries, a clear discontinuity between the "scientific culture" (as taught in school science courses) and the "common culture", at least there is between the two a background of shared experience, language and knowledge.

It seems reasonable to assume that there will be an even greater/more marked discontinuity when Western science curricula, with their values firmly rooted in their own culture, are brought into another culture with its different patterns of thinking, speaking and doing.

A failure to appreciate the cultural context of learning is clearly to blame for some of the problems faced by science curriculum development in African countries (Prophet 1990). This view is echoed by Urevbu (1984) who goes on to suggest that perhaps the greatest challenge facing science curriculum development in African countries is to bring what Horton (1971) calls "African traditional thought" into school science.

The African traditional world view has been variously described as a system of religious and philosophical beliefs that exists in traditional African society (Jegede and Okebukola 1991): events have a cause, but that cause is seen in personal terms- another person, a spirit or a god (Odhiambo 1972; Wilson 1981). Horton (1971) argues, in a very persuasive article, that on the basis of West and Central African research at least, there does appear to be a fundamental difference between the forms of thinking of traditional African culture and what he describes as Western scientific culture. As he puts it, Western science is based on things while African cosmology is based on people.

If one accepts that the traditional African and the Western scientific world views are based on different conceptual models (Ogunniyi 1988), one must ask to what extent the beliefs and explanations of the external world which students hold will be at variance with those which they meet in school science. Furthermore, will these affect their learning of school science - either through creating difficulties in understanding or through affecting attitudes to learning?

There is support for the view, put forward by Urevbu (1984), that many aspects of traditional African life have "counter-scientific" undertones. Wilson (1981) is of the opinion that traditional African world-views conflict in fundamental ways with the presuppositions of Western science. For example, research undertaken in Nigeria (cited in Jegede and Okebukola 1991) has shown that the existence of superstitious beliefs and taboos hinder science learning. Hewson (1988), drawing on Toulmin's thesis that one's conceptions depend on the environment, argues that the "ecological context of knowledge" in an African setting may result in conceptions in science that work for the student but which are not in accordance with conventional science (George and Glasgow 1988).

However an opposing view which I support is presented by Biesheuvel (1972). He argues though that there is in fact no inherent contradiction between the African spiritual cosmology and science. Whatever the differences, he contends that these are of degree rather than kind. In support of this position, Maddock (1981:13) reminds us that dualism exists in any culture, as he puts it, "the domain of the unaccountable is still very real in all societies."

In a study conducted in southern Nigeria Ogunniyi (1984) concludes that the two systems of thought (traditional and scientific) are not necessarily mutually exclusive of each other; neither are they always in conflict- for each system serves some useful purpose. Previous research done by the author (see Clark 1988) probes the interaction between students' sociocultural beliefs and formal scientific explanations for lightning. The conclusion is reached that sociocultural beliefs may exert a mediating influence when students decide how to interpret the scientific viewpoint which is presented to them in the classroom. In this particular instance the influence was relatively insignificant; the students seemed perfectly willing to accept a scientific explanation for that natural phenomenon.

Chamberlain (1981) in his work on superstitious beliefs and the learning of science in Nigeria, concluded that students do not necessarily see divine agencies at work where there are acceptable alternative explanations and where there is no conflict with their traditional beliefs.

This is surely consistent, from a constructivist position, with what is to be expected from any group of students within any learning context. When attempts are made to encourage students to be aware of and adopt alternative views of the world (as is often the case in science lessons), they may experience difficulties when their "socially acquired knowledge" does not conform with the conventional science of the classroom (see previous references to Solomon's work). In any event, it could be argued that the ability to sustain apparently contradictory beliefs is an ability that the scientist needs. We certainly teach our students the dual nature of components of atoms - sometimes treating them as particles and other times as waves (Chamberlain 1981:6).

This leads on to what is possibly the central issue in science curriculum development in the African context - as educational opportunities are opened up to a wider portion of the population, of immediate importance is the need to review the usefulness and <u>relevance</u> of science curricula (Makgothi and Nganunu 1991).

4.8 Issues of Relevance In Science Education

Although there have been some impressive attempts at curriculum innovation, science education in Africa remains largely unsatisfactory (Urevbu 1984). The reasons for this are extremely complex (see Ogunniyi 1986; Urevbu 1984; Knamillar 1984; Kahn 1990) and extend far beyond purely educational concerns - curriculum evaluation and reform clearly do not occur in a vacuum (see for example Bybee et al 1980; Coombs 1985; Dore 1976 and Bray et al 1986).

There is, as pointed out by Ogunniyi (1986), no simple solution to the multifarious problems facing science education in Africa. Yet seeing that most schooling takes place in a rural setting it is crucial that the form of science developed is relevant to the context for which it is intended. Consequently there is clearly a great need for relevance.

The question of relevance is a complex one, not least because education for relevance has different meanings for different people (Knamillar 1984). What is beyond doubt though is that science education should reflect the needs of the students and society as a whole (Ogunniyi 1986). As Urevbu (1984) puts it:

> new ways of teaching should take into consideration not only the students' pre-school background, but also the realities of African school laboratories, as well as the students' post-school environment... Curricula, methodology and teaching materials should, as far as possible, be drawn directly from the life of the community and from the environment. (1984:223)

Cole (1975) makes the point that there is a rich collection of cultural objects and beliefs with scientific bases in all African societies; the challenge lies in finding ways of making the student aware of the scientific and learning potential of his/her environment. Knamillar

(1990:3) takes this further in suggesting that one of the reasons why school science has remained alien to most black children is because it fails to take into account what science and technology local people are doing, what knowledge and skills they have and what problems they feel are important to consider.

In this respect, whatever their relative successes or failures, over the years there have been various attempts in different parts of Africa at developing materials which utilise traditional science and technology as a basis for extending school science courses (for an overview of this topic see Knamillar 1984; and for specific examples Yakuba 1984; Swift 1983; Knamillar 1990 and Bray et al 1986).

One example of the important implications of this approach (particularly for the development of a future science curriculum in South Africa), is the move away from the expectation that "doing science" requires expensive laboratory equipment (Wilson 1981; Urevbu 1984). The ZIMSCI project in Zimbabwe is a case in point (see Wright 1982); one of their organising principles (backed up by the research of among others - Dock 1979; 1981) was that most of the basic experiments of science can be satisfactorily performed with a low-cost kit of simple apparatus.

> The universal principles of science do not have to be presented in the pretty wrappings of the professional apparatus manufacturer. (Wright 1982:370)

In South Africa the Science Education Project (SEP) follows a similar approach (see chapter 5 for more background on SEP's work). Such an orientation resonates well with current international thinking on the role of practical work in school science; if we expect students to become involved in more issue-bound science, in which "real-world" problems are investigated, they are not restricted to laboratories or the special equipment they contain (Penick and Yager 1986). "Real" laboratories can exist almost anywhere, there is sufficient experience and apparatus in the everyday world of students (Richmond 1979). It has been argued (see Woolnough and Allsop 1985) that in any event sophisticated apparatus restricts creativity and in fact presents an additional stage in removing the science learned in school from the students' real world.

Whatever the themes which constitute relevant school science in an African context, these share the following features: attempting to deal with human problems at the local community level, teaching the skills of problem-solving and decision-making applied to real-life problems and increasing the production of goods and services among the poor (Knamillar 1984). As Nganunu (1991 cited in Makgothi and Nganunu 1991) put it:

> For someone who is not going to proceed for further studies, a useful and relevant science curriculum will help him to lead a healthier life, a more comfortable life, a more interesting life. (1991:L1)

The struggle for relevance in science education is certainly a daunting task, in conclusion let us reflect on the following:

> We have found in Malawi that it is a relatively easy task to dream up investigations for school children based on local science and technology. It is a much harder task to engender enthusiasm and confidence among science educators for such an approach. And it is equally difficult to design ways to infuse community-based, investigatory science and technology into school syllabuses, teacher training curricula and selection examinations at all levels. This is the real challenge for African science educators as we approach the 1990's. (Knamillar 1990:13)

The final section of this chapter is devoted to a consideration (albeit briefly) of some aspects of the existing science curriculum in South Africa. It must be noted that at no stage is the following discussion meant to be an exhaustive account of the present status quo in South African science education; rather it is intended to help contextualise my own attempt at materials development particularly in the light of the various issues dealt with so far in this chapter.

4.9 Science Education in South Africa

One consequence of the historical development of education in this country is that the provision (and more aptly under-provision) of science education spans a wide spectrum, from privileged white urban schools to impoverished black rural schools. Yet the majority of students in this country are black and attend schools which are situated in rural areas where the provision for education is most disadvantaged.

Not surprisingly then, given the nature of underdevelopment which characterises black education in this country, many of the problems experienced in science education in other African countries are found here. Although as Gray (1992b:1) points out, the situation is enormously complicated by the bizarre South African political situation.

One can attempt to summarise these problems as follows:

1. At both the primary and secondary level there is a critical shortage of skilled science teachers - many teachers are untrained or poorly qualified. In addition to which there is a high turnover of teachers. Particularly at the junior secondary level, teachers tend to move from one subject to the next.
2. Facilities are often inadequate, there are shortages

in essential material resources such as laboratory facilities, textbooks and other teaching aids. One consequence of inadequate pre-service training is that teachers are often ill-equipped to make the best use of whatever limited resources are available.

3. Effective science teaching (particularly practical work) requires not only a resource base, but also places considerable demands on teachers. In this regard there is an inadequate system of teacher support. Although SEP now represents a major development in this field, in-service training (INSET) initiatives are limited and highly localised (mostly in urban areas).

4. Teachers themselves are burdened by excessive teaching loads and have to cope with large classes (often in excess of 50 students at the secondary school level). This limits teachers' attempts to engage in more meaningful or innovative science teaching and tends to reinforce rote learning strategies.

6. Then there is the whole question of L2 learning and its impact on science teaching and learning (this issue formed the basis of chapter 2). And as will be discussed below, the syllabi are Euro-centric and inappropriate for our African context.

7. At the top end of schooling, teachers are restricted by the demands of an external examination system. As pointed out by Staples (1980), even though evaluation should not determine classroom practice, it will invariably do so. The following comment was written more than twenty years ago, but holds true today:

> the requirements of the matriculation (exam) has taken complete control. Teaching has become geared to results, non-examinable and extra-curricular material being neglected. (Colussi 1969:62)

8. Finally, for the past sixteen years (since the Soweto uprising in 1976) black education has been a

highly contested terrain, with a seemingly endless cycle of boycotts, disruptions and stayaways. The impact of the broader political crisis in South Africa has had an immeasurable effect on science education.

It is within such a context that the majority of students experience some semblance of science at school (General Science is a subject taken by all students up to the end of Standard 7). Given the legacy and ongoing influence of apartheid education, what then of the science which is taught?

For a start, the present science syllabi were drawn up by the white Transvaal Education Department (one of the eighteen departments which were created to manage apartheid education), and then copied with only minor changes by all the other education departments. These syllabi, as even a cursory glance at any South African school science textbook will show, would not seem out of place in any Western European classroom. Clearly there have been little in the way of attempts to adapt materials for local conditions. Given the nature of apartheid education, it could be argued that in any event in the eyes of the curriculum planners no other context but a white Western one existed.

Thus it should be of no surprise that, as Rollnick and Kahn (1991) put it, **the present science syllabi as they stand, whether compared to first or third world countries, are academic, outmoded and decontextualised.**

Problems with the existing science syllabi have been outlined by Blignaut et al (1989) and in a document produced by the "Science Curriculum Initiative in South Africa" (SCISA 1989). In developing their position statement towards a new syllabus for Standard 3-7 General Science, the SCISA initiative voices its dissatisfaction with the current General Science syllabi and existing processes of syllabus development and implementation. As SCISA points out, the current syllabus is "out of balance" in its treatment of science and of the society it is supposed to serve.

It appears as if the current South African science curriculum attempts to follow the "standard science education" (SSE) view of scientific method and experimentation (as described by Millar (1987;1989a) in the first section of this chapter). However, the syllabi tend to be so content-dominated that science is rarely presented as being anything other than a sequence of ordered facts that are not open to dispute. This in turn projects an image of science as infallible, received knowledge. So besides some idealised statements of intent such as, "pupils should be encouraged to do independent investigations" or "develop the ability to observe objectively and solve problems" (DET 1985:1) rarely are any of these goals attained.

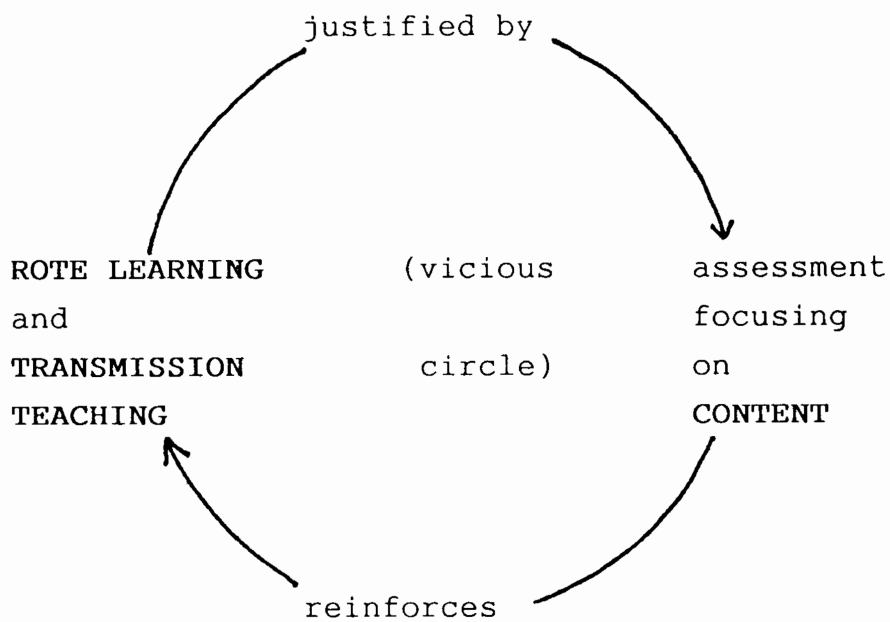
Also, in addition to the problems outlined above (large classes and heavy teaching loads), the focus on content and the academic bias of the syllabi tends to encourage rote learning and transmission modes of teaching. Muller (1987) reveals this rote learning tendency to be present in science classes at all levels in South African schools. According to Levy (1989) this academic bias has arisen out the dominance of a particular epistemological view of science and the same outmoded view of "scientific method" runs through the 1981 HSRC report on curriculum innovation submitted to the de Lange Commission (Rollnick and Kahn 1991:M8).

The situation can be summed up diagrammatically on the following page.

Figure 4.1

CONTENT DOMINATED
and
HIGHLY PRESCRIPTIVE
SYLLABI

has led to the dominance of...



On another level the hierarchical structure of the current syllabi and their adherence (in theory) to developmental sequencing are based on assumptions drawn from both behaviourist and developmental psychology. These assumptions have recently been extensively challenged by constructivist ideas and it is now generally accepted that children construct meaning through ongoing social interaction (as discussed earlier). As the SCISA report goes on to point out, in this regard the existing syllabus structure and the way it is implemented in schools is inadequate in facilitating meaningful learning in science.

In conclusion, whatever the context of schooling (either urban or rural, for white child or black), current science syllabi clearly do not relate to children's life experiences nor do they allow any scope for dealing with current and, more importantly, local issues. There is subsequently a distinct lack of relevance at all levels of science syllabi in both junior and secondary schooling.

Given then the issues raised in the previous sections of this chapter, there is a crucial need to begin to contextualise the science which is taught in schools, to consider what themes are feasible and meaningful, the sequence of principles and concepts which should be taught and the methodologies to be encouraged and supported. This implies that changes in content, methodology and contextual presentation will have to be made. The task is nothing less than the redefinition of science education in order to open the subject for all.

Herein lay the challenge in my own research work - to develop and successfully trial alternative text materials which, with limited objectives, attempt to meet the concerns articulated in this chapter.

Chapter 5
Materials Development

5.1 Introduction

I chose to work at the level of Standard 8 Physical Science, and to concentrate on developing materials for a specific section of the chemistry syllabus. The reasons for this choice of focus are summarised below:

1. As a trained analytical chemist, it seemed to make sense for me to work in an area I knew.

2. I was looking for a part of the existing syllabus which realistically encouraged student practical work. The conventional approach towards teaching "Acids, Bases and Salts" found in present textbooks clearly emphasises experimental work as a basis for teaching this section of work. From such a starting point I felt there was sufficient scope for adapting this topic to a more "issue - based" approach.

3. It was a section which was supposed to have been taught in both Standard 5 and Standard 7. Although one might expect students to enter Standard 8 with some kind of knowledge base, it was suspected that the majority of students' background knowledge was extremely limited. The concepts introduced in Standard 5 were reinforced and extended in Standard 7, yet my own experience of Standard 7 General Science teaching led me to believe that in most instances this section of work was simply left out. This was confirmed by the pretest exercise (see appendix 2) which is discussed further in chapter 7.

4. It was a section which I had previously attempted in an altogether less structured way to adapt to the context in which I was teaching. For a start, given the students' poor grounding, I had found that although it was assigned three weeks in the official work programme, it was difficult to cover in that time. It was decided then to aim at developing

materials to allow for approximately four weeks' teaching time.

5. A criticism which can be levelled at the Standard 8 Physical Science syllabus is that it is densely crowded with conceptually difficult work. This applies to "Acids, Bases and Salts". I had over the years observed how many students, particularly those with a poor grasp of English, were unable to cope with the demands of Standard 8 chemistry. They struggled to make sense of chemical equations, come to terms with concepts like the pH scale and in general seemed to come away with no clear understanding of what they had been studying.

Very few students seemed to make connections between the chemistry of the textbook and the examples of Acid - Base reactions they would meet in their everyday lives. It seemed not so much that this work was being taught out of context, but rather that it lacked any context at all!

This, then, was to prove the most decisive factor behind choosing to work on this section of the syllabus. There appeared numerous opportunities to illustrate and explain concepts of the syllabus in terms of the real-life experiences of students.

Having chosen a section of the syllabus on which to focus, I had to develop teaching resources which could be trialed with my two classes of Standard 8 students. The two main components were to be the trial text material and the practical kits needed to accompany the group experimental work.

5.2 Text Production

Mindful of the numerous concerns raised in the previous chapter, I was eager to explore the possibilities of developing more relevant curriculum material which would first and foremost relate school science more closely to the students' life experiences. A deliberate attempt was also going to be made to enable the students to consider the impact and implications of science for society. Not only that, but I also wished to approach the exercise of writing text material from a perspective which was sensitive to the linguistic demands of L2 learners, and, in so doing, to show a commitment to the concept of language across the curriculum (LAC).

A point worth emphasising is the notion of "usability". My desire was to produce and then trial at the classroom level curriculum materials which could justifiably be said to be usable within that context (in this regard you are referred back to the words of Prophet (1990) on page 4 of chapter 1).

However, as a practising teacher engaged in part-time research I was aware that there was a limit to the amount of time which I could spend on writing the trial text material and developing a supporting practical kit. Consequently I employed a strategy of identifying and then using existing curriculum resources as far as possible. In what was basically a pragmatic approach towards innovation, I set out to cover conceptual territory similar to that in the syllabus in my own "acids and alkalis" trial text material.

Although during the initial stages of materials development numerous texts were consulted, three main sources can be identified - Salters' Science Programme; Science by Investigation in Botswana; and the local Science Education Project (SEP). They are briefly described below:

5.2.1 Salters' Science Programme

Prompted by a call by the education authorities for "science for all", the various Salters' science courses (initiated in 1983) are a relatively new addition to the science curriculum development programme in the United Kingdom. The Salters' approach to developing a science course tends to differ markedly from the traditional one adopted by most curriculum developers. Instead of starting with a fixed body of concepts for which applications are built in to make the course as relevant as possible, the Salters' approach turns this process on its head by being "applications-led".

Each course has as its starting point the interests and experiences of children; from this base the relevant science is extracted. In terms of concepts the aim has been to develop reasonably balanced science courses which emphasize the development of science processes and skills while at the same time being as real and relevant for the students as possible. The philosophy behind the Salters' approach to science is best summarised by the following extract from one of their information brochures:

> Salters' Science offers a new approach to the teaching of science. Several important principles have guided the development of the course:
>
> * Science education is for all and science should be taught in a way that allows students of all abilities to acquire relevant and useful knowledge.
>
> * The starting points for all the materials in the lessons are the present interests and experiences of the students, or experiences which are readily recognisable to students as being of future significance.
>
> * Starting points are selected so that they illustrate scientific ideas in action or the value of scientific knowledge. In this way the course is **applications-led.**
>
> * Strategies adopted in lessons encourage students to take an **active** role in their learning.
>
> * The course materials allow maximum flexibility in lesson organisation, and are very thoroughly documented to provide a high degree of support and guidance for teachers working in less familiar areas or with more unusual teaching approaches.
>
> * The course materials are developed <u>by teachers</u> (my emphasis) at writing workshops. Materials are published initially in trial form, and extensive trials of material take place prior to revision in the light of comments from schools.
>
> (UYSEG 1990:3)

There are three distinctive Salters' programmes presently in use. In essence each course comprises the following: a comprehensive teachers guide; a number of unit guides (the course is made up of a number of units) which contain teachers' notes and student materials and guides which can be reproduced; student textbooks and a range of additional resources such as video material, data discs and 35 mm slides. The "Salters' Chemistry Course" for students between the ages of 13 and 16 studying chemistry to the GCSE level (roughly equivalent to our Standard 9) is the most established of the courses and the one which I found particularly useful.

According to Gray (1992a), Salters' Science has been well received in the United Kingdom and a growing number of schools are adopting one or more of the courses. Because of its "applications-led" approach, it provides students with relevant, accessible science and is consequently able to capture the interest of even those students who are disinclined to study the subject. A further important aspect of the Salters' programme has been its commitment to involving teachers at all stages in its development. Whatever the long term limitations in this approach, I agree that the ideal of teachers being the driving force in the development of new curricula should be supported as far as possible (hence my present research).

As with any developing curriculum programme, Salters' Science has come in for its fair share of criticism. For one, the courses are said to be "soft" on content, and because there is a greater emphasis on the development of skills and processes, teaching is more practically orientated and this places additional organisational demands on teachers. Furthermore, because of Salters' fundamentally different (applications-led) approach, teachers are required to master a host of new teaching strategies. For example, the use of role-play and discussion groups breaks the pattern of what has been traditionally associated with science teaching.

Whatever its limitations, the Salters' programme with its approach to teaching science in context, using topics rooted in the everyday experiences of students, proved the single most important inspiration behind the development of my own material.

5.2.2 Science by Investigation in Botswana

In 1986 began the process of extending access to education in Botswana from a total of seven to nine years of schooling. Alongside this expansion in the provision of universal junior secondary schooling there have been ongoing attempts to produce a more relevant science syllabus. A review of the whole nine-year Basic Science programme was made in 1987 and this stimulated a process of curriculum renewal which aimed to develop a science syllabus which would serve not only the needs of the individual in his/her daily life in Botswana but also the needs of the society as a whole (Makgothi and Nganunu 1991).

Thus came about "science by investigation", a science syllabus which incorporates a process approach to teaching in which a substantial part of each lesson has been set aside for investigative activities:

> Students should be trained to predict, plan, investigate, observe, collect data, record, think, interpret, analyze, solve problems, discuss, design, make and so on. In other words, we must teach processes but in the context of familiar and useful real-life application. (Nganunu 1991 in Makgothi and Nganunu 1991:L6)

One of the important aims of the nine-year Basic Science syllabus was to ensure that science would become accessible to all students, irrespective of whether they attend an urban or remote rural school. Cost restraints required the development of a cheap science kit which could be widely distributed. To this end the Zim-Sci (Zimbabwe Secondary Science) approach was used to develop a low cost science kit which attempted as far as possible to make use of commonly available materials. As Nganunu (1991 in Makgothi and Nganunu 1991:L8) points out

> The experience from Botswana and a number of other African countries is that by giving emphasis to real-life issues and traditional technologies, many of the school science topics can be taught using commonly available materials. For instance, by including topics such as 'chemicals in the household' and 'house construction', detergents, paint, milk powder, clay, wood, cement, etc become 'science equipment'.

One of the topics mentioned above - "chemicals in the home" has as one of its central themes acids and alkalis. Consequently this unit, with its thematic approach to teaching science, was able to offer me a framework of practical worksheets on which to base my own material.

5.2.3 The Science Education Project

The Science Education Project (SEP) founded in 1976, is a South African Non-Government Organisation (NGO) which works extensively in the field of science education. A mission statement agreed on by their staff in 1986 best sums up SEP's approach:

> SEP is a system for promoting innovation and change in science education in South Africa by encouraging an activity-based approach to science education in order to advance education in South Africa.
> It works with and serves the teachers and learners of science and does so by co-operating with communities, authorities and other concerned groups.
>
> (Whittaker & Morphet 1986:9)

The underlying philosophy of the project stresses a process approach towards the teaching of science in which science teachers should engage students in extensive "hands-on" experimentation. In this respect the SEP approach is summed up in this extract from their teachers' resource file:

> a) no student can absorb knowledge ready-to-use from a teacher. Instead, all students try to link newly-taught ideas with ideas they already hold
> b) students need to talk with each other and work with materials in order to make links between new ideas and existing ideas
> c) students should learn thinking skills which enable them to solve problems. Learning only the 'facts' about science is inadequate education. (Moodie and Rogan 1987b:6)

With its primary goal of encouraging activity-based science (mainly at the Standard 6, 7 and 8 levels), SEP is engaged in an ongoing process of developing and refining a number of low-cost science kits and accompanying worksheets. Furthermore, the central role of teachers in the process of innovation is acknowledged in the emphasis which SEP places on its teacher support programmes.

From its initial work in rural black schools in the Ciskei region of South Africa, SEP gradually expanded its operations so that by the late 1980s it had established a dozen regional centres and was working with teachers from about two thousand schools. Following representations in 1991 to the Independent Development Trust (IDT), SEP was given an extensive grant of money (R13 million over a period of three years). This grant put SEP in a position to increase its impact on science teaching at the Standard 6-8 level by a factor of three (SEP Annual Report 1991:1). Coupled with the signing of an agreement with the Department of Education and Training (DET) which permits SEP to work in all DET schools throughout South Africa, these developments have resulted in the organisation undergoing a period of rapid expansion.

Outside the State, SEP is the largest single organisation involved in secondary school science education in South Africa and as such is well placed to play a significant role in future science curriculum development in this country. Over the past few years I have had the opportunity to use SEP kits in my own teaching. The Standard 8 worksheets dealing with the topic "acids and bases" were an important source of ideas (and drawings) which I used in my own text material. In particular, the science kit (for Standards 6 & 7), and the Standard 8 science kit were a ready source of apparatus which I was able to adapt for use in my own practical kit.

Conscious of the complex language problems which L2 students experience when reading science texts I adopted a simplified "code of conduct" when writing up my text material. Adapted from Turk and Kirkman (1982:126) it was as follows:

Figure 5.1

Writing Code of Conduct

*Use shorter sentences where possible
*Use simple, exact vocabulary
*Avoid jargon
*Avoid abstract words and use concrete words to convey exact meaning
*Avoid roundabout, wordy phrases
*Avoid overuse of passive structures and nominalization

To Sum Up

Be variable and flexible when writing text materials

The text material was developed and written up in May/June 1991 during a period of six weeks study leave. The student handout was built around nine worksheets in which students undertake a series of group based practical investigations. These were drawn up and a handwritten text given for critical comment to one of my supervisors, Mr Roy Pickerill. The second draft was typed up on computer using a word processing package (Wordperfect), and the initial framework of worksheets fleshed out into a more comprehensive package (described by example below). Once again this draft was exposed to critical appraisal by Mr Pickerill. Eventually after numerous changes/modifications and following a final proofreading, a master copy was printed. Just over 100 copies of the trial text were then photocopied and collated. What was eventually given to each student at the beginning of the trialing exercise was a 54 page handout entitled "Acids and Alkalis - Chemicals in the Home". A copy of this handout is included as appendix 1 and is referred to extensively in the discussion in the following two pages.

The basic structure of one of these worksheets, "The strength of acids and alkalis" (see pages 14 - 21 of appendix 1), will now be described as an example of my attempts to develop a more issue-based approach towards teaching this section of the syllabus.

The first part is a group practical activity in which the students explore ways of determining the strengths of different acids and alkalis. In it they undertake a number of simple experiments guided by instructions written in the text and using apparatus from the practical kits. As they work through the different stages of each experiment they are expected to record their findings and answer a number of questions. Spaces are provided for this on the handout itself.

Once the practical work is completed they are introduced through an information sheet to the concept of the pH scale (a convenient way of expressing the relative strengths of acids and alkalis). In an attempt to contextualise the concepts embedded in the above-mentioned practical and content sections of the worksheet, students are then presented with two pages of information dealing with acid rain. This is followed by a comprehension exercise in which students read about the problems of acid rain in the Eastern Transvaal. This exercise serves a number of different purposes: it broadens their knowledge base, presents the topic in a South African context and, through its choice of questions, encourages students to apply their basic knowledge of the relative strengths of acids and alkalis and the pH scale. This particular comprehension exercise will be discussed further in chapter 8.

Because the hand-out is meant to stand as a self-contained unit of work, there are a number of more conventional homework exercises attached at the end of some of the worksheets (e.g. pages 12 and 27). In a number of instances, space was provided for additional note taking (e.g. pages 16, 33 and 45). On a number of occasions information was deliberately left out so that students could make their own notes.

A very important feature of the hand-out was the presence of a glossary. Given the language difficulties experienced by L2 users of scientific texts, a glossary of unfamiliar words and concepts was included at the end of the hand-out (see pages 53-4). Space was also provided to allow students to add extra words if the need arose. The effectiveness of this glossary will be discussed in chapter 8.

As an extension exercise each group of students in Standard 8A was expected to choose and participate in an independent investigation - this aspect of the work will also be discussed in chapter 7.

5.3 The Practical Kits

In order to undertake group practical work it was necessary to put together a suitable practical kit in conjunction with the text material. To this end an "acid and alkali" kit was devised. Photographs of the kit are shown below (see Figure 5.2 on the following page) and its contents displayed diagrammatically as appendix 8.

Basically each kit comprised two boxes and a baseboard. One box contained chemicals and the other, apparatus. The kits were almost entirely self-contained. Besides some common laboratory chemicals provided by the teacher, very little in the way of additional resources were needed during the four week trial period.

As with the text material I had to use existing resources as far as possible. In this regard I was able to put together the kit using apparatus and chemicals readily available to SEP. Once a prototype kit was devised equipment needed to make up eight such kits was purchased from Scientific Teaching Aids, the manufacturers of the SEP kits. With the help of the students in 8A the kits were then made ready for the first trialing exercise.

Although putting the practical kits together was a time-consuming exercise, it proved rewarding for a number of reasons. As with developments in both Zimbabwe and Botswana, it seems reasonable to assume that in this country cost restraints will ensure that similar low cost science kits are developed. In this regard, the basic apparatus in the SEP kits proved an excellent framework from which other low cost kits can be adapted. Furthermore, on a personal level, having to design and develop my own practical kit added significantly to a feeling of "ownership" of the project and heightened my sense of engagement in the actual process of materials development.

Figure 5.2

The Practical Kit

With the design and development of the trial text and supporting practical kit, the first phase of this research project was completed. What was to follow was the crucial trialing of this material with my two Standard 8 science classes at Luhlaza Senior Secondary school. Before discussing the research methodology employed during the classroom-based trialing exercises, it is important to firmly contextualise the next phase of this research project. The rest of this chapter is devoted then, to a description of the school and the two classes of students.

5.4 The School

Luhlaza Senior Secondary is a typical example of a school built by the Department of Education and Training (DET) during the 1980s - three rows of double-storeyed classrooms, all facebrick functionality and with a roll-on lawn. Luhlaza is situated in the sprawling black township of Khayelitsha about 30km from the centre of Cape Town.

Throughout South Africa the 1980s saw a rapid expansion in black secondary schooling. For example, in Cape Town in 1983 there were just four DET High schools. With the influx of people from rural areas having gained momentum following the scrapping of the Group Areas Legislation this number had grown to nine schools by 1988 and sixteen schools by 1991.

Luhlaza was opened in 1986. It was the first of a number of secondary schools planned for Khayelitsha. With a white principal and other white staff in certain key control and subject areas, it was clearly intended that Luhlaza would develop as Cape Town's "model DET school". It can be suggested that by supporting such a school, a broader state strategy was being met - that in an attempt to contain the persistent unrest in schooling which was endemic during most of the 1980s, DET tried where possible to shift the focus of education in the Western Cape away from the old troubled schools of the inner townships to the apparently functionally more efficient ones it was establishing in Khayelitsha.

It appears in retrospect hardly surprising to find that within the continuing spiral of school unrest, parents sought a kind of "best case" normality. In particular, to politically conservative parents a school such as Luhlaza was clearly a popular choice. Over the years Luhlaza had built up a reputation of being the only "successful" DET school in the Western Cape by virtue of its consistently good Matric results (over 80% pass rate in 1990).

However by the start of my trialing period in August 1991, the school with an enrolment of 1650 students and a staff complement of 46 teachers, was emerging from a painful period of internal crisis. A backlash against what was perceived as reactionary (essentially white) control of the school had seen the eviction of the white principal by the Student Representative Council (SRC) in February 1990. Although the vice-principal took over the day to day running of the school, the intervening period (February 1990 - August 1991) was characterised by continual conflict among the staff and student body as contending groups struggled for control.

Not surprisingly this conflict had an adverse effect on the normal functioning of the school. Looking at trends in teacher absenteeism gives one a rough measure of staff morale. By the middle of 1991, absenteeism ran on <u>average</u> at five per day; on some days up to nine out of 46 teachers would be absent. This figure clearly reflects the breakdown in morale among the teachers, as some members of staff took advantage of the apparent authority vacuum in the school.

Data collected in Standard 8A during the trialing period illustrates this. Over those four weeks students missed almost 20% of their lessons because of teacher absenteeism (this data will be discussed in some detail in chapter 7).

The decay in the school was most keenly felt at the classroom level where the high levels of teacher absenteeism started to affect student attendance as well. Not only that, but the students also became increasingly difficult to motivate and there was an inevitable decline in academic standards as the climate of learning was steadily eroded away. At the time it appeared as if Luhlaza was sinking into the same chaotic state which tragically affects so many other township schools.

It was within such a context that I began my research work.

5.5 The Students

I had been teaching at the school since the beginning of 1987 and had therefore taught through the turbulent events of the previous few years. During 1991 I taught the two Standard 8 classes studying Physical Science. Typical of those classes found in any township school, the Standard 8A class had 45 students and the Standard 8B class, 42 students. They were both mixed ability groups, for as in other township schools, no streaming other than by subject choice was possible. This was mostly caused by the chronic undersupply of teachers in black schools. Although a student-teacher ratio of 35:1 was used to determine the school's quota of teachers, this included in its calculation **all** members of staff (from principal down to the ordinary teacher). Consequences of this staffing ratio included chronic over-crowding of classes, particularly in the junior Standards (up to 65 students per class), and extremely heavy teaching loads for teachers. For example, during 1991 I was responsible for teaching over 250 students in 6 classes spread across four Standards (7 - 10), with 46 out of 50 teaching periods per week.

Before the start of the trialing exercise, students were asked to complete two questionnaires so that I could build a more detailed picture of the two classes with which I would be working. The first one was kept short and simple and was used to gather some basic information about the students. The second questionnaire tried to probe in some detail their attitudes and feelings towards science in general and their science textbook in particular. A detailed discussion of the students' responses to this second questionnaire is found in chapter 8.

The majority of students in both classes filled in and returned the questionnaires. However, no pressure was placed on a student who failed to hand one in, since I wanted the questionnaires to be answered as honestly as possible. Appendix 3 summarises the data collected in the first questionnaire. A number of observations can be drawn from this data.

At Luhlaza a policy was adopted of pre-selecting students for the Science/ Mathematics stream, based primarily on their performance in these two subjects in Standard 7. Students would have had to pass at least these two subjects before they were allowed to consider continuing with them in Standard 8. One consequence of this was that Standard 8A had within its ranks many of the students who had performed relatively well academically in our Standard 7 classes.

In 1991 it again proved difficult to select from the previous year's Standard 7 passes enough students to fill even one science class in Standard 8. Besides some academically very weak students who opted to continue with Science and Mathematics despite attempts to persuade them otherwise, there were also a number of students who were repeating Standard 8 (one for the third time).

In order to fill the second class it became necessary to take in students from outside the school. Although this was a common practice at other schools, Luhlaza tried where possible to limit the number of outsiders it took in. The basic rationale behind this policy was that academic standards differ widely from school to school (particularly between urban and rural areas). In the past we experienced problems with students who failed miserably at Luhlaza even though they came to us with excellent report cards (more often than not forged) from other schools.

The age distribution of students in the two classes was very similar; typically the age gap between the youngest and oldest student was at least five years. Usually in Standard 8 students range in age from 15 to 20 years old. In 1991 the average age in both classes was just over 17 years. Interestingly enough, eight students in 8B were attending their third different school in as many years as opposed to only two students in 8A. This is an apparently undocumented feature of secondary education in the Western Cape. There is a relatively large floating population of students who, from year to year, move from one school to another. The reasons for this are complex, and are tied to the broader crisis affecting black education in South Africa.

However, with increased pressure for places in secondary schools over the past few years, this "flux" of students has steadily declined. Students tend now to hold on to their places within a school: 21 students in 8A had attended Luhlaza from Standard 6 through to Standard 8 compared with only 10 students in the 8B class.

During registration, preference is given to those students who give Khayelitsha as their home address. Some students, in order to secure a place at a school, board during the week with relatives in Khayelitsha and then return home to another township at the weekend. A significant number of students have also been sent to school in Cape Town from other areas. When asked, 12 students in 8A and 11 students in Standard 8B said that they did not regard Cape Town as their home.

Standard 8A appeared to be a far more cohesive class, mainly due to the fact that 30 students in the class were promotion passes from our own Standard 7. By contrast, in Standard 8B more than half (25) of the students who responded to the questionnaire indicated that they were new to the school; and, of these, 12 students were straight from what can be regarded as rural schools. There were in fact more repeaters in Standard 8A, 11 compared to the 7 in 8B.

Throughout the year leading up to the trialing period, I had experienced problems teaching 8B. In common with other teachers I found them a difficult group of students to handle. They were hard to motivate, came late to class and were often restless and clearly uninterested in the subject. By the end of the third term more than half the class were failing science and no more than four students were getting higher than 50% in class tests.

These difficulties were usually blamed on the class being made up of such a diverse group of students; there was also a strong feeling among teachers that in order to make up numbers at the beginning of the year, many students had been placed somewhat unwillingly in the Science/Mathematics stream.

This came out during one of the interviews with the 8B students (extracts from student interviews and examples of their written work will, where possible, be quoted verbatim i.e. the editorial sic will not be used):

Michael: Some of the students maybe they arrived here at the school late so they didn't get a place... didn't get the subjects that they wanted, so they were given a place (in 8B). Maybe the teacher told him that there is a space at a certain subject... maybe they can go there for at least one year. So that he cannot miss the year, then he just go there. Then by the time he done the subject (science and maths) he's not that willing to do it, he's just... just for the sake he musn't miss the year. (8B, 08-10-91)

In reply to the last question of the second questionnaire (refer to appendix 4), in which they were asked to rank their subjects from most to least enjoyable, 23 out of 35 students in 8B ranked science in positions 4 to

6. This compares to the 12 out of 35 who answered in a similar fashion in 8A.

In contrast to 8B, 8A had a core of highly motivated students. Given the ongoing crisis in township schools and the myriad of problems that such schools faced, it often proved extremely difficult to meet the needs of more academically gifted students in the classroom. Consequently, these students were crying out for some kind of extra stimulus to supplement their endless school diet of limited, unchallenging "chalk and talk".

Herein lay a further major challenge when developing new text materials - on the one hand to awaken the interest of students who lacked intrinsic motivation and who appeared uninterested and bored by school science; and on the other to cater for the needs of more intrinsically motivated and academically able students.

Chapter 6
Research Methodology

6.1 Introduction

The process of developing appropriate text materials for L2 science students has as an important component, a classroom-based trialing exercise. It is only through exposure to the classroom and the students for which they are intended that any kind of studied evaluation of such materials can be made. The question to ask is: what kind of research methodology is best suited to such an enterprise?

In educational research there are two quite distinct perspectives or traditions, which, for the purposes of this discussion will be referred to as the "positivist" and the "interpretative ethnographic" traditions. These two paradigms embrace contrasting sets of assumptions, which have important implications for classroom based research because investigations can be undertaken in different ways with different notions about what constitutes valid and appropriate data (Hitchcock and Hughes 1989).

Cohen and Manion (1980) illustrate this point by suggesting that depending on which perspective one supports one will identify certain issues as being of interest and ignore others. This in turn will lead one to ask certain questions and not others, adopt certain research methods rather than others and show a preference for certain kinds of analysis, explanation and theory. Van Lier (1988) calls this initial "baggage" the researcher's assumptions, out of which one develops a frame of reference and research framework.

6.2 The positivist tradition

According to Van Lier (1988) there is a tendency to equate quality in research with the application of a scientific methodology modelled on the natural sciences. Consequently one tradition has adopted for its research design, to a greater or lesser extent, a positivistic, scientific model.

This positivist research tradition is characterized by Shaver and Larkins (1973) as being a carefully narrow scope of inquiry with predetermined variables and precise "objective" research instruments. Typified by "hypothesis testing", the techniques associated with the positivist model include: eliciting responses to pre-determined questions, describing phenomena, recording measurements and performing experiments. The data gathered by a positivist researcher may be variously described as being external, quantifiable, explanatory, publicly verifiable and replicable (Cohen & Manion 1980).

Within a positivist framework a researcher will adopt a detached and neutral role, and stand apart from the phenomena selected for investigation. The data is then examined in terms of some preformulated hypothesis which is subjected to certain verification procedures so that the original hypothesis is either confirmed or rejected.

Hitchcock and Hughes (1989:22) offer a useful overview of many of the criticisms levelled at this kind of educational research. They discuss how anti-positivists take issue with the tendency of positivism (drawing as it does on the assumptions of the scientific method with its emphasis on correlation, laws, and objectivity) to make human beings out of "things" whose actions are unproblematic, clearly self-evident, quantifiable, and able to be objectively investigated.

One further criticism of this approach is that in the search for quantifiable data researchers tend to destroy or ignore the qualitative context out of which all "data" emerge. In a similar vein, Van Lier (1988) suggests that it is questionable whether or not quantitative attempts to measure classroom performance add to our store of knowledge and understanding of what actually goes on in the classroom.

He believes that this can only be done by going into the classroom, by gathering and interpreting data in the context of their occurrence. A crucial point which van Lier makes is that this is not only a linguistic or cognitive context; it is also essentially a social one.

The positivist model has been regarded then as having a strait-jacket effect on the practice of educational research. Through its research methodology it places unnecessary constraints on which aspects of school and classroom life can be researched and how. As Hitchcock and Hughes conclude:

> The scientific model (is) increasingly seen as being incapable of capturing the fluidity, spontaneity, and creativity of classroom life. (1989:27)

6.3 The Interpretative Ethnographic Model

Partly in response to dissatisfaction with positivist experimental designs in recent years there has been increasing application of ethnography in educational research. Eisenhart (1988) describes how, with its roots in cultural anthropology and sociology, the interpretivist philosophy underlying ethnography is very different from the logical positivist ideas which guide traditional educational research. Originally developed to describe the "ways of living" of a social group, ethnography is typically described as the study of people's behaviour in naturally occurring, ongoing settings (Watson-Gegeo 1988).

Not surprisingly, as with any research paradigm, there are a number of different conceptions about the nature, methodological and theoretical power of ethnography (see for example Hammersley and Atkinson 1983:1-2). According to Woods (1986) the main emphasis is on discovery rather than testing of theory. Cohen and Manion (1980) suggest that data in interpretative studies are sources of hypotheses and as such precede any theorising. The notion of "grounded theory" (Glaser and Strauss 1967) is favoured by many ethnographers. This implies that any theories which are developed must be grounded in the actual data the researcher has gathered.

Van Lier (1988:54) considers the different conceptions of ethnography as ranging from strong to weak in terms of theoretical power. In a strong view ethnography is theory building; in a weak view, it is a tool used to identify relevant concepts, describe variables, and ultimately generate testable hypotheses. Van Lier goes on to describe an essentially hybrid conception of ethnography which in "Janus-faced" fashion looks both ways, and employs all reasonable methods of <u>both</u> quantitative and qualitative data gathering and analysis.

This seems to me to be a particularly useful description, seeing that ethnography has become in the eyes of some educational researchers a synonym for only qualitative research. It seems unfair to stereotype ethnographic research in this way, as interpretative researchers may use a variety of sources of data (both qualitative and quantitative) and any number of different data-analysis strategies during the course of their research work.

However, where the positivist and interpretative research perspectives diverge is in the attitudes to the data that they have gathered. From an interpretative perspective, the problem lies not so much with quantitative data per se, as in the way in which it is used and what it is used for. Austin (1991) makes the point that there is a danger that quantifiable data on classroom performance does not look beyond the obvious, and as Hitchcock and Hughes (1989) put it:

> Interpretative, ethnographic researchers are concerned to qualify through the eyes of insiders, rather than to quantify through the eyes of an observer...quantitative data on school and classroom processes need to be

> supplemented by contextual details supplied by interpretative qualitative techniques. (1989:38)

This has some very clear implications for the ways in which ethnographers go about their work. Ethnography is by definition descriptive, and represents an approach which emphasises research as process. It is holistic in the sense that behaviour in the classroom has to be seen in the broader social context (Shaver and Larkins 1973; Watson-Gegeo 1988) and a further requirement is the need to take the students' perspectives as the basis for description. This means that classroom studies require intensive immersion in the data and considerable familiarity with the research setting.

So unlike the positivist researcher who (as described above) adopts a detached and neutral role, the interpretative perspective demands participation; consequently there is no question of the researcher maintaining a neutral stance. As Woods (1986) puts it, the ethnographer is his/her own major research tool.

Broadly speaking, in the context of educational research, ethnography aims to provide a description and an interpretive-explanatory account of what students do in the classroom, the outcome of their interactions, and the way in which they understand what they are doing. To sum up:

> ...true ethnographic work is systematic, detailed and rigorous, rather than anecdotal or impressionistic. The promise of ethnography... lies in its emphasis on holistic, richly detailed descriptions and analyses of teacher-learner interactions and the multilevel contexts in which these interactions occur. (Watson-Gegeo 1988:588-9)

In the light of the above discussion I decided to locate my research in an interpretative ethnographic framework. This decision was motivated largely by the nature of work I had set out to do.

Having produced a package of text and supporting practical kits, my next step was to subject them to actual classroom-based trialing exercises with each of my two Standard 8 classes. The task facing me was to observe, as critically as possible, the students' interaction with the new material over what would be at least a four-week period of work. Seeing that the classroom activities during each trialing exercise would focus around almost continuous group practical work, this clearly represented a major departure for the students from their normal diet of mostly "chalk and talk" teaching. What I needed then to do was to obtain as authentic as possible an account of classroom life over this period.

6.4 Ethnographic Data Collection

Ethnographic methods offer an approach for systematically documenting classroom interactions in rich, contextualised detail. However the teaching-learning process is so complex that any one single-method approach to data collection will yield only limited and possibly misleading information; consequently ethnography is **multimodal** and a wide range of data collecting techniques is employed.

According to Hitchcock and Hughes (1989) three basic processes constitute the central ingredients of ethnography:

1. Observation - listening to and looking at what the students are doing.
2. Interrogation - talking to the students about their actions (using interviews).
3. Documentary and oral data collection - the interpretation of meanings from written and oral data.

The following discussion will focus on these different "ingredients" and describe how I used them during the course of my research work.

Participant Observation

An essential and defining characteristic of ethnographic research is that a central portion of the data derives directly from interaction in the classroom; it is therefore inevitable that the single most important component of classroom research is observation (Van Lier 1988).

In particular, what is known as participant observation is the major technique available for studying classroom interaction from the perspective of those being studied. More accurately described as a role (Walker 1985), the teacher-researcher uses a number of different techniques and methods, observing overtly with the knowledge and consent of the students (participant-as-observer) interaction in the classroom. It requires the teacher to be simultaneously involved as an insider and detached enough to allow reflection as an outsider. As Van Lier (1988) puts it:

> ...combined with recording, transcription and analysis, it can be a rigorous method of classroom interaction analysis, one which allows the researcher to be both involved in the classroom and to take a detached, analytical stand for the purposes of description and interpretation. (1988:40)

Field Notes

According to Hammersley and Atkinson (1983) field notes are the traditional means in ethnography for recording "observational data". During the respective trialing exercises I recorded my observations, reflections and reactions to events taking place in the classroom. These notes helped me to focus on particular issues and reflect on my general impressions of the various daily classroom activities.

Seeing that the students were actively engaged for most of the time in group work, a central focus of my note-taking was to observe the interaction which took place both within and between the different groups, particularly during periods when practical activities were being undertaken (the dynamics of group work are taken up in chapter 7).

In practice this meant that I walked around the laboratory with a clipboard and an observation sheet upon which I recorded my impressions of each group. This proved a simple way to keep an ongoing record of first hand information. I was not always able to make copious notes on what was taking place around me; as the teacher-facilitator I was often kept busy assisting the different groups with specific queries and requests for assistance.

It must also be borne in mind that these were in every sense of the word "trial" exercises. There were occasions when, for any number of reasons, the practical activities stalled and my attention would be diverted from note keeping. This tended to happen during the first week of each trial exercise as the students struggled to come to terms with what was for them a decidedly novel approach to school science.

There were occasions when the students were able to proceed by themselves with only a minimal input required from me - often this was limited to a five minute introduction at the beginning of the lesson. At times like these I was free to wander around the groups at will.

In response to the practical difficulties which any teacher-researcher will experience while engaging in classroom based participant-observation I learnt, with a little practice, to make short, pertinent comments. If need be I could elaborate on these notes at the end of a lesson and return to them after school to study them in my own time. These field notes were an invaluable aide-memoir and often formed the basis of what I wrote up in my research diary.

Research Diary

In line with the ethnographic notion of "research as process", in which there is an ongoing open-ended dialogue between data collection and analysis, the keeping of a research diary allowed me to engage in critical reflection during each of the two trialing exercises.

Kept on a daily basis, it helped to contextualise the research and to give it body. I was able to use it to document not only the activities in the science laboratory but also to make comments about the day to day events taking place in and around the school.

Student Diaries

According to Hopkins (1985), student diaries are good for feedback in that they provide a student perspective on what is taking place in the classroom, not only that but they can assist in the identification of student problems and as such provide an important source of information for triangulation.

Before the trial exercise with the Standard 8A class began, a number of students were approached and asked if they would be willing to keep a daily diary. Five volunteered and, although they were given the option of writing it in either English or Xhosa (their mother-tongue), all chose to use English. This was after a discussion among themselves in which they agreed that keeping a diary would also be a useful opportunity to practise their English writing skills.

Each student was then given a small notebook and, seeing that only one of them indicated that he had kept a diary before, I gave them a short talk explaining how they might go about it. At the end of the trialing period they handed in their diaries and these were then used as an additional source of feedback.

As expected, a low level of L2 writing skills hampered the students in their attempts to express their thoughts and impressions in English. However, two of them tried to write at least a paragraph each day and from their comments (see chapter 7 and 8 for examples) some useful insights were gained. In retrospect, if the students had written their thoughts and impressions in Xhosa, the student diaries would have been a more valuable source of data.

Interviews

As a distinctive research technique, interviews may serve a number of purposes. They can be used to verify observations (Hopkins 1985), and in conjunction with other data gathering techniques can follow up unexpected results. In particular, as Woods (1986) notes, they are often the only way for finding out what the perspectives of people are, Tuckman (1972 in Cohen and Manion 1980:243) describes how:

> by providing access to what is 'inside a person's head', (it) makes it possible to measure what a person knows (knowledge or information), what a person likes or dislikes (values and preferences), and what a person thinks (attitudes and beliefs).

Woods (1986) gives extensive advice about interviewing techniques, recommending that the setting for the interview should be informal, relaxed and unconfrontational. At the beginning the purpose of the interview should be explained in a simple, unpatronising way and the students given clear assurances of anonymity and confidentiality. Woods favours the use of unstructured interviews, with the interviewer using what he calls an "enabling framework"- this involves a loose, open-ended and flexible approach which may become more structured as the interview progresses. Hammersley and Atkinson (1983) point out that ethnographers do not restrict themselves to a single mode of questioning. For example, one can employ non-directive questions which are relatively open-ended or, at the extreme, questions which require a simple yes or no.

It is important that the interviewer cultivates the art of listening (something many teachers are not particularly good at doing!), and establishes a feeling of trust and rapport with the interviewees, since this will facilitate the sincere and honest expression of their personal views.

Interviews do however pose particular problems of their own. As LeCompte and Goetz (1982) point out, there is the question of credibility of participant reports in interviewing. In either conscious or unconscious ways, the students may seek to project themselves in the best possible light, or to distort things to provide what they believe the interviewer wants to hear.

As a strategy for correcting bias and distortion, Wax (1971 cited in LeCompte and Goetz 1982) emphasizes the need for maintaining contact (despite personal preferences and prejudices) with a diversity of participants. Such a strategy of cross-informant interviewing helps validate and confirm the findings of interviews across a broader spectrum of participants. In this respect Woods (1986) suggests that one holds interviews with the students in their friendship groups; not only does this help to put the students at ease but also being together in a group tends to shift the power balance in their direction. Another advantage of interviewing students together in this way is that they act as prompts, checks and balances to each other, making it easier for inaccuracies to be corrected and for incidents and reactions to be recalled and analyzed.

Over the course of the two classroom trialing exercises I recorded a number of interviews with the students. A central focus of most interviews involved probing the student's reactions towards the "ease of use" of the trial text material and supporting practical kits, and reflecting on whatever issues arose out of the day to day group practical activities. At the same time the opportunity was taken to explore a wide range of topics/issues, for example the problems they experienced with English as the medium of instruction and with the language of the science textbook in particular. The following table offers a brief summary of these interviews.

Date of Interview	Group Number	General Description of interview
	Standard 8A	
15/8/92	A	Broad ranging, exploratory, impressions of the first week, general L2 issues etc.
19/8/92	D	As above (also picking up on issues which arose out of the first interview)
27/8/92	Individual	Acid rain comprehension exercise
28/8/92	A	After the school boycott
29/8/92	B	As for 15/8 and 19/8
9/9/92	D + H	Wide-ranging, general problems with school science
18/9/92	A	Overview of trialing exercise, in particular the text material
	Standard 8B	
8/10/92	Mixed group	Exploratory, wide ranging as for 8A
21/10/92	Mixed group	Overview of trialing exercise, as for 8A

Table 6.1

As the table on the previous page shows, nearly all the interviews were conducted with groups of students (usually 5 or 6 students at a time). At the very beginning of each trial exercise the students had been allowed to organise their own groups, so in most cases they were working with their friends. A more extensive programme of interviewing was undertaken with the one class, and although it was not possible to organise interviews with every group, at least 20 students representing a broad cross-section of the Standard 8A's participated in at least one interview. In addition to these group interviews, on one occasion a number of students were interviewed on an individual basis.

In general, during the group interviews the more vocal members tended to dominate the discussion. Some students whose English was particularly poor were too shy to speak up or struggled, even with the help of their fellow students, to make themselves understood. The holding of interviews in English rather than in Xhosa is recognised as a real limitation in a research project such as this where the researcher and participants speak a different language.

One way in which I attempted to get around this language barrier was to cultivate a number of key informants. These were students with whom I tried to form especially close relationships; they served in the words of Woods (1986), as "proxy participant observers". Through the many informal (unrecorded) discussions held with these students after class, during lunchbreak or after school, much light was shed on the trialing exercise from the students' perspective and they provided me then with an invaluable day to day input.

Due to time constraints, fewer interviews were conducted in the Standard 8B class; also, a slightly different format was employed. Each of the 8 groups delegated one member to represent them (usually their group leader) and these 8 students were then interviewed together. In some ways this proved a more successful format, because the group leaders tended to be students who actively participated in the class and were thus more inclined to be reflective about what was going on. Furthermore they appeared to enjoy the responsibility of reporting back on behalf of their respective groups.

In conclusion, the different interviews proved a valuable source of data and as such form an important feature of various discussions in chapters 7 and 8.

Questionnaires

The questionnaire, or "interview by proxy" Walker (1985:91) has a number of advantages over more qualitative methods of data collection. As Woods (1986) observes, it is a useful means for collecting quantifiable "hard data" across a broader sample of respondents than can be reached by interviews and can therefore be a starter to more qualitative methods of data collection. In particular the analysis of a questionnaire provides feedback on a number of levels and allows for direct comparison of groups and individuals. Cohen and Manion (1980) suggest that it tends to be more reliable than the interview because it is anonymous and thus encourages greater honesty. An interesting point made by Walker (1985) is that in asking certain questions one indicates an interest in certain kinds of data. In this sense the questions are as important then as the answers.

Questionnaires have their problems though: one which is noted by Hopkins (1985) is that their effectiveness depends very much on the reading and comprehension abilities of the respondents. This is a particular concern when dealing with L2 students and it was subsequently kept in mind when I drew up the two questionnaires which my students would have to fill in.

These two questionnaires were referred to in the previous chapter; the first one (see appendix 3) was used to gather some basic information about the students (age, previous schools, place of birth etc.). The second one (see appendix 4) tried to probe in some detail their attitudes and feelings towards school science in general and their science textbook in particular, and is discussed in some detail in chapter 8.

Other Documentary Evidence

In addition to the above forms of data collection a wide range of other documentary evidence was collected, copied and collated during the course of the research project, including, for example, numerous samples of the students' attempts at each of the various homework tasks (letter writing, comprehension exercises for example); an analysis of the test written before the trialing exercise; and the teacher attendance record. Much use of this data will be made in chapters 7 and 8.

6.5 Validity in Ethnographic Research

An important concern of any research project is that of validity. LeCompte and Goetz (1982) argue that ethnography can lay claim to a high level of internal validity because of the kinds of data collection and analysis techniques used:

1. Continual data analysis over a period of time (a total of nine weeks in my case).
2. Informant interviewing (my nine taped interviews and numerous informal discussions).
3. Participant observation, conducted in natural settings that reflect the reality of the life experiences of the participants more accurately than do contrived settings (the two classroom based trialing exercises).

A further important validating mechanism is the process of self-monitoring (termed "disciplined subjectivity") in which the ethnographic researcher develops the skills of detachment and reflection, and in so doing exposes all phases of the research activity to continual questioning and evaluation. Wilson (1977:258) suggests that this technique is as thorough and intrinsically objective as any other kind of research.

A major means of validifying accounts and observations in interpretative research is through **triangulation.** Triangulation is defined as a combination of two or more methods of data collection. The putting together of information from a number of different data sources and/or data collected through different research methods are an important strategy for arriving at "valid" or dependable findings in ethnographic work. Both Van Lier (1988) and Woods (1986) make the point that the greater the triangulation, the greater is the confidence in the observed findings.

Cohen and Manion (1980) discuss a number of different types of triangulation. Of interest here are the two categories of "methodological triangulation" which I employed:

1. **Within methods** - concerns the replication of a study as a check on reliability and theory confirmation. This was achieved during the course of my research work by undertaking the trialing exercise in both Standard 8 classes.
2. **Between methods** - this involves the use of two or more methods and embraces the notion of convergence between independent measures of the same objective (as with the use of participant observation, interviews, collection of documentation etc.).

There is clearly a strong and respectable research tradition which shows the theory-building potential of ethnographic study (see for example Hammersley and Atkinson 1983). Yet one thing is certain; because the notion of objectivity is both complex and relative, the debate between interpretative and positivistic scientific research will continue unabated and is unlikely ever to be resolved.

In conclusion, an interpretative ethnographic research methodology is committed to using a wide range of both qualitative and quantitative data collecting techniques in a holistic open-ended approach to "research as process". Ethnography is able then to provide the methodology necessary for obtaining an authentic account of what was taking place in my classroom without forcing the data into a theory and avoiding the temptation, as Hitchcock and Hughes (1989:42) put it, of "hammering reality into shape". As such, ethnography proved well suited to a piece of what Scriven (1967) would refer to as "seat of the pants" research such as mine.

Figure 7.1

Trialing the Material

Chapter 7
Trialing the Material

The trialing exercise in 1991 took place in two distinct phases: with the Standard 8As between August 8 and September 9, and the Standard 8Bs from September 30 to October 25.

7.1 The Pretest Exercise

Before starting the trial period students in each class were asked to write a short 30 minute test. The object of the test was to probe students' background knowledge of acids and bases given that they were supposed to have been taught about this topic in both Standards 5 and 7. Indeed, many of the concepts dealt with in Standard 8 science were being considered, albeit in more detail, for the third time in four years.

A copy of this pretest together with an analysis of student responses to certain key questions are summarised in appendix 2. It was decided to omit from this analysis the pretests of the students who were repeating Standard 8. Some of the questions asked here could be answered from their prior knowledge of Standard 8 science.

When it comes to their recall of Standard 7 science, it is interesting to note that 27 students (42%) indicated that they had not been taught any of the chapter dealing with acids and bases in Standard 7. Indeed, only seven students indicated that they had been taught all of the chapter in the previous year.

This is not a surprising finding given the problems which beset black education in this country. Of significance to this discussion is the time available for classroom teaching. In my experience it is limited by a variety of factors; a considerable amount of time is wasted at the beginning of the year during student registration (usually two weeks), and the end-of-year exams may be spread over seven weeks of the final term. An average school year is made up of around 41 weeks; the syllabus of a subject is spread over 32 weeks; yet rarely is there more than 26 weeks available teaching time! Added to this, a seemingly endless cycle of student boycotts and stayaways further cuts into the school year.

Of more significance are the problems inherent in the subject itself, where low levels of teacher expertise results in chapters of science losing out to the biology component of the syllabus which has a more easily managed concept/content load. Many teachers who are responsible for teaching Standard 6 and 7 General Science have a college qualification in biology rather than science. Although it is perhaps almost impossible to prove, I would contend that a relatively large number of General Science teachers use as an excuse the shortages of time (as explained above) to avoid teaching certain conceptuall[illegible]icult science topics.

This assertion is backed up by some of the student responses to later questions in the pretest. Questions 17 and 18 basically tested the students' ability to complete a relatively simple word and chemical equation drawn from the Standard 7 work. Even though there were some students who were academically very able, no-one was able to complete the word equation and only three managed to complete the chemical equation successfully. The problems are of course extremely complex ones, for they extend into both conceptual and language problems which students experience with the basic codification of chemistry. Be this as it may, it remains disturbing to find just how poor the students' grasp of basic concepts in chemistry is. This must in large part be a result of inadequate teaching in the lower Standards.

Here is another example: the concept of neutralisation, first introduced in Standard 5. It is disturbing to note how even after further exposure in Standard 7, by far the vast majority of students (60 out of 65) were unable to explain what was meant by the word. One can assume that by Standard

8 conceptual confusion was firmly entrenched. In Question 22 students were asked to explain how to dilute a strong acid. That so few students managed the correct answer (18 out of 65) once again suggests that it was an area of content work either ignored or badly explained in Standard 7.

In any event the pretest seemed to confirm what any teacher of science quickly discovers for him/herself that the cause of many of the difficulties students experience in Standard 8 lies in their impoverished background from Standards 6 and 7 General Science, and that this is in turn built on a shaky foundation of primary school science.

7.2 Setting up the Groups

In each class before the start of the trialing exercise the students were given the opportunity to divide themselves into eight groups (there being eight sets of kits available). The groups consisted of either five or six students. Besides some gentle persuading here and there (particularly in 8B), students formed groups without much difficulty.

A typical feature of every township school is the variety of "study groups" which the students form among themselves. Study groups are indeed very popular (particularly in the higher Standards) and they arise out of the students' need to share the burden of studying under often extremely adverse conditions.

For many students study time is a precious commodity. For the girls in particular there is the burden of domestic chores which makes it difficult for them to find time for studying at home. Being able to spend an hour or so after school in the company of fellow students, sharing the responsibility of assisting each other in homework exercises, often plays an important role in their academic performance. Working with others is also a way of sharing the burden of studying through the medium of English, which, as the discussion in chapter 2 suggests, is a major area of difficulty.

So although the thought of running continuous group practical work for a period of four weeks in classes of over forty students appeared an intimidating prospect, it was hoped that the established pattern of study groups would make the transition to group work a relatively smooth one.

Each group was asked to nominate one student (the group leader) who would be expected to take responsibility for seeing that the apparatus was kept clean and the kits neat and tidy. Another member of the group was shown how to clean glassware and assigned a sink in which to do this. Within each group students were urged to share responsibility for undertaking the different tasks as they arose.

At the end of each laboratory session the kits were returned to a central position (see appendix 6 for diagram of laboratory layout) and the group leader recorded the day's progress on a log sheet pasted in front of their kit storage spot (see appendix 7 for example of log sheet).

7.3 An Overview of the Trialing Exercises

A number of factors influenced the decision not to run the trial concurrently in both 8A and 8B.

First and foremost, the controlled immersion on a number of separate occasions of the trial material into the classroom, while critically evaluating it using a range of ethnographic data gathering techniques, was regarded as an important validating measure. In the light of the discussion on "within methods" triangulation in chapter 6, a single or simultaneous trialing exercise appeared an inadequate "test" of the text material and in particular the accompanying practical kits.

In particular, I was naturally uncertain of the suitability and "ease of use" of the kits for group practical work. Splitting the trial into two phases, conveniently separated as they were by the third-term school holiday, allowed me to reflect critically on the first phase and modify my approach where necessary for work with the 8Bs. Things of interest noted during the first trialing exercise could be followed up and any unexpected problems/errors/omissions could be accommodated the second time around.

In any case, for logistical reasons alone, with just one set of kits it would have been extremely difficult managing group practical work in both classes at the same time. It would also have left me little time to get on with the crucial task of attempting an "in context" evaluation of the material.

The first entry of my 8B research diary hopefully illustrates on a practical level the usefulness of this two-phase approach:

> Monday 30 September
> Supposed to be the first day of school term! No students present, two reasons - 1) Rumour of VAT march in town and 2) Confusion over when schools were to reopen after holiday....
> Anyway it was a lucky break as I was going to make up reagents, indicators and generally fuss over the kits after school - it ended up taking me 3.5 hours to sort everything out.
> Problem: blue flowers still give me a "green" indicator (Cameron suggests maybe Xhosa/Sotho share same word for Green/ Blue, thus explaining why Botswana "science by investigation" material talks of the proverbial blue indicator!).
> I need to purchase a few more things like vinegar and Carlton towels, and I made up 1.5 molar H_2SO_4; HCl and HNO_3 as well as Citric, Tartaric acid 1 molar solutions.
> Changing from Epsom Salts to Bicarbonate of Soda as an alkali, seeing that it didn't work with the 8As at all well.

Instead of interviewing the separate groups modify approach to talking to group leaders after two weeks. I suspect though that everything is going to be done at a rush - important to document just how chaotic this 4th term ends up being.
Changes to kits - less litmus paper, more clearly labelled spare bottles (x2) and remember to leave out the Epsom salts from the kits.

7.3.1 <u>The 8A Trialing Exercise</u>

I chose to start the trialing exercise with the Standard 8As. I felt I had built up a relationship of trust with them which would allow them to see the whole exercise as a stimulating challenge and change from the normal course of study. Any anxieties I had about how the students in 8A would respond to the trial were swiftly dispelled. Consider the following extract from my 8A research diary:

Monday 12 August
General air of expectancy, students seemed intrigued by what was going to happen in this section of work.
This science period was the one straight after lunch, usually a problem with late comers. This time everyone present within five minutes (except 4 girls)...
...Because of the lack of time, students were told to come after school to familiarise themselves with the kits. It looked as if Group E wasn't very keen.
<u>Everyone</u> was present after school.

It must be noted that during the trialing phase with 8A a significant number of disruptions to normal tuition was experienced. In an attempt to quantify exactly how much time was lost a record of teacher attendance was kept. This yielded some extremely interesting information.

7.3.2 Teacher Attendance in 8A

The record of class attendance by the 8A teachers during the trialing exercise is tabulated below. The following abbreviations are used in the table:

TpT	Teacher present teaching - as implied the teacher spent at least some of the period(s) teaching the students.
Tp	Teacher present - but no attempt was made by the teacher to actually teach the students.
Ta	Teacher was absent from the class for the whole period(s).
TLpT or TLp	Teacher came at least 10 minutes late to the period(s).

	Period									
Date	1	2	3	4	5	6	7	8	9	10
13/8	TpT	TpT	TpT	TpT	TpT	TpT	TpT	TpT	Ta	Ta
14/8	Ta	TpT	TpT	TpT	TpT		no	classes		
15/8	Ta	Ta	TpT	TpT	TpT	Tp	TLp	TpT	TpT	TpT
16/8				no	classes				TpT	TpT
19/8	Ta	TpT	TpT	TpT	TpT	TpT	Ta	Ta	TpT	TpT
20/8	Ta	Ta	TpT	TpT	TpT	TpT	TpT	TpT	no classes	
21/8	Ta	TpT	Ta	TpT	TpT	TpT	TpT	TpT	no classes	
22/8 - 23/8					no	classes				
26/8	Ta	TpT	TpT	TpT	TpT	TpT	TLp	Tp	Tp	Tp
27/8	Ta	Ta	TpT	TpT	TpT	TpT	TpT	TpT	Ta	Ta
28/8	Tp	TLpT	TpT	TpT	TpT	TpT	TpT	TpT	TpT	TpT
29/8	Tp	Tp	TpT	TpT	TpT	TLpT	TpT	TpT	TpT	TpT
30/8	Tp	Tp	TLp	Tp	TpT	Tp	Tp	TpT	TpT	-
2/9	Tp	TpT	Ta	Ta	Ta	Ta	Ta	TpT	TpT	Ta
3/9	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
4/9	Tp	TLp	TpT	TpT	TpT	TLpT	TpT	TpT	Ta	Ta
5/9	Tp	TpT	Ta	Ta	Ta	Ta	Ta	TpT	TpT	TpT
6/9	Tp	TpT	TpT	Tp	TpT	Ta	Ta	TpT	TpT	-
9/9				no	classes					

Table 7.1

This data was carefully gathered. For a start no attempt was made to keep records over the first few days. I felt it would be better to wait until we were well under way with the work before asking a student in 8A to help me.

A student with whom I had a good rapport, and who ended up being one of my key informants during the trialing period, was asked to assist me in collecting information concerning 8A teacher attendance. I tried to explain to him, within the context of my research work, why I wanted to gather this data. Given that many students were frustrated about all the teaching time they lost, he readily agreed to help and assured me that he knew how not to arouse the suspicions of his teachers!

At the end of each day he came along and used a basic code (see above table) to fill in a simple period register. There were a number of days on which no record was kept; because of the delicate nature of this data I wanted him to be under no pressure; if he forgot to come and fill in the register it was left at that.

Indicated on the table are days or part thereof on which school was disrupted, for example a stayaway (discussed later in this chapter) was experienced on August 22 and 23.

Records were kept for a total of 19 out of the 23 days over which 8A worked on this section of work - this translates into a total of 190 teaching periods. The following analysis of the periods makes interesting reading:

TpT	a total of 85 out of 190 periods
Tp	a total of 17 out of 190 periods
Ta	a total of 32 out of 190 periods
TLp/T	a total of 7 out of 190 periods
No School	a total of 49 out of 190 periods

What can be made of these figures?

Because of the chronic shortage of staff and because of an erratic pattern of teacher absenteeism, the school was in no position to make arrangements to supervise classes of absent teachers. In most instances an absent teacher means a class left to its own devices without work to do. One can deduce from the data that a total of **32 (Ta) + 49 (No School) = 81 out of 190** periods were effectively **lost** to teaching. Putting it another way, **43% of teaching time was lost during this 23 day period of schooling.**

I wondered why students were willing to accept that some teachers seemed to spend an inordinate amount of time not teaching them:

Question: **Do you get angry when you're not being taught?**
Thozama: Yes
Fraizer: Not being taught... what?
Question: **If say, a teacher was not teaching you?**
Fraizer: Yes too angry
Solomzi: But... but I can't say that we get angry sir, because when the teacher is absent at school, we start saying "Yeah that's good!"
Fraizer: But okay, but not all the time
Thozama: Not (when it happens) everyday
Fraizer: Not all of us at first, because we want to study at those days
Solomzi: Ya, I can... ya we get angry when the teacher is not doing the work
Monde: Like when we are going to write a test, that's an advantage, like when we are going to write a test the next period and the teacher doesn't teach, then we say 'Oh thank you, thank you...' (others laugh)

(Group A, 28-08-91)

By and large the students are powerless in the face of teachers who do not teach consistently throughout the year. As Monde suggests above, students actually welcome the opportunity to study for a test in another subject's period;

no doubt some teachers use this to their own advantage.

In general, data such as this is open to numerous interpretations. If nothing else, it suggests that for extended periods of the school year students rarely experience a full day's teaching. For example, referring to the table, on no day were all 8A's teachers in class and teaching!

7.3.3 Stayaways and Boycotts

How do the students respond to the inevitable boycotts and stayaways which are such a common feature of township schooling? Here I would like to make use of two examples, one in which school was disrupted without warning for a day, and then the effect of a more organised stayaway.

The events of the 16th of August illustrate what has in the past been a common occurrence in the townships, the fairly spontaneous disruption of schooling without warning for a single day. From early in the morning lessons were disrupted due to rumours of an impending student mass meeting. In the ensuing confusion most students began drifting off home after 10a.m. However, a group of Standard 8As hung around the laboratory and indicated to me that they wanted to come in and carry on with the practical investigations. It became clear that many of the class were still at school unsure whether or not to go off home (the science lesson was due later in the day). Those students present in the laboratory agreed to talk to the others and spread the word that we would all continue with science once things had settled down (i.e. everybody else had gone off home).

At 1.25 pm, with the school empty of almost all other students, 8A arrived and we carried on until after the normal closing time. Hours after everyone else had gone home almost the entire class (only <u>two</u> were absent) were willing to come into the laboratory, sit down and without too much apparent difficulty "shut out" the events of the day. This stands as further testimony to the students' remarkable adaptability in the face of what are so clearly adverse learning conditions. And in some way it must also be taken as an indication that the students found this practical-based approach a much more interesting way of doing science!

The second week of the 8A trialing exercise (19 - 23 August) was severely disrupted due to a "Week of Action" called by the student organisation COSAS (Congress of South African Students). In principle COSAS had agreed that normal school tuition was not to be disrupted; in practice the exact opposite almost always occurred. This is reflected in comments I made in my research diary at the time:

> Monday 19 August
> Today went in a rush, trying to get ahead of tomorrow's boycott. Latest story was that it is due to swing into gear after 12 o'clock. But with so much uncertainty the students (and teachers) are very restless.
>
> Thursday 22 August
> No school - today there is supposed to be a march in town by COSAS. Maybe 200 students milled around until they were told to go to town. Teachers released at 9.30am; most went on home.

One group of students was interviewed before and after the stayaway of 22-3 August. Before the stayaway they appeared cautiously optimistic that the stayaway would have no major impact on their studies:

Question: **Does it make you feel discouraged a bit or not?**
(All): No...
Fraizer: Yes, I think that after it has ended we shall proceed with our work... while there is time to work we will work and then... while the days of

the stayaway are on we'll stop and then we will do it (work) afterwards.

Monde: But our minds will be relaxed from the time of holiday, and maybe there will be one day in the week after next when we will be some... disorganised 'cos we have not been learning and have forgot what we do this week.

Thozama: Well, we must use every chance that we get for next week... even if it is 30 minutes...we may use it so that we do not get left behind.

(Group A, 15-08-91)

However when interviewed soon after the two day stayaway, the same students (joined by Solomzi and Ayanda) were clearly dispirited by these events:

Solomzi: You feel sad, or angry because you lose... boycotts influence our education, we get behind in our education and we cannot finish the syllabus.

Monde: It does waste time, the programme for the boycott happening during school hours... quite time wasting.

Question: Have you grown to accept it as part of schooling these days?

Thozama: Well I felt so sad, because I didn't understand what that holiday was about, I didn't hear anything.

Mondi: (laughing) holiday!

Thozama: ...it was a... (others: stayaway) stayaway. I didn't hear what it was about, I just heard that there was going to be no school on Thursday and Friday.

Fraizer: To me it...it is a waste of time, sitting at home and thinking of what I would be doing if I was at school. So I think it is a waste of time. But, I think that in these days I've accepted to it is everyday...

Question: **But have you learnt to sort of... work around it, I mean...**

Fraizer: I can accept it?

Question: **Yes**

Thozama: Yes

Monde: No... we've got used to it.

Solomzi: But we accept it because of the majority... but some of us we don't want it some of us, because you see the problem is that at the end of the year we are not going to finish the syllabus. Then it will cause a trouble to us in Standard 9... this book will say 'you know this from Standard 8'. This (stayaway) is why we do not finish the syllabus.

Ayanda: I feel sad, because it is a waste of time.

Question: **What effect do you think it has on your attitude to work?**

Solomzi: It has an effect because sometime you feel lazy to cope... you can't cope. Let's say you've got a stayaway today, then tomorrow you can't cope, you also feel hung-over you see.

Thozama: Well, if you spend a day at home when you are a student, your parents say you must work because you are at home. So you do not have a chance to use your books or study because you are a little bit tired because you have worked the whole day.

Question: **I imagine that is true for the girls, but do the boys have to do some work as well?**

Fraizer: Yes, there is work.

In discussing the different chores they had to do, it appeared as if most of them were kept busy by their parents/guardians. As Thozama rather wistfully put it;

Thozama: There are no boys at home, so I had to do <u>everything</u>, the garden, the washing... everything.

(Group A, 28-08-91)

This then is the reality of secondary schooling in black townships around the country: disruptions, stayaways and erratic teacher attendance. My point is simply this - one cannot view the activities of the science laboratory in isolation. As one engages students in a programme of practical work, however structured it might be, the unstructured nature of schooling will impact on the implementation of such a programme. When engaged in classroom-based research one must be able to accommodate the inevitable delays and disruptions which accompany the "stop-start" nature of township schooling.

However, rather than seeing such occurrences as barriers to successful research, they add a critical dimension which both enriches and deepens one's work. Furthermore, reflecting upon the complex dynamics of such a research context highlights the importance of moving beyond rigid empirical research tools when engaging in classroom-based research.

7.3.4 The 8B Trialing Exercise

The trial period with the 8Bs took quite a different course. As suggested earlier (in the extract from my research diary) I had the opportunity to modify my approach based on my experiences with the 8As. Circumstances were also different in that we faced a definite time constraint, the trialing starting as it did at the beginning of the last term.

A feature of township secondary schooling is that the amount of available teaching time during the 4th term is very limited. For example, at Luhlaza the final exams effectively began with the writing of language first papers on October 14, almost seven weeks before the end of term. The last two weeks of the trial would normally have been reserved for revision work, so it was only in science that teaching continued.

Having the first papers written during the trial period did have an effect on the students. The following extract from my research diary illustrates this:

> Monday 14 October
> Shortened periods (30 instead of 35 minutes - to allow for six periods before break, the writing of Xhosa first paper after lunch).
> Dealt with acid rain, students distracted by upcoming essay/letter exams, messes everything up. It's like announcing the exams are going to begin in full! We have been put under immense pressure by neighbouring schools' action of starting exams early to put forward our exams from November 4 to October 28. Don't know if I will finish off all of this work now.
> The point I was trying to make with doing this work in the 4th term was to show how the term disintegrates in front of your eyes... You start off hoping to have up to five weeks for teaching but then it boils down to two weeks followed by three days of shortened periods after which teachers will undoubtedly start marking! After this there is only 1.5 weeks until 25 October then it's all over...

At the level of student politics the approaching exams tended to have a moderating influence; usually very few disturbances were experienced in the run up to end of year exams. This again proved to be the case in 1991. Between September 30 and October 25 no days were lost to a student-led boycott or stayaway. This was in stark contrast to the trialing exercise with the 8As, where nearly five full days (49 periods) were wasted.

As mentioned to earlier, I felt that the 8Bs had a more ambivalent attitude towards their school science. In reply to the last question in the second questionnaire (refer to appendix 4), in which they were asked to rank their subjects from most to least enjoyable, 23 out of 35 ranked science at position 4-6. This compared with 14 out of 35 who answered in a similar fashion in 8A.

I began the trial period with the 8Bs, then, anticipating two possible problems: firstly, that there would be a distinct lack of interest among some students and, secondly that due to the approaching exams we might run out of time. The first issue will be taken up in the next section of this chapter. With respect to the problems anticipated with running out of time, as feared, the approaching examinations began to impact increasingly on the trialing exercise. I noted this in my research diary:

> Tuesday 22 October
> Used two lost periods plus half an hour after school. After spending one period on demonstration work, the students got a bit frustrated with the practicals. Problems ranging from students not reading instructions, missing out steps, starting on the wrong page, using up too much reagents...a sense of having to rush through things.
> Found today a very draining experience, very tiring, lots of shouting and also a lot of patient explaining! Overriding impression is one of many kids not really trying to understand what's going on.
> It is a very difficult time to work, with the exams due to start and the school grinding down to its pre-exam halt...

Conditions became increasingly difficult as the exams drew nearer; in retrospect the fourth term was not at all conducive to engaging in student based research such as this. Even though in some respects the 8B trialing exercise failed to provide as rigorous a test of the material as that with the 8As, enough data was gathered to be of valuable assistance in the evaluation of the effectiveness of the trial text material.

The rest of this chapter is devoted to considering various aspects of the two trialing exercises from the perspective of the students. In particular to reflect on how the students felt about this departure from the conventional textbook approach to a more issue-based approach to teaching and learning science. How they responded to the group practical activities (in particular what happened with the independent investigation among the 8As) and a number of examples of where the data gathered from the students during the course of the two trials could be of assistance in the reformulation of certain aspects of the trial text material.

7.4 Group Practical Work

The group practical experiments in the worksheets were regarded as a central strategy for encouraging the students to engage in more active learning, that is, to become more fully involved in their own learning (Bentley and Watts 1989). Yet as Woolnough and Allsop (1985) points out, practical work can be regarded as the "Achilles heel" of school science. In chapter 2 some of the criticisms levelled at discovery learning and its attendant practical work were dealt with. The point being made was that practical work can end up as being rote discovery learning, characterised by what Solomon (1980) describes as "worksheet-dominated, cookery book type practicals".

Mindful of these criticisms, I will draw on the data gathered during the two trialing exercises to consider how my students responded to the structured programme of practical work.

In the first place, seeing that the students in most other subjects are exposed to a fairly unchallenging diet of expository teaching, it came as no surprise that they responded positively to the practical activities. On numerous occasions during the interviews students expressed their interest in this work:

Mfundo: I'd say it is enjoyable and understandable because we are experiencing the thing that we are doing, it's not like reading from the textbook.
(Group A, 15-08-91)

Peter: It makes it easier to understand... in the textbook we don't see the chemicals and when we are doing the practical work we see those chemicals. We start to investigate something ourselves and not just taught by the teacher.
(Mixed 8B, 08-10-91)

Solomzi: If you are just theorizing, then you feel it is boring.
(Group A, 28-08-91)

Zolisa: Because we used to be lousy and drowsy...(laughter) (Mixed 8B, 08-10-91)

Another source of comments were the student diaries. Here is an extract from one of them:

> Wednesday 14 August
> This is the most interesting day... because now we are doing experiments by ourselves and it is not the teacher who is doing the experiment and we watch him do it. It is a good thing because we are not being spoon-feeded and it is not like before when you were told that something is an acid now you are proving it.
> (Faizer)

As expected the students appreciated the opportunity to do the practical work together in groups. After an initial period of uncertainty (usually the first week) most of them adjusted remarkably quickly to group work. In this respect, it appears as if my hunch that the student study groups would facilitate science practical work was correct. In many cases the students accepted that the group leader who <u>they</u> had themselves appointed, would take the lead and an encouraging sign was that as the trialing periods progressed the students became more adept at delegating responsibilities and tasks to the various members of the group.

There were markedly more problems in 8B. A number of groups throughout the trial period struggled to work successfully together as a team. The coping levels varied considerably across the class as this extract from my research diary illustrates:

> Tuesday 8 October
> Group C is a problem, nobody taking responsibility so nobody particularly interested. Not engaging at all!
> Group A very noisy sometimes not getting very far, either all interfering or arguing together.
> Group B is very hesitant; most of them look insecure, but seeming to be gaining in confidence.
> Group D and E working fine.
> Group F is the really motivated group - they move smoothly ahead by themselves.

Although I was interested in probing the problems experienced in some groups as the students attempted to work together, I realised that the dynamics of such group interaction is a highly complex matter (and worthy of a dissertation in itself). A useful overview of the problems associated with groupwork is, however, given by Watts (1991:52); in suggesting that it relies on the temperaments, common goals, attitudes, skills, ideas etc. of several people who have to work in accord to try to achieve a positive result, Watts highlights the complexity of such co-operative learning.

The group leaders in 8B were asked during an interview to reflect on the problems being experienced in their groups. Although some of them tried to pass off the problem as being one of "lazy students", there was clearly more to it than that. What came out in the interview was that the central issue seemed to be one of motivation. As mentioned in chapter 5, some groups had students for whom science was not their first choice of subject. Basically they found themselves in the class somewhat against their will (hence the low rating enjoyed by science in 8B in the attitudinal survey). Coupled to this, quite a few students were clearly very unsure of their own abilities. As explained earlier, based on their performance in science tests, for most of the 8Bs, science was a "failing subject". Consequently they lacked the confidence to try things for themselves and were very hesitant when following (for example) the experimental procedures.

Many of these points are summed up by one of the group leaders as he reflects on the practical work:

Michael: In my group I first found out that in the first week we had a difficulty of... ah understanding what was going on... not used to working with groups, so we sort of handled the kit in a tense way. Now people are getting used to work with the kit and each and everybody wants to do... to do something at his or her own, so we are getting used. But what I've noticed in some groups is that some of the people are not used for working with groups then... well at times like these, they feel ashamed of themselves being amongst the others working in groups. So somebody feels shy... and just says that and that.

(8B mixed, 08-10-91)

With hindsight it would have been better to exercise more direct control over the composition of the different groups. Allowing the students to form their own groups without interference had worked for the 8As but created problems for the 8Bs. Of course what tended to happen in some groups was that a few students ended up doing all the work. A possible way around this problem is to include within the worksheets a number of practical activities which students have to do either alone or in pairs.

In general the students in both classes took to the notion of group practical work with much enthusiasm, as the above quote indicates and the following extract from a student diary confirms:

> Friday 16 August
> The most thing that I liked about today's experimental work is that although it was difficult we have worked it as a group effort and this gives us practice on how to work as group and it so interesting to work as a group. Today's work also make us to think and not expect our teacher to tell us the answer and it trained us to think more like a scientist. (Fraizer)

Yet as noted earlier, one of the greatest problems facing practical work is that it can end up as being passive "recipe science". So for all the enthusiasm shown by the students, the critical question which has to be asked is to what extent did the practical work achieve its aim of engaging the students in more reflective and self-directed learning?

Looking back over both trial periods, it became evident that the students, given a little bit of practice, learnt without too much difficulty to follow the basic instructions presented to them in the worksheets. Yet as they grew in confidence they became increasingly adept at following the experimental procedures without reflecting on what they were doing. I noticed on a number of occasions that students would skip the introduction to a worksheet, and then pick out from the text only those instructions which they felt they needed in order to complete the experimental procedures. Furthermore, if a procedure did not work they tended to ignore the problem and to move on to the next stage of the worksheet. Here are two extracts from my research diaries which highlight this problem:

> 8A Thursday 15 August
> ...what's disturbing is that students are not really thinking about what they are doing; they just follow instructions blindly.
>
> 8B Tuesday 22 October
> Like the 8As, nobody seemed to mind missing out instructions. Even when they got an answer which they agreed looked strange, they would leave it alone and move on...

The students seemed then to have slipped easily into a way of doing experimental work which runs the risk of being labelled passive "recipe following". Unfortunately this tends to negate a central aim of the practical work - which is to encourage the students to engage in more active learning.

On the one hand, the text itself was at times at fault. I realised that in a number of instances instructions needed to be rewritten, and that a more carefully thought out questioning technique would encourage more careful reading. For example, the test for carbon dioxide (Worksheet 6, pg 32 of appendix 1) raises the issue of causality. In response to what was observed in the reaction, one student had written:

> "Carbon dioxide was formed **and** the limewater turned milky."

Another student from the same group read this response and commented that it should read:

> "The limewater turned milky **because** of the presence of carbon dioxide."

He then wrote this down as his answer. The first student disagreed with this as she failed to see the difference between **and** and **because**. In a future rewrite of this worksheet, questions need to be structured so that this causal connection is emphasised (later in this chapter some further examples of possible changes to the text will be considered). This example also highlights the problems which many L2 students experience with understanding and using logical connectives like **because**.

There is also a need to integrate more formal "lessoning", students need to be held up and forced to reflect on the practical activities they are engaged in. This boils down to more careful instruction on the part of the teacher, and includes, for example, running through the procedures in advance and then more consistent summing up at the end of each lesson/learning activity.

There are of course a variety of other factors which give rise to "recipe following". The reasons why students appear to be such poor interpreters of texts are in turn complex and, as will be suggested in the following chapter, are to a large extent linked to the inadequate reading strategies they have available. It clearly points towards more deep-rooted problems which the students have when it comes to reading L2 texts (more on this in chapter 8).

7.5 The Group Investigation

The group investigation was an attempt with fairly limited expectations to engage the students in 8A in some kind of self-directed learning. Unfortunately time restraints prevented me from undertaking a similar exercise with the 8Bs. It was hoped that after doing the more formal practical worksheets in class, they would be able to complete a more open-ended investigation in their own time.

Students first heard about the investigation in the introduction to the handout and were told that they would be

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13 September
Group A - the first two weeks they kept on shifting from wanting to do one topic to another. Eventually they agreed on the investigation of the "pH of liquids' (a very straight forward one!). After discussing it with them they agreed to try something a bit more challenging, the "pH of soil samples'. It took them a week to gather five (!) soil samples from the different townships. They were given an extract from a Standard 5 textbook which gave them an idea of how to go about testing for pH. They didn't know what to do with their wet samples; after prompting they agreed upon a way of drying them out (they would leave them in the sun for a few hours). A few days later they came back and asked for some distilled water (they had by now read the extract from the Standard 5 textbook).

On the first day of the new term, after school, a meeting was held with the various group leaders. It transpired that in the holidays very little progress was made and the students requested a further extension. A discussion ensued in which I tried to establish where the major problems were. Two groups admitted that they struggled to get students to work together after school. Many tried to use as an excuse the fact that the students lived in different townships, some that attempts to meet had failed because students were unwilling to give up their holiday time. Each group leader then had to sit down and write a short progress report; here are some examples of what they wrote:

Group H   Chart of Acid Rain for Geography Students

We have done nothing. Because we are not at the same place, some of us live at far places so we didn't consult each other. We decided to do it during this term after school (tomorrow).

Group E The pH of Liquids that we drink

We have check the pH of tea; coffee; milk of magnesia; water; tea with milk; coffee with milk. We were trying to find other liquids that we drink or buy them. We haven't got money to buy other liquids. We have decided that each member in group E must bring any liquid from home. We will finish this on Thursday.

When it was pointed out that they had been "busy" with these investigations for more than 6 weeks, they all agreed that their progress was, to say the least, disappointing. By this stage I was preoccupied by the trialing exercise in 8B and growing increasingly despondent about the apparent failure of the group investigations. However, we decided to carry on; the students agreed to stay in after school over the next few days so that they could try to get something together and I agreed to help pay for any materials they needed to buy. Every group opted to prepare a wallchart, so they were supplied with the necessary stationery and allowed to use the laboratory every day after school.

The presentations took place over two days (17-18 October); one person from each group described their chart and fielded questions from the rest of the class. The students clearly enjoyed this opportunity to quiz their fellow classmates about the topics they had chosen to investigate. In some ways the end result justified what had been for all of us a frustrating experience.

7.6 Group Work - a Reflection

With the group investigations I had clearly underestimated the problems that the students would experience. Upon reflection I realised that it was unfair of me to expect too much of them. For most students this was their first attempt after nearly ten years of schooling to work in groups on their own. In many ways it brought home to me an appreciation of the extent to which their previous learning experiences (years of rote learning) left them inadequately prepared for self-directed learning. It also taught me a valuable lesson, in that I needed to redefine more clearly my own role during such an exercise, and that my attempts to be a resource (rather than a source) for learning would in future require a lot more careful thought and preparation.

With regard to what appeared all too often as a "recipe following" response to the worksheet experimentation, this too came as no surprise. On a number of occasions the practical activities relied on students possessing a certain level of expertise in different "process skills" (such as learning to observe, measure, record information, make inferences and state relationships). Clearly these skills cannot be developed overnight, so it seems almost inevitable that at first, as a coping strategy, students would resort to a passive approach in following experimental procedures. It can be argued, then, that "recipe following" during practical work has to be seen as an inevitable first step along the road towards more self-directed learning.

Therefore the challenge lies in developing in the students the skills needed for more active learning, and this should really have started long before the students were confronted with a structured unit like "acids and alkalis". In this regard, one possible solution lies in a series of modules/units, not necessarily linked to any particular science content, which introduce and develop in the students the various process skills mentioned above.

I was conscious all the time that the two trialing exercises represented for me just as great a departure from the normal pattern of teaching as it did for the students. I recognised my own inexperience in running continuous large-scale group practical work in classes of over 45 students. For example, the demands in terms of preparation were very heavy (as mentioned earlier I was responsible for teaching over 250 students in a full programme of teaching), and few, if any, township schools have the luxury of a laboratory assistant. I quickly discovered that this proved a perfect opportunity for the students to get involved from the beginning in an active and meaningful way. As one of the 8As put it in her first entry of her diary:

> 5 August
> After school eight students in our class helped in putting up the new science equipment. This was a very exciting job. We prepared 8 kits for all eight groups in our class. As I looked everyone seemed to enjoy what he was doing. We were moving up and down putting the stuff in the boxes. This was very interesting because for the first time we do things by ourselves. This was just the start there's more we will do without being helped. (Nomvuyo)

Besides their own work, in different ways students were kept involved in the day-to-day running of the practical work (resupplying groups with reagents, cleaning the laboratory, cleaning apparatus). In retrospect I believe that this helped all of us to view the exercise as a co-operative venture and allowed the students in particular to gain a sense of "ownership" over the practical work.

The practicalities of large-scale group work did however limit me in my role as a participant-observer. On a number of occasions, particularly during the course of the first trialing exercise when the students experienced problems with certain experimental procedures, I had to concentrate on helping them and there was little time for writing up any on-the-spot observations. However, things were easier the second time around when I could at least predict and to a large extent pre-empt problem areas. In future in similar circumstances it would be useful to have a second researcher participating in the work.

7.7 The Practical Kits

One of the most positive aspects to both trialing exercises was that in general the practical kits were a complete success. I had expected that the students would experience some difficulty in handling the apparatus (such as the test tubes and the evaporating basin), yet I was pleasantly surprised to find how carefully they worked. There was an acceptable level of reagent consumption; the small bottles in each group's chemistry kit were refilled before the 8Bs started and fresh stocks of the standard acid and alkali solutions were made up. In 8A only two test tubes were broken during the entire course of the trialing exercise, and in 8B four test tubes and an evaporating basin needed to be replaced.

7.8 Student Contributions to Text Evaluation

Data from the two trialing exercises will be used extensively in the following chapter to look at some of the problems L2 students experience when they interact with science texts. Examples of where the students were able to evaluate the language of the trial text will be given. What will be discussed here briefly are a few examples of where the students were able to offer valuable insights into other aspects of the text. In the following discussion please refer to the handout in appendix 1.

During one particular interview with Group A (18-09-91), we went through the handout together and the students made certain suggestions about things which could be changed. For example, on page 8 when dealing with "diluting laboratory acids", one student pointed out that at the time they had wondered why they were not allowed to add water to a concentrated acid. It was suggested that more information was needed, and I realised that it presented an opportunity to introduce the students to exothermic and endothermic reactions. They reminded me of the problems we had experienced with using tap water in Worksheet 2, and the need to rework page 11 clarifying the difference between tap water (which is alkaline in Khayelitsha), rain water (which is acidic) and distilled water. They wanted to know more about distilled water, perhaps a separate information sheet on how to make it and where is it used would be useful.

I was particularly interested to see how the students would respond to my attempts at more "issue-based" topics, and they were asked to give their opinions of the different exercises like "how to make a cake rise" and "acid rain":

Michael: Once again sir, about this acid rain in the Eastern Transvaal, I found it very interesting to know such things. Because I'd say that mostly in my group, there are people who usually like to... dig holes of answers, 'How is this happening, why is this happening... the way it is happening'. (Mixed 8B, 21-10-91)

Question: **What about today's things on cakes. What do the boys feel about that?**
All: Laughing...
Andile: It has a place (Mixed 8B, 21-10-91)

Naturally they did not always agree with each other, when asked about whether or not there was enough information on "Applications of the Acid-Carbonate Reaction" on page 36:

Fraizer: I think that there is enough information, the little information about Enos is right because... here is this thing (turning to the previous page) in the "Rising of a Cake", I think there should be more information because this thing... let me say... we do the mixtures of the cake everyday but we don't know what's happening there, what's happening with the bread, why it is rising, so I think...

Monde: What about Enos, we use it everyday at our homes?

Thozama: We don't need to know that.

Monde: Why not?

Thozama: You just have to buy it from the shop. You don't have to make it yourself...

Monde: I mean why does it fizz when you pour it? Shouldn't it be mentioned here, why it fizzes?

Fraizer: (the arbitrator) I think there should be something but not much. (Group A, 18-09-91)

This seems to illustrate that one needs to make more information available to those students who are interested in pursuing the topic further. It was suggested that alongside the basic text a series of additional readings could be made available.

By the end of the handout they started to make suggestions about topics for different comprehension exercises. After the teacher demonstration on "The Dangers of Strong Acids and Alkalis" one student in 8A asked if it was possible for battery acid to eat up a body. Another student recalled having read recently about the case of a mass murderer who had used concentrated sulphuric acid to dissolve his victims' bodies. The class agreed that it would make a good (if somewhat gruesome) topic for a comprehension exercise.

The final worksheet dealt with the safety problems associated with household chemicals. Once again the students were able to think up an interesting exercise - that of rewriting the warning labels of common household reagents in simplified English which everyone could understand.

Another way in which the interviews were valuable was that they gave me the opportunity to clarify some of the observations I made during the course of the practical work. This proved an interesting exercise. More than once I found out that I was reaching the wrong conclusions.

For example on page 25 of Worksheet 4, the students had to heat a filtrate in an evaporating basin, until all of the liquid had boiled off. In 8B I had noticed that some of the groups did not boil off all of the liquid and assumed that the reason was that they had not read the instruction carefully enough. My solution was to consider highlighting it as follows - "Heat the evaporating basin gently until **all** of the liquid has evaporated". Then during the course of one interview I asked the students why they had failed to follow the instruction:

Andile: We were a bit scared, sir, of the evaporating basin, sir, that it would break when it gets hotter.

Fezekile: We felt the same thing, that if that basin became hot it will break.

(8B mixed, 21-10-91)

It had nothing to do with the instruction; it was because I had failed to explain to the students that our evaporating basins were made out of heat resistant glass! Of course the students' real-world experience tells them that if you heat glass objects they will often crack (and in the townships few people can afford pyrex). This taught me a valuable lesson, and seemed to underline once again the importance of interviewing the students during a trialing exercise.

One final example is provided in Worksheet 8. On page 42 there is what I thought was a simple table in which the students have to record two temperature readings and then work out a change in temperature. I noticed that in 8A many students were unsure what to write in the final column of the table. The students indicated that they were confused by the wording "change in temperature". During one interview a lengthy discussion failed to come up with an alternative, "By how much does the temperature change" and "What is the difference in temperature" were both rejected as being no clearer than the original statement. After all the suggestions for changing the wording, one student had this to say:

Fraizer: But I think that you must not change this, you must leave it like this...

Question: **Why?**

Fraizer: But try to explain to the students what to do you mean 'change in temperature' in order for them in future...

Thozama: Get used...

Fraizer: ...when you are again talking of a thing like this so they can just know it.

(Group A, 18-09-91)

Inadvertently Fraizer was raising a crucial point. The answer does not always lie in "writing out" something which the students struggle to understand. Of more importance is instruction, and a need to develop in L2 students the skills required for interpreting the more complex language style of scientific texts. Subsequently in 8B before starting this experiment I explained what was required in the table and, according to my class notes, almost all the students managed to fill in the table correctly.

7.9 Conclusion

The issues involved in deciding what constitutes effective practical work are complex (see Woolnough and Allsop 1985), particularly in contexts such as a township school in which there are serious shortages of both human and material resources. The group practical work undertaken during the trialing exercises may have been at best only a hesitant step forward for most students. But as is so often the case, it is invariably the first step which is most crucial. Whatever limitations were evident in the experiences of the two classes, the fact remains that we were able to sustain in both cases a period of around four weeks continual large scale group practical work. As a visitor to the school put it:

> The students had to be told to pack away their kits and tidy up. They did not even notice the double period was over. Clearly, they had enjoyed the lesson. I was amazed to hear that there were 45 students in the class. I didn't think group activity would work so well with so many students. (Oxenham 1991:2)

Some aims were achieved; students had the opportunity to begin to learn many of the process skills associated with scientific investigations; they learnt to work with others and to some extent learnt at least their own limitations when it came to taking on responsibility for the direction and planning of their own work (I refer of course to the group investigations). In my role as participant-observer I was able to see, particularly in 8B among students who had little interest in formal academic science, how in co-operative group work they found areas in which they could succeed and in which they learnt to appreciate the work of others. And maybe for the first time in school science they began to discover that they were much more capable than they had realised.

Chapter 8
Data Analysis

8.1 Introduction

The role of language in the learning of science was discussed in chapter 2, where among other things it was suggested that science teachers need to place a greater emphasis on the use of language in science lessons. In this respect, data gathered during the course of the trialing exercises highlighted a number of language-related problems which have a bearing on any attempt to produce more accessible text material for L2 learners.

In chapter 3 the various text-based factors which have been identified as presenting reading difficulties for L2 readers of science texts were discussed in some detail. The trialing exercises gave me the opportunity to explore some of these factors from the students' _own_ perspectives.

The primary purpose of this chapter is to illustrate by example how some of the different forms of data gathered during the course of the two trialing exercises can be used as a kind of diagnostic tool, allowing the researcher to probe the various language difficulties experienced by the students as they interact with science texts. In addition to which, two excerpts from the Standard 8 Physical Science textbook used by both classes will be analyzed in terms of the language criteria outlined in chapter 2.

8.2 The Students and their Science Textbook

In section 3.4 mention was made of previous research which I undertook into the readability of science texts being used by my Standard 8 and 9 L2 students (see Clark 1987). The results obtained from the readability formulae and modified Cloze Procedure, although limited in both scope and validity provided quantitative data which at the very least highlighted the extent to which my L2 students struggle to read and understand their science textbooks.

Since my Standard 8 students in 1991 were using exactly the same textbook as the one analyzed in 1987, this earlier research work (whatever its limitations) gave me a useful platform from which I could continue my exploration of students' text-related reading problems.

In the following discussion there are three main sources of data namely, the textbook questionnaire (see appendix 4), the pretest exercise (see appendix 2), and the various student interviews. Referring to the textbook questionnaire, it is not my intention to enter into a detailed statistical analysis of the students' responses to the various questions. Instead of that, the data is used in its broadest sense to build a general picture of the students' feelings and attitudes towards their science textbook. To all intents and purposes the responses from the two classes have been considered together. As can be seen from the summary (see appendix 4) in almost every question (excluding Question 13), student responses across the 8A and 8B classes show a similar trend.

8.2.1 The Use of Textbooks

The first major point of interest which came out of the questionnaire concerns the extent to which the students use their science textbook. Of the 83 students who filled in the questionnaire, more than half (46) admitted to reading the textbook only before a test or exam and a further 25 students indicated that they read their textbook once or twice a week.

If it is accepted that the textbook is the single most important resource for teaching and learning school science, this is a disturbing finding. From these figures one can assume that many students are either unwilling or unable to use the textbook to any great extent as a resource for learning the subject.

With hindsight it must be noted that Question 4 is ambiguous. Students could interpret it as asking them to comment either on their conceptual understanding of the content of the book or on their feelings on the general level of text readability. Be this as it may, it is significant to note that, when asked "How much of what you read in the textbook do you understand?" 31 students (37%) answered "Not much of what I read" and a further 37 students (45%) thought that they were understanding "about half" of what they read. Only a small percentage (18%) of students thought that they understood "most of what I read".

If so many students struggle to understand the textbook it seems hardly surprising that they use it so infrequently. Responses to Question 4 would appear then to be consistent with the low levels of textbook usage recorded in Question 1.

Question 7 of the questionnaire was a further attempt at probing the students' feelings towards the language used in the textbook. Fifty-six out of 83 students (68%) chose to answer "sometimes I understand the English but I often stay confused about the work in the textbook" and only one in five (20%) felt satisfied that they understood enough of the English being used.

What is it about the language of the textbook which creates such barriers to comprehension?

8.2.2 The Standard 8 Physical Science Textbook

Before exploring some of the reading difficulties which students experience with science texts, it would be instructive to consider their science textbook in terms of the various text-based factors identified in chapter 3 as presenting reading difficulties for L2 readers.

To this end two excerpts from "Physical Science 8" by Brink and Jones (1985) will be considered. It must be noted, though, that the following discussion is not intended as an exhaustive critique of the "readability" of either the excerpts themselves or of the science textbook as a whole. Instead such a focus, however brief it might be, serves to contextualise the students' own comments on the difficulties they experience when reading their science textbooks.

For a start, as suggested in section 5.1, the Standard 8 Physical Science syllabus is densely crowded with conceptually difficult material. Besides questioning the need for including much of this work in the syllabus in the first place (a consideration which unfortunately lies outside the scope of this dissertation), it does however place writers of texts in an unenviable position: that of having to present the complex, abstract concepts of science in language which will be understood by the students. This is a particular problem evident in both of the excerpts from the textbook.

Referring to the passage: "The Atom-A Misnomer?" taken from page 136 of the textbook.

Figure 8.1

11.1 The atom — a misnomer?

For time immemorial, man has been fascinated by the composition of matter. Even long before Christ, Greek philosophers proclaimed that matter consists of tiny particles. **Democritus** (± 420 B.C.) named such particles **atoms**, derived from a Greek word '**atomos**' meaning *indivisible*. You will have to establish the validity of this term.

These earlier theories were only philosophical doctrine and because they were not based on experimental evidence, we shall pay no further attention to them. For the following 2 000 years no contributions were made towards the development of the theory of the particle nature of matter. Towards the middle of the seventeenth century, Robert Boyle and Isaac Newton began to realize that scientific theory could be based only on accurate experimental observations. Some years later, in 1803, **Dalton** put forward the first real atomic theory.

Brink and Jones (1985:136)

1. In the first place the passage contains a number of unfamiliar non-technical vocabulary words such as: **misnomer, derived, indivisible, validity** and **proclaimed.** It was noted in section 3.4.2 that such words, which can be categorised into Barnes (1969) second (specialist language not presented) and third (language of secondary education) registers, will create comprehension difficulties for L2 readers. Even the heading of the passage "The Atom-A **Misnomer**" is itself confusing given that it contains such an unfamiliar word.

2. In the second paragraph there is an example of "substitution and lexical reiteration" (one of the five principal categories of cohesion):

> These **earlier theories** were only philosophical doctrine and because **they** were not based on experimental evidence, we shall pay no further attention to **them.**

Young and Nuttall (1989:257) suggests that there is a danger that the L2 reader will not make the connection between the original words and those used later in the passage. This is a real possibility in this sentence, given that the reader is required to grasp not only the content but also the context of the sentence (this issue is picked up below).

3. Yet the use, at the very beginning of the passage, of a fixed expression "**For** (sic) **time immemorial**" points towards what can, from a reading perspective, be regarded as the text's most problematic feature.

The extent to which reading is successful depends, according to the interactive reading model discussed in chapter 3, upon a range of reader and text-related factors. Because reading is an interactive process between reader and text, the contribution of the reader's <u>background knowledge</u> in constructing the coherence of any text has crucial implications, particularly for L2 readers of texts. In this respect Johnson (1981) goes so far as to suggest that inaccessible background knowledge is the single most significant factor in reading comprehension.

For instance, Carrell (1983) argues on the basis of her research, that when non-native speakers of English process text they are unable to make effective use of content and textual clues. This led Pillay (1988:86) to conclude that L2 readers are linguistically bound to a text.

In particular Carrell and Eisterhold (1988:562) note how implicit cultural knowledge is often presupposed by a text and consequently the content of a text can only be understood in its context. One implication of this is that in some instances the socio-cultural context of the writer may alienate the reader and in so doing create a barrier to comprehension.

In the discussion on coherence (see section 3.4.5), it was suggested that this is a particular problem evident in some South African science textbooks. Written mostly for a white L1 audience, they tend to have a distinctly Euro-centric bias. This is illustrated in the above passage; in delving into the historical roots of modern atomic theory, the writer of the text makes assumptions about the kind of background knowledge available to the students (<u>and</u> teachers) who read it. For example, what sense will be made by L2 readers of statements such as; "**Greek philosophers proclaimed...**" and "these early theories were only **philosophical doctrine**"?. Not only do L2 readers have to cope with a number of complex and abstract ideas, but they also find them embedded in context-reduced texts far removed from their own life experiences.

The second passage: "A modern model for the electron structure of an atom" taken from page 157 of the textbook, will now be considered.

Figure 8.2

13.1 A modern model for the electron structure of an atom

Bohr's theory that electrons travel in fixed orbits around the nucleus of the atom has definite shortcomings. It cannot, for example, account for the origin of all line spectra which you observed with the aid of a spectroscope as in Experiment 11.1

Owing to the fact that the electron has such a very small mass, it is impossible to determine its *position and velocity* simultaneously without disturbing it. It is thus not possible to predict fixed orbits along which these particles may move. We can at best define spaces or regions of electron-movement (called **orbitals**) in which electrons will probably be found. This extreme measure of *uncertainty*, coupled with the establishing of definite positions for electrons, is summarized by **Heisenberg** in his **uncertainty principle**.

To understand the uncertainty principle more clearly, look at the dartboard in Fig. 13.1. It is obvious when we look at the distribution (density) of holes on the board, that the dart has in the past struck the central portion more frequently than the outer area of the board. Should a person now prepare to throw at the board, we may with reasonable certainty predict that the dart will probably strike the board close to the centre, where the holes are more numerous. The possibility (*less likely*) that it will strike the outer edge is reflected by the fact that there are relatively few holes in this area.

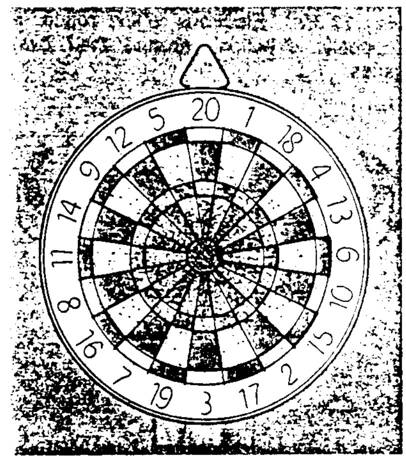

Fig. 13.1 The concept of 'probability'.

Similarly, the orbitals represent *the most likely spaces* in which the electrons concerned may move. These orbitals are not sharply defined or confined, as is the case with the Bohr orbits, but become more sparse towards the outside (Fig. 13.5). The most probable position of the electron is indicated by the inner section of the orbitals, but the possibility does exist that electrons may still be found along the outer boundaries of these spaces.

Just as light, as you will learn, exhibits both wave and particle characteristics, so also electrons, which until now have been considered as particles, possess *wave characteristics*. This supposition was confirmed by great mathematicians like Einstein, De Broglie, Max Planck and Erwin Schrödinger and it enabled them, with the aid of mathematical manipulations known as *wave mechanics*, to define the orbitals more correctly.

Brink and Jones (1985:157)

1. Once again the passage contains a number of words which would be unclear to L2 readers at the Standard 8 level: **predict**, **relatively**, **sparse**, **exhibits** and **supposition** to name a few.

2. At a later stage in this chapter the problems which L2 readers experience when attempting to distinguish between the everyday meaning of a word and its particular meaning in scientific discourse will be discussed. It is however worth noting here a number of examples of where students may struggle to choose the correct contextual meaning for a word: "**Owing** to the fact that...", "**coupled** with the establishing of...", " the distribution (**density**) of holes" and "is **reflected** by the fact that...".

Referring to section 3.4.1, the second passage, more so than the first one, reflects a style of writing common to many expository scientific texts. Consequently it displays some of the features of scientific writing singled out by both Strevens (1976) and Sutton (1982) as creating comprehension difficulties.

3. There is a number of long and complicated noun-phrases; for example, "**spaces or regions of electron movement**", "**most likely spaces**".

4. Since in general overlong sentences are difficult to read, it is important to note that the average sentence length of a similar passage taken from the Chemistry section of this book was reported as being 24 words/sentence (with a range of 10 - 41 words/sentence)(Clark 1987:20). By contrast Marland (1977) computed the average sentence length for passages of narrative text as being only 11 words.

However, as suggested in section 3.4.3, an ideal sentence length cannot be "fixed"; rather it should be determined by the complexity of the information presented in the text. In this instance the text deals with some complex and abstract concepts in atomic theory which may be best described in sentences of more variable length. The point made by both Williams (1985) and Young and Nuttall (1989) is that any individual syntactically complex sentence does not in itself create a readability problem; rather, the impact of syntactic structure on readability is cumulative (see page 54).

5. A frequent criticism of the stiff and formal style of scientific writing is that it contains a high proportion of passive constructions. There are a number of passive structures in this text, e.g. - "**The most probable position of the electron is indicated <u>by</u> the inner section of the orbitals...**". However in general, it appears that the authors have made a concerted attempt to avoid the excessive use of passive constructions. This is certainly a positive trend evident in many of the latest school science textbooks.

6. The frequent use of logical connectives (an important cohesive device) has been identified as causing comprehension difficulties for L2 readers of science texts. Here there are a number of examples: "**Owing to the fact that**"; **thus** and **similarly**. This last connective was specifically identified by Gardner (1977) as being very difficult (see also the findings of Cumming 1991).

7. As in the first excerpt, it is likely that the cohesive device of substitution and lexical reiteration will create comprehension difficulties for L2 readers. Consider the following two examples:

> "...the **electron** has such a very small mass, it is impossible to determine **its** position and velocity simultaneously without disturbing **it**. It is thus not possible to predict fixed orbits along which these **particles** may move."

> "The most probable position of the electron is indicated by the inner section of the **orbitals**, but the possibility does exist that electrons may still be found along the outer boundaries of these **spaces**."

8. It was noted in the discussion on coherence (see section 3.4.5) that visual literacy is a highly complex topic. The question which has to be asked is whether illustrations such as Figure 13.1 help or hinder comprehension. This leads us on to consider the extended metaphor employed in this passage to explain Heisenberg's uncertainty principle.

In section 2.6.1, it was suggested that L2 students will experience specific difficulties with the metaphorical use of language in science (see Sutton 1981). As Shortland and Gregory (1991) points out, analogies in particular are a powerful descriptive tool, yet their use may present L2 learners with added problems of comprehension. This seems to be the case here, where the authors of the text employ what is clearly a culturally specific analogy in their explanation of the uncertainty principle. The game of darts is <u>not</u> in my experience a common pastime of the black L2 students whom I have taught.

It is ironic then that the paragraph begins with the statement: "To understand the uncertainty principle more clearly, look at the dartboard shown in Fig 13.1." Without a set of darts and a dartboard (and a very careful explanation from someone who knows how to play darts), it is doubtful that L2 readers will find the analogy at all helpful in making sense of the complex and highly abstract concepts embedded in atomic orbital theory.

A further indication of the complexity of the subject matter is reflected in the extensive use of modals in this passage. For example, "**Should** a person now prepare"; "we **may** with reasonable certainty predict" and "the dart **will** probably strike". These are particularly complex statements of possibility and probability, which L2 readers will have great difficulty in understanding.

Hopefully the above discussion has illustrated (albeit briefly) how the science textbook may, by virtue of the language used and the material being taught, create comprehension difficulties for L2 readers. Furthermore, these problems are in fact exacerbated by context reduced expository texts which were clearly not designed for the linguistic situation of L2 readers. Given these circumstances, it is hardly surprising to find (as in the textbook questionnaire) that the majority of my Standard 8 students struggle to use the textbook as an accessible resource for learning.

In the following discussion the focus shifts firmly to the students' own perceptions of the language difficulties they encounter when reading science texts.

8.2.3 Scientific Language and the Textbook

Students were given the opportunity to express their feelings in Question 5 of the questionnaire "What is it about the textbook which you think makes it difficult to understand?". Time and again the students commented on the difficulty they experienced with the English used in the textbook:

> "Textbook's English is very difficult to me to understand and it doesn't make sense."
>
> "Some words are difficult and are confusing."
>
> "The textbook have difficult words in it and difficult to understand its English we students of black nation."
>
> "It is that the textbook must be change and they must try to write it simple that everybody should understand it easy."

The following comments illustrate how some students were able to identify scientific English as posing particular reading problems for them:

> "Many of the words are written in science words and some are bombastic words."
>
> "On this books have some words that have been used by scientist and has a difficult words to understand."
>
> "Most of the words so difficult especial scientific words."

In the discussion on vocabulary issues in section 3.4.2, I concluded on the basis of my previous research (Clark 1987) that L2 readers acquire new technical/conceptual terms without too much difficulty. Further evidence for this assertion comes from the pretest which the students wrote before the start of each trial exercise (for a summary of the results see appendix 2).

For example, in one question the students were asked the meaning of the word **soluble**, which had been introduced to them as far back as Standard 5 General Science. Given the problems experienced by L2 users of English it may come as a surprise that 75% (49 out of 65) of the students were able to explain in their own words what **soluble** meant.

One possible explanation for the apparent ease with which Standard 8 students, whose L2 skills are still generally so weak, are able to use words like **soluble** is that the memorising of such words of specialist vocabulary is accepted by the students as an inevitable part of learning the content of the subject. It could be suggested that such words are seen by the students as "facts" which have to be learnt in much the same way that a history student has to learn dates, or a geography student the names of rivers and mountain ranges.

Of course in this instance another important consideration is that **soluble** is an example of a specialist word which in school science tends to have a clear, unambiguous meaning and it is consequently relatively easy to learn.

It was also extremely interesting to note how the students incorporated a whole range of other formal scientific words into their explanations for the meaning of **soluble**:

"it can **dissolve** in water..."
"to **combine** with water..."
"it **absorbs** the water..."

Some of the students who had a poorer command of English resorted to everyday words in their explanations:

"it (soluble) means that it **disappears** on water..."
"an acid can **melt** in water..."

The word **melt** has a specific meaning in science (a substance changing phase from a solid into a liquid), so strictly speaking it is used here incorrectly. Although it is important that students are discouraged from using **melt** in this context, it is debatable whether or not they will suffer any great conceptual confusion through the imprecise use of this word.

In some instances a closer look at some of the words students incorrectly use can help identify possible sources of conceptual confusion. For example, in Worksheet 6 (see page 32 of appendix 1), the students are asked to describe what happens when dilute sulphuric acid is added to some magnesium carbonate in a test tube. During the course of their experimentation they would observe a reaction taking place and see small bubbles of a gas in the test tube.

Some of the students whose English was particularly poor, wrote down that the liquid was **boiling**. Why use this word? Their life world experience of seeing bubbles in a liquid would in many instances be that of water boiling, so they naturally assumed that a similar event was taking place here! The problem is this: equating the release of a gas in the reaction between magnesium carbonate and sulphuric acid (a chemical process) with that of water boiling (a physical process) may lead to considerable conceptual confusion over the difference between physical and chemical changes.

When this occurs it becomes vital that students are actively discouraged from using the word **boiling** to describe a gas being released. However, when this takes place it does offer the teacher the opportunity to assist the students to acquire the necessary vocabulary <u>and</u> sort out whatever conceptual confusion may arise.

Once again referring to the discussion of science vocabulary in chapter 3, I concurred with others (such as Wegerhoff 1981) that readers tend to struggle more with the non-technical vocabulary of scientific texts and in particular, with familiar words and phrases which have been invested with new technical meanings.

Consider for example the lack of understanding the students displayed in the pretest exercise with the word **neutral**; 78% of students were unclear of its meaning in this context. Why is this?

One possible explanation is that the students have been exposed to a number of different usages of this word in both Standards 5 and 7. In a chemistry context it refers to a substance which is neither an acid nor a base. Yet it has another meaning in physics with which the students are familiar from their study of electricity in Standard 7: an object is said to be neutral if it is neither positively nor negatively charged. To add to the confusion it is a word, with a number of familiar everyday usages (e.g. in the game of soccer one talks of a neutral referee), which has been invested with different scientific meanings.

The problems students experience with words such as this illustrate the importance of instruction; great care is needed when introducing words which have different meanings in different scientific contexts. If care is not taken during teaching there is a good chance that students will mix up the different meanings and this may result in considerable conceptual confusion (as appears to be the case here).

The following extract from one of the interviews gives an example of where a student became confused between the everyday meaning of a word and its particular meaning in scientific discourse:

Fraizer: Sorry sir, I don't know... maybe this word (pointing to 'appear') I'm misusing it. Because when I see your definition here (in the glossary) is 'to seem like', but the way I use it like when 'somethings emerging... when something is emerging now', can you say 'appear'?

(Group A, 18-09-91)

How often do students run into similar problems when reading expository science texts with their particular style of language usage? There is clearly a problem in that assumptions are made, from the writer of the text down to the teacher in the classroom, that L2 students will automatically assign the correct meaning to words which can so often mean different things in different contexts.

Given the apparent difficulties which students experience with scientific prose, I attempted during a number of the interviews to get them to give their opinions as to why they thought that scientific English is different from narrative English. Although they often had very little to say on the matter (it was clearly the first time anyone had ever raised the issue with them at school), on one occasion the topic gave rise to a lively discussion. Here is an extract from it:

Question: How do you feel about having to use words like 'decant'?

Monde: It would be a lot easier... there wasn't any need to use 'decant'.

Question: Why do you think the textbook has these big words?

Mfundo: I don't know...

Fraizer: I think it's to differentiate the laboratory English from the normal English.

Thozama: I think science is science and English is English, so we can't mix the words of science and English.

Question: But... when I go home why don't I say to my wife 'Please dear, decant for me a cup of tea?'

Thozama: No you can't (laughter). Because it's science, you can't say 'decant', you have to speak English, clear English!

Question: Why?

Monde: You're not in the lab.

Thozama: Yes, you're not in the lab; you're in your house.

A little later on in the same interview...

Question: Why do scientists talk in a certain way?

Mfundo: It's part of being a <u>learned person</u> (my emphasis).

(Group A, 15-08-91)

Question: Why do we use such words?

Xolile: I think... in my own words it is made so that it ... people can identify that this is science and that it is not like any other subjects.

(Group B, 29-08-91)

As suggested earlier, acquiring a scientific vocabulary is accepted by most students as being a necessary part of learning the subject. As the above extract from the Group A interview shows, some students were clearly amused that I was questioning the language of the subject which I teach! In any event, as discussed in section 3.4.1, the issue has less to do with the use of scientific terminology per se than with the style of writing adopted in scientific texts (you may recall Turk and Kirkman's disdainful comment, "the heavy soil of scientific prose").

8.2.4 Sentence Length

Earlier in this chapter it was suggested that overlong sentences are difficult to read. In response to a statement in Question 8 of the questionnaire, 37 students (45%) felt that sentences in the science textbook were often too long and complicated. A number of the student responses to Question 5 referred directly to the difficulty they experience with long sentences:

> "The sentences are too long and its English is far beyond our understanding."

> "The definitions of the textbook are too long, and I can't understand it."

> "The textbook talks too much about something that is being describe and sometimes it makes people confused."

In the interviews students had similar comments to make:

Peggy: The textbook is telling all things, it has too long sentences, so you can't read a long sentence... and you are reading a long sentence you are going to forget about the other words.
(Group A, 15-08-91)

Question: What happens when you read a long sentence?
Andile: You get bored.
Xolile: You can't remember anything that you have read...
(Group B, 29-08-91)

8.2.5 Unfamiliar Words

In a number of ways problems are compounded for L2 readers of school science texts; not only are they faced with lengthy passages of text which may bear unrealistically heavy concept loads, but also with new or unfamiliar words. During a number of the interviews, students explained how they coped with unfamiliar words in the text:

Question: **What happens when you come across a word you don't understand?**
Mfundo: I just ignore it (the rest of the group laughs).
(Group A, 15-08-91)

Question: **If you come across a new word, do you bother to look it up (in a dictionary)?**
Jackson: Ahh... sometimes.
Solomzi: But we used to skip them... if you don't understand the word, then you just skip them.
Luvo: Yeah...
Jackson: That's when we concerned to look at our dictionaries, if you can't work out that thing we don't understand because of this word, you don't understand the sentence...
(Group D, 19-08-91)

Toby: There are different words in the textbook... if you have a dictionary you can understand what is meant by that name in the textbook. But, if you have not got a dictionary... you didn't know the name there, you didn't know the word.
(Mixed 8B, 08-10-91)

When it came to dictionaries, just under half the students (39 of them) indicated that they either owned a dictionary or had access to one on a regular basis. However in my experience it is unusual to find a student bringing a dictionary to class, let alone pulling one out and using it. This is hardly surprising, since, given the circumstances, the problems which students experience when faced with new words in a text go beyond simply looking up the offending word in a dictionary.

For a start, in a learning environment dominated by transmission modes of teaching, students rarely have the opportunity in class to halt the flow of teacher-talk to ask the meaning of an unfamiliar word. Also it is unrealistic to expect that teachers, who may themselves have a poor command of English, would actively encourage students to pause when reading to look up the meaning of an unfamiliar word or phrase.

Furthermore, as was noted in section 3.4.2, in the discussion on introducing new words and specialist terminology, the standard dictionary format may not be suitable. This would appear to be the case in instances (as discussed earlier) when words have different meanings in different contexts. One cannot assume that the student will always choose the correct meaning from those offered in the dictionary.

In any event, the effective use of a dictionary when reading a text requires skill and considerable discipline on the part of the reader. Unfortunately, given the context of their schooling, one cannot assume that most L2 students have acquired such skills:

Xolile: Sometimes you write it (the new word) on the scrap of paper, but it may happen that the scrap of paper is lost.

Jimmy: No, it makes it difficult because you have to check the dictionary. It takes a long time.

(Group B, 29-08-91)

Peggy: Sometimes I'm just ignoring them (the new words), sometimes I'm just taking a dictionary then... then I think it's too difficult to me to take a dictionary when I'm reading the textbook. All those difficult words, I have to check them in the dictionary, I'm not going to put them in my notebook, so I just going to forget them. That's why... why I (her emphasis) don't like the textbook.

(Group A, 15-08-91)

This comment by Peggy seems to sum up the approach (let us call it "Peggy's path of least resistance") adopted by many of the students when they are faced with new words in the text - they tend to gloss over them, skipping words and missing meaning as they go along. As Peggy quite firmly indicated, her inability to understand the language of the textbook had a negative effect on her attitude towards it! It is hardly surprising to discover that Peggy was one of the students who indicated that she read the textbook only before a test or exam.

Clearly the student dictionary (in one form or another) has an important role to play as a reading aid in a content subject like science. On the one hand, the standard format employed by dictionaries needs to be carefully reconsidered, particularly when it comes to words which are known to occur with different meanings in different contexts in school science texts. It also becomes important that ways are found to equip students with the skills needed to use a dictionary effectively. This is not simply the job of the language teacher but needs to be taken up as a specific task by the subject teacher as well, for as others have noted, (see Wegerhoff 1981 and Harrison 1973) the key to comprehension of science texts is instruction, and clearly the key to instruction is the teacher.

Since there are different ways in which new words can be introduced in a text, during the interviews students were asked how they felt new words should be introduced:

Question: How should the textbook explain words?

Solomzi: I think they must be on every page, sir.

Jackson: At the bottom of the page.

Solomzi: Yeah, so that when you read the notes you don't have to go to look up every word (in a dictionary).

Nolusindiso: Back page (the glossary).

Jimmy: I think... both methods are the same because if you find some words are difficult and then you see them on the bottom of the page.

Andile: I think just both, because if you read and you find that there is a word difficult and you turn back to look for it, it will take a long time to finish what you read, and sometimes you will not understand what you are reading. I think to me it is best to have both sides, to have it in all pages... or at the top of the page.

(Group B, 29-08-91)

8.2.6 The Glossary

When drawing up the trial text material an attempt was made to adopt a definite strategy for presenting new words. Those words which I thought would present difficulties to the students were highlighted in the text and a glossary was drawn up at the back of the handout (see pages 53-54 of appendix 1). When it came to the comprehension exercises certain words were deliberately left unmarked in the text. I was interested to see whether or not students would take it upon themselves to either ask me for their meanings or whether they would find them out for themselves. To this end space was provided on the last page of the handout for additional words to be added to the glossary.

When it came to the explanations of the different words in the glossary, the students generally agreed that most words were clearly explained. During the course of the student interviews they were asked to comment on the glossary, and in some instances had some valuable contributions to make:

Question: Did you find the glossary useful or not?

Monde: Could help to put new words on each page or to say 'you should understand the following words from this worksheet that you have done'.

(Group A, 18-09-91)

It was encouraging to note that on a number of occasions during the trial exercises, students asked that certain words be added to the glossary (e.g. words like - **decant**; **potency**; **disintegrate**; **dissociate**; **concentrate**; were eventually added). However, I noticed that most of the students did not bother to add their own words to the glossary.

For example, the final worksheet had an exercise in which the students had to read through two newspaper articles (see pages 51-2 of appendix 1). During an interview with Group A (18-09-91) we went through these two articles and the students rather sheepishly pointed out a number of words which they did not understand (**apocryphal**; **antidote**; **lobby** and **induce**), to name a few.

As a way around the problem of students not taking it upon themselves to add words to their glossaries, one student suggested that, as elsewhere in the text, I should have either underlined or highlighted the new words. And then, as part of the actual comprehension exercise itself, I should have asked students to find out what the new words meant and then told them to include them in the glossary at the back of the handout.

I realised then that unless they were prompted in some way most students would take the "path of least resistance" and continue to adopt the same strategy as they did with the textbook - they would simply skip the difficult words and hope that they would still be able to make sense of the passage. This response is of course perfectly understandable. As suggested above the ability to use a dictionary effectively (or in this case a glossary) as an aid to comprehension is a learning skill which has to be developed in students. If nothing else, the poor use made of the glossary highlights once again the critical role which the teacher must play in developing the language skills of his/her students.

Interestingly enough, whatever their reservations about the textbook, the majority of students (51 out of 67) rejected the idea that the textbook should be written in their mother tongue (Xhosa). In one of the interviews the students had this to say:

Xolile: The problems (with the textbook) are not so big that we cannot cover them, because if you write the textbook in Xhosa we are going to find some difficulties when we are... like in other countries.

Andile: And also our English is going to get poor...

(Group B, 29-08-91)

A popular perception I had noted in the past among my students was their belief that the science textbooks being used by white students were better than the ones they were given. This is consistent with their belief that the inherent inequalities of education in South Africa extend to the kinds of textbooks which are available to the different education departments.

Solomzi: I don't know sir why the trouble... but if you take say our textbooks and compare it with one from a whites, let's say so you'll find it is more easier than our textbook.

(Group D, 19-08-91)

Whatever the situation is in other school subjects, this is not really the case in Physical Science, where only a relatively limited range of textbooks is published in this country. As noted elsewhere, a basic problem is that essentially the textbooks are written for L1 users, and as such are often unsuitable for an L2 context. This does, however, touch on an important issue; black students are quite understandably extremely sensitive about being given material which could be perceived as being "inferior". One legacy of apartheid education is that in the immediate future it will be difficult to introduce and find acceptance for a separate series of textbooks written specifically for L2 users.

By and large the students seemed willing to concede that many of the problems they faced when reading the textbook were due to their own inadequate English language skills. When asked why this was the case most shrugged it off as a sign of their own "laziness" to learn the subject. They were asked on a number of occasions what they thought could be done in science lessons to improve their English:

Xolile: I think that there should be some periods where we speak English... because some of us when they go home they do not practise, they just sit and look at the textbook.

(Group B, 29-08-91)

This comment follows on from a suggestion made by a fellow teacher, that during the group work the students should be allowed to speak only English in class. This was tried on one occasion with the Standard 8As. At the end of the day I made the following comment in my research diary:

> Thursday 27 August
> ... In response to our 'English only' day - only a few groups (A in particular) tried to communicate in English with each other. Most others (group E!) sat in complete silence for almost the entire period!

Clearly little can be read into an isolated exercise like that, yet it did highlight the extent to which the students are unused, unable and perhaps even unwilling to practise their English. In this regard, the problems of the L2 classroom are immense.

In section 2.3 (see page 10), Rangaka (1982) describes how students, lacking oral competence in English, kept their mouths firmly shut in class. Yet unfortunately this is often the only place where students are exposed to spoken English, for they rarely have any reason to use it outside the context of the classroom. Even if they want to talk they are hardly encouraged to do so. Given the nature of classroom interaction (dominated as it is by teacher-talk), students rarely get the opportunity to say anything in any language, let alone English.

To make matters worse, as pointed out by Buthelezi (1984), the English taught at school tends to focus on developing grammatical rather than communicative competence. One can conclude, then, that some students, besides the rare occasion on which they are called upon to read from their textbook in class, literally never bother to speak a word of English from one day to the next.

The inability of some of my Standard 8 students to communicate in even simple spoken English was made apparent time and again during the interviews. I tried discussing this issue with a group of girls who were repeating Standard 8, and who I knew could hardly express themselves in English. Although it ended up being a particularly one-sided discussion, during the course of one interview (Group B, 29-08-91) they appeared to accept my assertion that their poor English skills were contributing significantly to their problems in learning science.

It was, however, encouraging to learn that many students (once they got used to the idea) seemed happy enough to see science lessons as a vehicle for language learning:

Mfundo: They should be mixed... 'cos you are learning English here in science as well, so it helps you to progress in your English work.

(Group A, 15-08-91)

Question: **Do you think it should be the job of the science teacher to teach you some English?**
Sandile: Yes.
Luvo: Mmm... it is.
Sandile: Yes, I think it is all right sir for you to teach us, because what we are doing the science we are doing it in English, so I think it is all right to write some...
Luvo: Write some letters
Sandile: Some comprehensions.

(Group D, 19-08-91)

8.3 The letter Writing and Comprehension Exercises

As a response to the problems which students experience in "deciphering" the language and content of the science textbook, teachers often end up having to rewrite large parts of the text as summary notes in simplified English. Given the shortages of resources which plague black education in South Africa, these summaries are invariably done on the chalkboard which results in a significant amount of classroom time being spent in note-taking.

Yet for all this copying of notes, students are rarely taught how or encouraged to write their own notes. Besides the occasional letter and essay in English it seems as if they are not required in any structured way to develop their own L2 writing skills.

When devising the trial text material it was hoped that some of the language difficulties experienced by students could be addressed more explicitly through an increased emphasis on classroom and homework tasks which involve, among other things, the use of written language. To this end a number of comprehension exercises were included in the trial text and in line with the Salters' "science in context" approach their topics were carefully chosen to link closely with the work being covered in the worksheets.

8.3.1 Letter Writing

The letter writing exercise (see page 13 of appendix 1) was certainly one which the students would not normally associate with the science classroom. In it they had to read a fictitious article, about the theft of some chemicals from our school laboratory, which had supposedly appeared in a local newspaper. After answering a few comprehension type questions they had to write a letter to the newspaper's editor pointing out a number of factual scientific errors which had appeared in the article.

To ensure that the exercise was taken seriously, the students were told that their letters would be marked both by myself and their English teacher and that a mark would be allocated for inclusion in their English yearmark. One added advantage of the letter-writing exercise is that it offered me a rare opportunity to collaborate with the teacher of another subject.

To any experienced L2 English teacher most of the grammatical problems briefly described below are commonplace ones, but to a science teacher tunnel-visioned by the demands of teaching the content of his subject they were an important insight into how deep-seated the students' language problems are.

a) Students failed to use the correct participles **a** or **the**.

> "Mercury is very dangerous if you put **the light** to it"

b) They had problems using correct sequence of tenses.

> "This chemical is dangerous because it **is explodes** if **expose** to air."
> "Magnesium is not dangerous as such but when you **burnt** it, it **became** flammable."
> "I **advise** him to bring back **that** chemicals **has** stolen on Sunday night."

c) Students were often unsure when to finish a sentence. In addition to this problem, consider the grammatical errors in the following extract from one student's letter:

> "I've suggest to tell you that you've **done** mistake **on** that chapter saying that it **explose** when **it expose** to the air I ask you to write another news paper telling about more **on chemestry** and apologising to the readers of your paper about your mistake."

d) Students tended to mix up words which sounded or were spelt similarly. For example, many students mixed up the words **expose** and **explode**. On a number of occasions students wrote things like:

> "the magnesium **explosed** in the air"
> "these chemicals are too dangerous and these chemicals can explode if they are **explosed to** air."

And in the following:

> "Magnessium does not explodes in air if exposed, It only **expose** when burnt. It **expose with** big and bright light."

e) Given the absence of prepositions, as we know them, in Xhosa, it is not surprising that students struggled to use prepositions correctly in English. Indeed it is unusual to find students at this level who can comfortably choose the correct English preposition:

> "**in** my knowledge"
> "When I was reading the Cape Times Newspaper **on** yesterday"
> "I had read **at** your newspaper"
> "explain the knowledge of magnesium clearly as you did **to** mercury"

f) Some strange words appeared at times, such as **sparkles** (with sparks) and **exploders** (explosive). An interesting exercise in itself was to explore with individual students the meanings of the seemingly nonsensical words they used.

For example, one student wrote "**aitinate** the fire". When asked it became clear that she was trying to use the word **activate** and thus to say "**activate** the fire". Instead of simply saying "light the fire" the student was attempting to use a word which she had picked up as having a specific meaning and usage in science. That the word activate was being used out of context is of no great significance. What is of more interest is her attempt to write what she felt to be correct scientific English.

g) As to be expected, there was the inevitable confusion over the spelling of certain words. For example, as can be seen from some of the above extracts, **Magnesium** was often spelt incorrectly as **Magnessium**, even though this word is mentioned on a number of occasions in the comprehension passage.

And of course one received some refreshingly direct responses to the "misinformation" presented in the article. As one student pointed out at the end of his letter:

> "I advice you to stop publishing wrong information to other people because the people are not going to buy the Cape Times..."

8.3.2 The Comprehension Exercises

Three comprehension exercises were included in the trial text material. One of them, entitled 'Acid Rain', (see pages 20-21 of appendix 1) formed part of Worksheet 3 which was described in chapter 5. This comprehension passage was taken from an article which appeared in a local newspaper. At the time of compiling the trial text, the article was edited and the language simplified. A number of words which I thought the students would not understand were highlighted and their meanings explained in the glossary. As I was interested to see the students' response I deliberately left unexplained a number of abbreviations: **CSIR**, **PWV** and **ESCOM**.

On a number of occasions during the interviews students pointed out words (e.g. **compare**) and expressions (e.g. "**public awareness**") which they did not understand. In itself this was not a problem, since these words were duly noted down for inclusion in a redrafted glossary. What was disturbing was that time and again students admitted to having made no attempt when doing the comprehension exercise to look up unfamiliar words or to ask me about them in class.

There is no doubt that in some instances an unfamiliar word can be ignored or a meaning assigned to it which allows the student to construct some kind of acceptable explanation (however inaccurate it may be) from the text. But there is a danger, particularly in a subject like science, that students fail to build up a working vocabulary of those general vocabulary words with a scientific bias (of which the word **compare** is an example). These words belong, in terms of Barnes' (1969) classification, to the "language register of secondary education" and as such have been identified as creating reading and comprehension difficulties for both L1 and L2 readers (see Wegerhoff 1981; Clark 1987). As Sutton (1980) puts it, students struggle to use for themselves the "thinking words" which mobilise the more easily learnt technical terms.

It appeared as if in this comprehension exercise the weaker readers were adopting the same reading strategy they applied to the textbook, what I described earlier as "Peggy's path of least resistance" (see page 180). When faced with new or difficult words they gloss over the text skipping out the problem words without attempting to establish their meaning. If, as this implies, those students fail to engage as active participants in the reading process, they will probably fail in their attempts to comprehend the text.

It is these <u>inadequate reading strategies</u> which go a long way to explaining why students, remain "locked out" of a text even when it is written in much simplified English.

For example, Question 5 asked: "What are the 5 sources of atmospheric pollution?". Not surprisingly during the course of the interviews a number of students indicated that they did not understand what the word **sources** meant and they were consequently unable to answer the question correctly. But an interesting answer to this question was given by 13 students in Std 8A and 5 students in Std 8B who listed as their five sources of atmospheric pollution the following: **environmentalists, acidification, petro-chemical, generated** and **effective**.

At first when going through their homework I could not understand why they choose those words. It was only after I had interviewed two of the students that they explained that, failing to understand the question, (because of the word **sources**) they chose instead the five words they saw highlighted in the text! How a word like **effective** could in any way be interpreted by students as being a source of atmospheric pollution illustrates how inadequate their command of English is.

As mentioned above, I had deliberately left the abbreviations unmarked in the comprehension passage. Yet at no stage either before or after they had handed in their answers did any student in either class approach me to ask what they stood for. Of course some students had their own ideas about what the abbreviations meant, as the following extract from one of the interviews shows:

Zolisa: What is the C...CSIR?
Question: Does anybody know what the CSIR is?
All: No...
Question: So why didn't anybody ask me?
Michael: Yes sir, I wondered what it is... then as I read the list, the sentence read 'The CSIR's Mr S...(Skoroszewski) says the acid rain damages our environment...' I thought that these maybe, they are the group of people who are working under that certain person or scientist.
Andile: I thought it was the name of a company sir, who are looking for the climate here in South Africa.
Fezekile: I thought it was a group of people working...
Question: So, what should I have done? Should I have explained what it is or asked it as a question?
Tobie: You should have explained it.

Others: You should have asked it.

Michael: You should have asked it as a question, because we should have taken the responsibility to look for that abbreviation.

Zolisa: And the PWV area?

Question: Does anybody understand what the PWV area is?

Andile: The Transvaal.

Michael: The region in the Transvaal, the Orange Free State.

Question: But the abbreviation itself?

Silence...

Question: What is it which stops you asking those questions?

Lindelwa: Shy to ask...

Zilani: Embarrassed.

Fezekile: Yes... it is something that I thought that the rest of the class knew...and they would laugh at me.

(8B, 21-10-91)

The last three comments touch on another serious problem faced by students. In my experience the majority of them are extremely reluctant to ask any kind of question in front of their classmates (be it about a word, concept or experimental procedure which they do not understand).

The reasons for this are complex. For one, a fear of ridicule which Fezekile articulated above is common and, in addition to being unsure about the subject matter in question, a student may feel inhibited to ask about it because of a poor command of English. But more than that it appears to be closely linked to the ways in which students have learnt to interact with teachers in the classroom.

My observations are consistent with those reported by Macdonald and Rogan (1988), who, after working in a similar black L2 context concluded that students tend to ask more questions of their peers than of their teachers. When pressed about the matter, my students suggested that another reason why they were uncomfortable about asking questions was that at no stage in the past had they been encouraged to do so by their teachers. On a number of occasions students had related incidents (often when they were at a highly impressionable age in primary school), where they had asked a question which had led them to be ridiculed or mocked by a teacher. One could argue rather cynically that in a context which predisposes towards transmission modes of teaching, one way in which some teachers (especially those who are unsure of their own positions) maintain control in the classroom is to ensure that students do not ask too many questions.

Science lessons represent less then 20% of all instruction, so if in other subjects students continue to experience lessons dominated by teacher talk, it is hardly surprising that they fail to use the opportunity to ask more questions in my class. It is unrealistic in such a context to expect students to be able to "switch" modes of classroom interaction simply when they move from one classroom to another.

Whatever the reasons, the students' failure to ask questions is a barrier to effective learning in the classroom, particularly as they move up into the senior classes where they have to cope with increasingly complex subject matter embedded in increasingly difficult texts.

On a positive note, I observed during the respective trialing exercises how in a number of ways group work encouraged the asking of questions. Not only were the students able to call me over and ask assistance without involving the rest of the class but also it allowed individual students who were unwilling to ask a question to pose it through the group as a whole.

In general the students had little difficulty answering questions which required straight recall of information from the comprehension passage. However it was where students had to interpret the text and then attempt to explain something in their own words that the range of competency in English writing skills across the class became apparent. I will illustrate this by concentrating on student responses (from both classes) to just one question: "What can be done to lessen the problems of acid rain?"

What is not at issue here is the accuracy of their answers, but rather the extent to which students were able to communicate their ideas in English. For a start, a few students showed a good command of English:

> "Yes. We should reduce sulphuric dioxide. We must find another method of making electricity but it must be not so expensive. Every industry must be aware of what's going on."

> "Yes there is something that can be done, firstly we can try to improve the way electricity is done."

In the case of other students, whatever their grammatical errors, it is possible to make sense out of the following answers:

> "I think there must be new thing released which does not have much smoke such as carbon monoxide, sulphur dioxide and many others."

> "Yes to reduce the use of electric so that less electricity would be needed than as usual."

In contrast, though, the following answers verge on the unintelligible:

> "Yes, we can make these burning fuels to save the pollution from the others."

> "Yes in the coal building the smoke must diluted before rich out air."

In the last example the student is trying to say something along the lines of: "In the power station the smoke (which contains the pollutant sulphur dioxide) must be treated before it is released into the air" . Even if she had written: "Yes, in the power station the smoke must diluted before it reaches the air" the person reading it would have at least had an idea of what she was trying to say. This is not at all a bad answer, if only it could have been understood as such!

Consider this final example:

"No, these acid rains caused by chemicals which makes this systems of things better in human beings."

Unlike the previous example where it was relatively easy to reconstruct what the student was trying to say, I found that in this case I could make no sense of the answer at all. So during one interview I asked the student who wrote it to explain to me what he was trying to say:

Ntsikilelo: I was trying to say these chemicals cannot be lessened because these chemicals are also useful... or are... I think is also necessary to... to use. For instance, some of them are... like the chemicals that is... in the motor car. So the motor car is bringing that chemical, so the motor car is useful whereas that chemical is given off in the atmosphere.
(Individual, 27-08-91)

Ntsikilelo was starting to make more sense now. He seemed to be reasoning as follows: When motor car engines use petrol they produce a pollutant which causes acid rain, but we are reliant on motor cars so we have to accept the pollution they cause. For a Standard 8 student who has been exposed to little in the way of formal instruction about environmental issues, Ntsikilelo's answer is a very good one, but his inability to express himself in English stood firmly in the way of anyone's understanding what he was trying to say.

How often this must occur in a L2 classroom context! A student may know perfectly well what he wants to say but be unable to do so because of an inability to express himself in English. It could be argued that comprehension exercises such as these are one way in which students can confront their L2 problems more directly, for they can play a role in convincing the student (and content subject teacher) of the need, in contexts other than the English lesson, for students to develop their language skills so that they can begin to communicate their ideas more freely in English.

During the course of many of the experiments students had to write down their observations. It is argued that here is another case of where some student's weak English disadvantages them. If they write something in unintelligible English it is questionable when they come to read over the work whether they are always able to decipher what they have written. On a number of occasions during the trialing exercises I asked students to explain their written observations, only to find that they were unclear about what they had written. This is certainly an area which requires further elucidation and inquiry.

8.4 Conclusion

An analysis of some of the data gathered during the course of the two trialing exercises gave me, the science teacher, an appreciation of how deep-seated the students' English language problems are. It confirmed what I had long suspected - that after close on six years instruction through the medium of English (since Standard 3) many students had not yet acquired a level of competency which allowed them to cope with the demands of learning science in an L2. In particular I observed how some of the students' poor reading skills created comprehension difficulties for them, even when they were presented with what appeared to be fairly "accessible" (from a linguistic perspective) text material. Clearly students need to taught and guided in the reading strategies which will allow them to become competent readers of L2 science texts.

In this regard, as in other areas of L2 learning, the key issue seems to be one of <u>instruction</u>. Furthermore, the various exercises in the trial text (letter writing, comprehensions etc.) are ways in which this can take place <u>not only</u> in the language classroom but also in the science laboratory itself. For this to be successful it needs to be acknowledged that the primary responsibility for teaching the language required to master science rests with the science teacher.

Chapter 9

Conclusions and Recommendations for Future Research

9.1 Teachers as Curriculum Developers

Despite the limitations experienced as a practising teacher engaged in part-time research, during the course of this research project I was able to develop a package of curriculum material which was successfully trialed with nearly 90 students in two separate classroom-based exercises. More than anything else this project demonstrated that it was possible, within the constraints of the present education system, to explore creatively alternative approaches to presenting a topic in the existing science syllabus.

Furthermore, by engaging in classroom based trialing of my own material, it was possible to highlight the vital role which practising teachers can play, particularly in the early stages of curriculum development. Keogh (1992), drawing on the work of Naidoo and Pillay (1991), summarises the reasons why the strategy of teacher participation in curriculum development proves to be effective. These are worth noting because they sum up my own feelings about the usefulness of this research project:

> * teachers participating in the development are more familiar with the innovation, and confident in implementing and sustaining it.
> * teachers have a greater sense of commitment in implementing the innovation.
> * it leads to the development of more appropriate innovations which are realistic and are in tune with the context in which teachers work.
> * it promotes teacher development.
> * it leads to teacher empowerment. (1992:6)

However one consequence of exploratory research such as this was that it was undertaken in relative isolation from others. This may be regarded as an inherent limitation but it does open up numerous possibilities for further research; there is a clear need for other teachers, in more collective ventures, to develop further packages of science curriculum materials.

In this regard, my experiences during this research project underscore the importance of "immersing" curriculum materials in classroom-based trials at an early stage in their development. It is suggested that in future a similar, but more extensive model of "multiple immersions" is employed, in order to ascertain the suitability of the materials for a wider variety of contexts (L1 and L2, urban and rural).

Furthermore, in order to develop a broader base for future work with respect to science curriculum innovation, such work would have to be linked to other initiatives, not only in other parts of this country but elsewhere in Africa.

9.2 Ethnography

With regard to the research methodology, ethnography with its open-ended holistic approach to "research as process" proved itself well suited to the particular needs of a teacher-researcher such as myself. With an emphasis on both qualitative and quantitative data gathering techniques, it successfully allowed me to bridge the gulf between pure, academic research and the everyday realities of my classroom teaching. Significantly the trialing exercises produced a wealth of primary data, only some of which, given the constraints imposed by a dissertation write-up, could be reported and included here.

The advantages of using ethnographic research techniques extend beyond the relatively narrow scope of this research work; it offered me the opportunity to reflect on my own teaching praxis and allowed me to gain fresh insights into the complex interaction which was taking place not only in my own classroom but within the broader context of the school.

One example of this came through the teacher attendance exercise in 8A. That during a 23 day period over which records were kept, nearly half (43%) the available teaching time was lost to teaching gives an interesting insight into one aspect of the "stop-start" nature of black township schooling during the early 1990s. It is suggested that reflecting upon the complex dynamics of such a research setting further underlines the value of moving beyond rigid empirical research methodologies when engaging in classroom-based research.

The trialing exercises were primarily intended as a critical test of the effectiveness of the trial text material and the supporting practical kits. During the course of the 8A and 8B trial exercises it became apparent that quite a few modifications to the text could be made. In chapter 7, examples were given of where the students suggested changes to the text, and my own observations would lead to a variety of further modifications. What became apparent, and is further testimony to the value of an ethnographic research methodology, is that the students were able to contribute significantly in the evaluation of the trial material. As such they must be seen as being able to play a crucial role in the ongoing process of developing curriculum materials. As the students are the all important "end-users" of the material in question this seems an important point to make and it opens up possibilities for future research. The students' role in the whole process of curriculum development needs to be carefully considered and expanded upon.

In any event the point behind the trialing exercises was to expose the material to a period of critical evaluation and reflection in the context for which it was intended.

9.3 Group Practical Work

One of the most important aspects of the trialing exercises was that it provided the opportunity to observe and reflect on large scale group practical work. In particular the practical kits were successful - large classes of students were able to use eight sets of kits in fairly extensive experimental work without running into any major functional problems. Once the initial cost of the kits had been met, costs incurred by the breakage rate of glassware and consumption levels of chemicals never became excessively high. Indeed, the only "chemical" which tended to disappear rather too fast was the icing sugar used for making sherbet! (see page 36 of appendix 1).

When it comes to the structured practical work itself, it was shown in chapter 7 that the issues involved in deciding what constitutes effective practical work are very complex. Although most students by and large fell into the trap of "recipe following", it was suggested that this has to be seen as the inevitable first step towards more self-directed learning.

Doing practical work per se does not automatically improve the students' knowledge and understanding of science, but what it is able to do is add a richer dimension to the students' experience of science. The added student interest aroused through more relevant and contextualised learning activities prepares the ground for students to engage in more reflective learning.

However, it is crucial that chalk-and-talk transmission teaching is not simply replaced with a "ritual" of poorly understood practical work. Rather, the ideal learning situation in the science classroom and/or laboratory is a suitable mix of activities which engage students physically and cognitively in the science being learnt. Clearly such learning should be both "hands-on" and "minds-on".

The group investigations attempted with the 8As were a disappointment, but the difficulties which students experienced when attempting to engage in a more self-directed learning activity should be seen as a comment on their previous learning experiences (an endless diet of "chalk and talk") rather than anything else. It is confidently asserted that if the same students were given the opportunity to try an investigation again the outcome would be decidedly more encouraging.

Clearly the students need to develop a range of skills (to observe, measure, record information, make inferences and state relationships) before they can be expected to engage successfully in the practical activities in a package such as this. In this regard, a suggestion for future research is the development and trialing of a series of units of work which introduce and help to develop these various process skills. These are needed not only in the secondary school but from the year in which students are first introduced to General Science - Standard 3.

The group investigation also brought home to me my own limitations as a teacher in such a context. The assumption cannot be made that teachers, irrespective of the qualifications they hold, automatically come to the classroom adequately equipped with the range of skills and access to resources needed to cope with the demands of running large-scale practical work. This raises what has always seemed to me to be one of the greatest contradictions in education in this country; we have a situation where the least skilled teachers are teaching in the context which demands the most skills.

On a number of occasions (particularly in chapters 2 and 4) it was pointed out that conditions in black schools predispose teachers to transmission modes of teaching. Yet it can be argued that large class sizes, heavy teaching loads, shortages of resources and the demands of having to teach science to L2 learners will limit <u>even</u> the most able teacher's attempts to engage in more meaningful or innovative science teaching.

Earlier in this chapter it was mentioned that a strong motivation for drawing teachers into the process of curriculum development is that it promotes teacher development and empowerment. As such it needs to be developed as a powerful vehicle for bringing about innovation and change in a teacher's day-to-day praxis in the classroom. This is a complex issue which is taken up further in the discussion below on In-Service Training.

A primary focus of this research has been the production of an accessible text for L2 science students which was sensitive to the language problems they experience when reading expository science texts. As the following discussion will show, data gathered during the course of the two trialing exercises was successfully used for probing some of the language difficulties which L2 students experience when reading expository science texts. This highlights another advantage in using an ethnographic research methodology; clearly the classroom-based trialing of curriculum materials has immense potential for fulfilling at the same time a variety of secondary functions. For example, in this dissertation my focus has been firmly on L2 problems with science texts, yet the data gathered during the trialing exercises could just as easily be used to probe the conceptual problems students experience in this section of chemistry.

9.4 "Brother can you spare me a book I can understand?"

As explained in chapter 2, a basic premise underlying this research is that in the context of black schooling the textbook is the major resource for teaching and learning science. However, the students' responses to the questionnaire reinforced by numerous comments during the interviews, illustrated the extent to which they are unwilling and/or unable to use their present textbook as a resource in science. Significantly, more than half of the students said that they read their textbook only before a test or exam.

When asked, students indicated that it was by and large the language of the textbook which was creating a barrier to comprehension. When it comes to vocabulary, most students were willing to accept that the learning of specialist scientific words is a necessary part of instruction in the subject. Where they experience major difficulties is with the non-technical vocabulary of scientific texts and in particular with familiar words and phrases which acquire specific meanings in science. In this respect the problem is tied up with the expository style employed by writers of scientific texts (the use of roundabout wordy phrases, overlong sentences etc.).

Even though an awareness of the problems which L2 readers experience with scientific texts had informed my attempts to write more accessible text materials, I noticed on a number of occasions during the course of the trialing exercises how easily some students became "locked out" of the text. This lack of comprehension appears to be the major problem which students experience with their science textbook. The weaker readers in particular appear to concentrate on each individual word, and to be processing text word by word. This suggests that they are at best comprehending at the word and sentence level and in so doing are unlikely to establish discourse meaning from the text as a whole.

Further evidence of inadequate reading strategies was the failure of some students to cope with new or unfamiliar words in a text. Although almost than half the students indicated that they either owned or had access to a dictionary, it seems as if they rarely used one to good advantage. It is suggested that students lack the skills to make effective use of a dictionary. In addition to which, the standard format employed in dictionaries used by school students needs to be carefully reconsidered. A rethink is needed about the ways in which new words are introduced in science texts and the more extensive use of glossaries (as in the trial text) should be considered. As mentioned above, one of the biggest problems students have is with words and phrases which acquire specific meanings in science. This issue needs to be explored further and there appears to be a strong case for developing subject-specific learner's dictionaries which take these difficulties into account.

Furthermore, if it is accepted that there is an important cultural context to learning science this has to be reflected not only in the content of the textbook but also in the language which is used. For example, the discussion on the two excerpts taken from the Standard 8 science textbook highlighted the need for writers of texts to acknowledge that L2 students may have great difficulties with the metaphorical language which is used. Whatever their reservations about their science textbook, the majority of students (76%) rejected the idea that it should be written in their mother tongue (Xhosa). In chapter 8 it was noted that black students are extremely sensitive about being given material which could be considered to be "inferior". One legacy of apartheid is that for the immediate future it will be difficult to introduce and find acceptance for a separate series of textbooks which are written specifically for L2 users. Yet herein lies the challenge - to produce materials which reflect as far as possible a common South African context. I would argue that my handout "Acids and Alkalis - Chemicals in the Home", represents an attempt to do just that.

To sum up, it appears that a **failure to develop appropriate reading strategies** lies at the heart of the problems which many students experience with context-reduced, expository science textbooks. There is evidence that even at the Standard 8 level, some students' L2 reading skills are still quite severely limited. The point must surely be this: instead of simply trying to "fix" the text for L2 users one needs to focus attention much more closely on the role of the reader in the reading process.

9.5 Language across the Curriculum

These problems seem to be tied to issues beyond the science classroom. Poor reading skills in science suggest one further consequence of the fact that English L2 instruction in this country still tends to concentrate on developing grammatical rather than communicative competence. Not only that, but a feature of existing methods of teaching English to L2 users is a tendency to concentrate on reading narrative texts. Consequently students are given little or no instruction in how to read expository texts.

But in addition to the reading problems which students experience, they are often poor speakers and writers of English as well. This was evident in the inability of some of my Standard 8 students to communicate in even simple spoken English. An analysis of the letter writing and comprehension exercises and of a random sample of the experimental observations they wrote on their handouts, indicated the poor writing skills which many of the students possess.

There is a clear need to improve the language competence of L2 learners, for the impact of their poor L2 skills has a significant effect on their academic performance in a subject like science. The key to comprehension of science material is <u>instruction</u>, and it must be accepted that it is the science teacher who must take on the responsibility for teaching the language required to master the subject. This implies that the only person who can adequately teach the reading of scientific texts is the science teacher.

In the light of my own research, I agree with Peires (1988) that the notion that each teacher as a teacher of language should be firmly extended into an L2 context. In no particular order, here are a few implications of such a

"Language across the Curriculum" (LAC) stance for science teachers:

> *An awareness of the different problems involved in speaking, as opposed to reading and writing an L2.
> *An awareness of how language is learnt and specifically how L2 learning differs from L1 learning.
> *What is meant by communication as opposed to competence - and how to teach and test it.
> *How to develop teaching strategies which are specifically geared to the needs of the L2 learner.

In this respect it was encouraging to learn that many students seemed happy enough to see science lessons as a vehicle for language learning. For example, the letter writing exercise and various comprehension exercises were well received by the students. It is suggested that such an emphasis on classroom and homework tasks which involve, among other things, the use of written language are some ways in which the L2 difficulties which students experience can be addressed. Clearly there is a great need to develop a whole range of instructional materials in school science which are specifically aimed at improving the L2 competencies of <u>both</u> teachers and students.

But how a science teacher acquires the necessary competence to do this and what role the language teacher continues to play is frequently glossed over. This raises particular problems in black schools where the vast majority of teachers are themselves L2 speakers of the medium of instruction and who often have an inadequate command of English. There is a real danger that we become trapped in the rhetoric of Language Across the Curriculum (LAC) without being able to translate it into new styles of teaching and classroom interaction.

A commitment to LAC has major implications for both Pre-Service (PRESET) and In-Service Training (INSET) of teachers. It seems reasonable to assume that for a start, as part of the reconstruction of science education, we are faced with establishing an extensive programme of in-service support. Yet it is generally acknowledged that previous initiatives by the State at centre-based INSET were unsuccessful. What is needed is an INSET model which emphasises an ongoing school-focused, teacher-led approach. More than this there is a clear need to develop strategies for linking together PRESET with an ongoing process of INSET (see Gray 1992c). There are some encouraging developments in this regard: in science education SEP has over the years accumulated extensive experience in working with junior secondary school General Science teachers. However given the considerable constraints imposed by the present situation, the issue becomes one of going to scale on a national level.

For whether it is linked to redefining their role(s) as curriculum developers, LAC practitioners or implementers of future science curriculum, teachers need to be encouraged and supported in their struggle to change their classroom praxis.

In conclusion, the findings of this research confirm time and again the vital role which language plays (particularly in an L2 context) in the teaching and learning of school science. In particular it has shown that the textbook, which is the primary resource in science, is sadly also a major source of difficulty. Because of their failure to develop adequate reading strategies and because of the inappropriateness of existing texts, students remain "locked out" of the textbook.

Herein lies a crucial focus for future research: to develop a range of appropriate text materials and instructional strategies which will meet both the needs and expectations of L2 learners. The possibilities are endless; the probabilities are certainly more limited. Either way the challenge has to be met.

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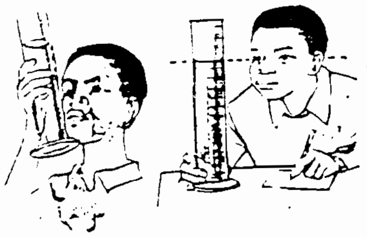
APPENDIX 1

ACIDS and ALKALIS

Chemicals in the home

Standard 8 Physical Science

CONTENTS



INTRODUCTION

Chemistry is the study of how different chemical **substances** react with each other.

Can you remember the very first chemicals you studied in Standard 5 General Science?

You were introduced to two important groups of chemicals called **acids** and **bases.**
Can you remember anything about these chemicals?

You were taught about different ways of testing for acids and bases. You were taught what acids and bases are used for.

In Standard 7 General Science you continued your study of acids and bases.

You had another look at some of the **properties** of acids. You saw the effect of acids on substances called **indicators.**
You had a look at some of the typical reactions of acids.

Bases were described in Standard 7 as 'acid destroyers'.
Bases were said to **neutralise** acids making **salt-like** substances.

Neutralisation was described as the **process** in which a base neutralises (destroys) the properties of an acid.
You were also told about a special class of bases called **alkalis.**

Alkalis are bases which can dissolve in water.

During the next four weeks we continue our study of acids and look at the soluble bases called alkalis.

First we look at where acids and alkalis are found in the home. You may be surprised to see where they are found!

Next, we look at how acids and alkalis are identified.
We **investigate** some of their dangers and some of their chemical properties.
We investigate the reactions of acids with metals and carbonates.
Also we will study again the neutralisation reaction.

The emphasis throughout this section of chemistry is on group practical work. Together you will make your way through a series of experiments. At the same time you will work on a number of different activities.

One of the most important things you will do is to work together in your group on a special **investigation.**
*More information about the special group investigation will be given to you by your teacher.

*In this unit of work you will find words which have been **highlighted.** Sometimes words have been highlighted to point out an important fact or idea. Sometimes these are words whose meanings may be unclear to you. At the back of this handout there is a **glossary** where you can look up the meanings of difficult words.

SAFETY SYMBOLS

Sometimes you will see the **international safety symbols** on bottles of chemicals. You should be able to recognise these safety symbols and understand their warnings.

This symbol shows that the substance is dangerous to the skin and eyes.
These substances should not be touched
e.g. iodine crystals.

This symbol is used for materials which **burn easily**. When working with these materials care must be taken with flames and sparks e.g. methanol.

This symbol is used with chemicals that are **dangerous to touch**, they burn the skin. These chemicals react with other materials e.g. nitric acid.

This warns that the material being used can **explode**, especially when it is heated or exposed to a flame
e.g. potassium permanganate.

These chemicals are **poisonous.** They can kill if they are eaten or drunk
e.g. lead nitrate.
These chemicals must be handled very carefully.

This warns that the material being used is dangerous to **breath in** (inhale).
It gives off **dangerous gases**
e.g. nail varnish.

SAFETY RULES

*When doing practical work it is very important that you remember to follow some basic safety precautions.
*Make a short list of what you think are the most important safety rules:

____

____

____

____

____

____

____

AIMS OF THIS SECTION OF WORK

When you have completed this section of work you will have learnt about the following:-

*Chemicals used in the home belong to certain groups with their own properties.

*Acids are an important group of chemicals present in many sustances found in the household.

*Some properties of acidic substances.

*Alkalis are a second important group of chemicals present in many substances in the household.

*Strong acids and alkalis can be very harmful.

*Acidic and alkaline solutions neutralise each other.

*How to work together in a group and carry out practical chemical tests on your own.

*How a study of chemistry involves more than just learning facts out of a book.

And hopefully you will have had some fun learning about acids and alkalis!

WORKSHEET 1 CHEMICALS IN THE HOME

1.What is in the home ?

a) Make a list of chemicals you know of that are commonly used at home.

____

____

____

b) Your teacher will show you some chemicals found at home. Write down their names.

____

____

____

c) You see that you have the names of many different chemicals. Can you find a way to **classify** them? We use the word **classify** to mean '**put chemicals into different groups**'. You will have to think up some rules to help you decide which group a chemical belongs to. Write down your ideas for different groups of chemicals.

____

____

____

____

2. ACIDS AND ALKALIS

a) One way of **classifying** substances is by **taste**. Your teacher will give you two substances to taste. Put a little bit of each substance on your finger and taste with the tip of your tongue. Write down the names of A and B and their taste.

NAME OF SUBSTANCE A ____________ **TASTE** _________

NAME OF SUBSTANCE B ____________ **TASTE** _________

b) Can you think of foods which taste like substance A or like substance B? Write the names of these foods in the table below.

Foods which	taste like
substance A	substance B

SUBSTANCES WHICH TASTE SOUR ARE CALLED ACIDS
SUBSTANCES WHICH TASTE BITTER ARE CALLED ALKALIS

IMPORTANT NOTICE!

In the science laboratory, **taste** is **not** a good way of identifying something. **Smell** is also **not** a good way of identifying something. Many chemicals, such as acids and alkalis, are very dangerous to taste or smell. You should only taste or smell something when the teacher tells you to.

Remember: **SAFETY FIRST**

3. ACID AND ALKALI INDICATORS

Since using taste and smell is so dangerous, we need another way of identifying acids and alkalis. We use substances called **indicators**.

INDICATORS ARE CHEMICALS THAT INDICATE (SHOW) WHETHER A SUBSTANCE IS ACIDIC OR ALKALINE

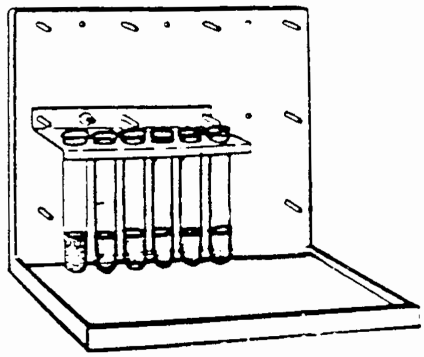
In Standard 7 you heard about a number of different indicators. In this experiment you are going to use an indicator made out of **flower petals**.

*Your teacher will give you two coloured solutions. These coloured solutions were made by boiling coloured flowers in water. These two coloured solutions are going to be our **indicators**.

***What colour is solution 1 ?** ______________

***What colour is solution 2 ?** ______________

PROCEDURE

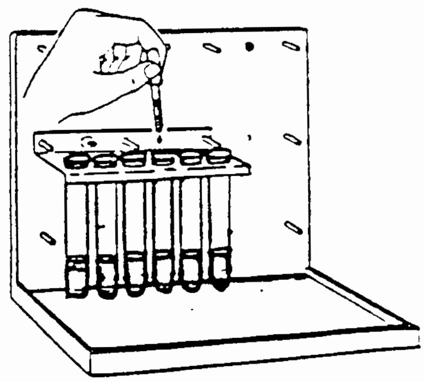


*Pour some of indicator 1 into each of 6 test tubes.

*Use the eyedropper, add small amounts of the different household chemicals to separate test tubes.

*Record your observations in the table below.

Remember to wash out the eyedropper after adding each chemical !



*When you have finished, carefully clean out the test tubes.

*Now repeat the experiment this time using indicator 2.

*Once again record your observations in the table below.

CHEMICAL TESTED	RED INDICATOR	BLUE INDICATOR	ACID or ALKALI
Vinegar (Acetic Acid)			
Tartaric Acid			
Citric Acid			
Handy Andy			
Epsom salts			
Milk of Magnesia			

QUESTIONS

1. Which chemicals cause a change in the red indicator?

____

____

Are these chemicals acids or alkalis? ______________

2. Which chemicals cause a change in the blue indicator?

____

____

Are these chemicals acids or alkalis? ______________

HOMEWORK

1. What happens when an acid is added to a red coloured indicator?

____

____

2. What happens when an alkali is added to a blue coloured indicator?

____

____

3. Suppose you are given three **unknown** liquids A, B and C.

Liquid A causes blue indicator to change to red.
Blue indicator does not change colour in liquid B.
Liquid C causes red indicator to change to blue.

Answer these questions about the three liquids:
3.1 Which liquid is an acid?

____

3.2 Which liquid is an alkali?

____

3.3 Liquid B does not cause the blue indicator to change colour. What does this tell us about liquid B?

____

____

DILUTING LABORATORY ACIDS

In Standard 7 you were introduced to a number of laboratory acids.

***Can you remember their names?**

Here are their chemical formulae, next to each formula write down the name of the laboratory acid.

1. HCl	....
2. H_2SO_4	....
3. HNO_3	....

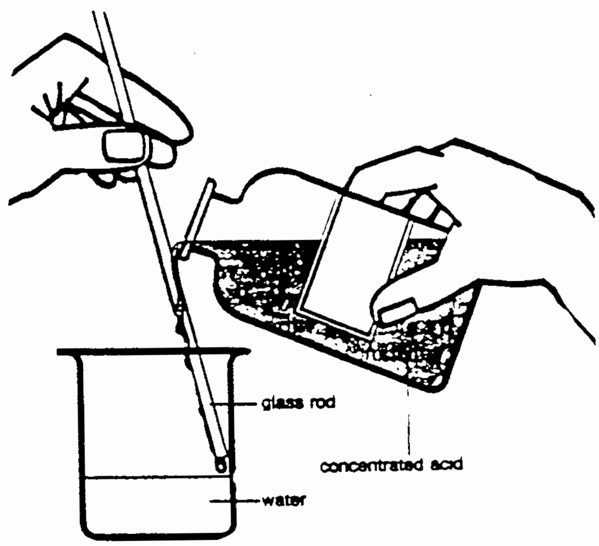
Acids are supplied to the laboratory as **concentrated acids**. These concentrated acids are very dangerous. We have to handle concentrated acids very carefully. If you spill some concentrated acid it can burn a hole in your clothes!
Because they are so dangerous, **only the teacher will ever handle the concentrated acids**.

In all our experiments we will use **dilute acids**.
How do we make a dilute acid?

A dilute acid is made by mixing some concentrated acid with water.
We say the concentrated acid has been **diluted** with water.

*The drawing shows the correct way of diluting a concentrated acid with water.

***Even dilute acids must be handled with great care.**



THE IMPORTANT THING TO REMEMBER IS THAT **THE ACID IS ALWAYS ADDED TO THE WATER. WATER IS <u>NEVER</u> ADDED TO THE ACID.**

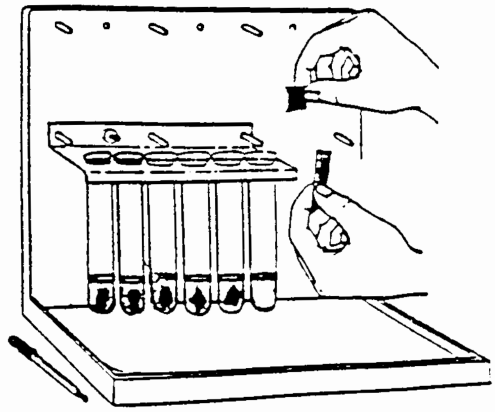
WORKSHEET 2 USING LABORATORY INDICATORS

We will now use some other kinds of indicators. We will test these indicators with some acids and alkalis.

1. THE EFFECT OF ACIDS ON INDICATORS

Procedure

Take 6 test tubes and put them in the test tube stand. Use the felt pen and **label** the test tubes from 1 - 6. Fill each test tube about a quarter full with one of the following acids:



1. **dilute hydrochloric acid**
2. **dilute sulphuric acid**
3. **dilute nitric acid**
4. **vinegar (acetic acid)**
5. **citric acid solution**
6. **tartaric acid solution**

*You must now have a look at the effect of these acids on 3 different indicators. The 3 indicators to use are:

red litmus, blue litmus and bromothymol blue

*Start off with the blue litmus paper.

*Drop a small piece of blue litmus paper into each of the test tubes. Does anything happen to the litmus paper?
*Record you observations in the table below.

*Now you can repeat this **procedure** using small pieces of red litmus paper. Once again record your observations in the table.

*What about using a **liquid indicator?**

*Add 2 drops of bromothymol blue to each test tube. After adding the indicator shake each test tube gently.
*Don't forget to record your observations in the table.

Acid	Colour of blue litmus in acid	Colour of red litmus in acid	Colour of bromothymol blue in acid
hydrochloric acid			
sulphuric acid			
nitric acid			
acetic acid			
citric acid			
tartaric acid			

2. EFFECT OF ALKALIS ON INDICATORS

Procedure

*You must use the same procedure as in the first part of the experiment.
*But this time you will use 6 alkali solutions. The alkali solutions are:

1. Sodium hydroxide solution (NaOH)
2. Potassium hydroxide solution (KOH)
3. Calcium hydroxide solution ________
4. Milk of Magnesia
5. Epsom salts
6. Handy Andy

*If you are not sure what to do look back to the previous page.
*Do not forget to record your observations in the table below. Make up your own headings for the table!

*Can you think of a way to **sum up** what you have been looking at? Try and write a couple of short sentences in the space below.

HINT: Write things like 'Acids turn blue litmus.....'

Remember, in a summary you must try and write down only the really important information.

____

____

____

____

____

3. USING LITMUS WITH A SALT SOLUTION

Procedure

*Now you must take 2 clean test tubes.
*In the one test tube pour some water.
*Into the second test tube pour some salt solution. This salt solution was made by **dissolving** a few **crystals** of table salt ($NaCl$) in some water.

Liquid	Colour change with blue litmus paper	Colour change with red litmus paper
Water		
Salt Solution		

Question
Did the water or the salt solution cause a change in colour in the litmus paper? _________

A substance that does not make litmus paper change colour is called NEUTRAL. WATER and many SALT SOLUTIONS are neutral.

***Please note**: When we talk about **salt solutions**, we are not just talking about table salt which you put on your food.
The name SALT is given to a large, important group of chemicals. Table salt, whose chemical name is sodium chloride, is just one example of a salt. In the next few weeks you will meet a number of these chemicals we call salts.

4. UNKNOWN LIQUIDS - ACID, ALKALI or NEUTRAL?

*Your teacher will give you some **unknown** liquids **A**, **B**, **C**, **D** and **E**. You must use one of the indicators to find out if they are acidic, alkaline or neutral.
*Write down your findings in the table below.

Liquid	Acid, Alkali or Neutral
A	
B	
C	
D	
E	

HOMEWORK

1a) Give the names of three laboratory acids

____

b) What are two properties of acids? ______________________

____

2a) Give the names of three laboratory alkalis

____

b) What are two properties of alkalis? ______________________

____

3a) Water is neutral. What does this mean? ______________________

____

b) How would you show a friend that water is neutral? ______________

____

____

NOTES

EXERCISE THEFT!

The following story appeared recently in the Cape Times.

> **POISON THEFT**
> **FROM SCHOOL**
>
> Mercury and magnesium - which explodes if exposed to air - were stolen from Luhlaza Senior School in Khayelitsha, on Sunday night. Police believe that some children broke into the science laboratory at the school. Police have contacted the local civic and have toured the area around the school to warn parents. A police spokesman said 'The chemicals which were stolen are amongst the most dangerous chemicals you could possibly handle.

This story has a worrying headline. Answer the following questions on a blank page in your notes.

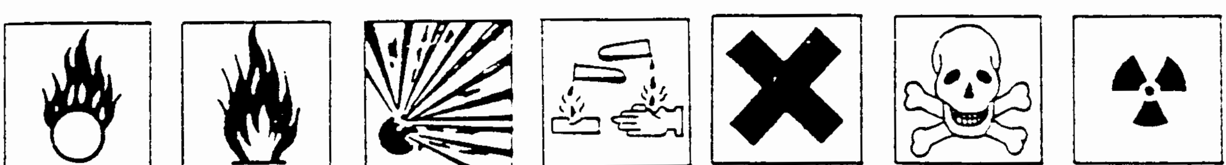
1. What poison was stolen from the school?

2. Which of the warning symbols would you expect to find on the bottle of poison?

3. Is magnesium really explosive? Which of the warning symbols would you expect to find on a bottle of magnesium?

4. Suppose you discovered that one of your friends had stolen the chemicals. What would you advise him/her to do?

5. Write a short letter to the Cape Times. In the letter explain why you think that their knowledge of the chemistry of magnesium is not very good.

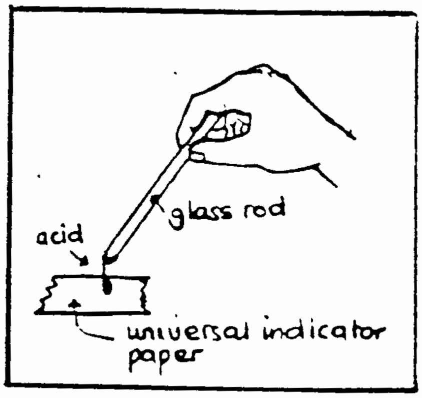


A B C D E F G

WORKSHEET 3
THE STRENGTH OF ACIDS AND ALKALIS

Litmus paper is an example of an indicator often used in the science laboratory. Litmus paper can tell us if a substance is an acid, or an alkali or is neutral.
However, Litmus paper does <u>not</u> show us the **strength** of an acid or alkali. Is the acid strong or weak? Is the alkali strong or weak?
An indicator which <u>does</u> show us the strength of an acid or alkali is called **universal indicator**.

1. UNIVERSAL INDICATOR AND ACIDS



*Your teacher will give you some strips of indicator paper. Tear each strip into 3 pieces.
*Use the glass rod and put a drop of each acid onto a separate piece of indicator paper.
*Remember to clean your glass rod after putting it in each acid!

*Fill in your observations in the table below.

ACID	Colour with universal indicator paper
sulphuric acid	
acetic acid	
hydrochloric acid	
tartaric acid	
nitric acid	
citric acid	

*Ask your teacher for a copy of the **universal indicator colour chart**. Use this chart to finish off the following sentences.

a) Strong acids turn universal indicator paper __________

b) Weak acids turn universal indicator paper __________

c) Two examples of strong acids are ______________________________________

____

d) Two examples of weak acids are ______________________________________

____

2. UNIVERSAL INDICATOR AND ALKALIS

Let's see if alkalis have different strengths as well.
*You must use the same method as in the first part of this experiment.

ALKALI	Colour with universal indicator paper
Sodium Hydroxide	
Handy Andy	
Potassium Hydroxide	
Epsom Salts	
Calcium Hydroxide	
Milk of Magnesia	

*Use the universal indicator colour chart to help you answer the following questions.

a) Strong alkalis turn universal indicator paper ________

b) Weak alkalis turn universal indicator paper _________

c) Two examples of strong alkalis are ____________________________________

____

d) Two examples of weak alkalis are ____________________________________

____

3. UNIVERSAL INDICATOR AND NEUTRAL SOLUTIONS

You already know that water and salt solutions are called neutral.
*Find out the colour of universal indicator paper in water and in salt solutions.
*Fill in your findings in the table below.

Substance	Colour with universal indicator paper
Water	
Salt solution	

QUESTION

Neutral substances turn universal indicator paper _______

4 COLOUR SCALE

Look back at the results of your work over the last two pages. Can you see how the universal indicator paper turned different colours in acids, alkalis and in neutral solutions. You used the universal indicator chart to help you decide if a solution was, for example, a strong acid or a weak acid.
You can put this information together and make your own **universal indicator colour scale.**

STRONG ACID	**WEAK ACID**	**NEUTRAL**	**WEAK ALKALI**	**STRONG ALKALI**

NOTES

INFORMATION SHEET

THE pH SCALE

In the last experiment you looked at the strengths of acids and alkalis. You found out that different substances turned universal indicator into different colours.
An acidic substance like sulphuric acid turned universal indicator a strong red colour. An alkaline substance like sodium hydroxide turned universal indicator a dark purple colour. You made your own colour chart showing the range of different colours.

There is another way of showing the strengths of acids and alkalis. We use a scale of numbers from 1 to 14. This scale is known as the **pH scale**, and the numbers are called pH numbers.

We can represent the pH scale in a diagram.

UNIVERSAL INDICATOR CHART

red orange yellow green blue purple

pH	1	2	3	4	5	6	7	8	9	10	11	12	13	14

ACIDS NEUTRAL ALKALIS

*The pH scale tells us that **strong acids** have a **pH** of **1**.
Weak acids have a **pH** of **6**.

*The pH number 7 is the midway point in the pH scale.
Substances which are neither acidic nor alkaline have a pH of 7.
Pure water has a pH of 7.
Pure water is neither an acid nor an alkali, pure water is said to be neutral.

*The pH scale tells us that **weak alkalis** have a **pH** of **8**.
Strong alkalis have a **pH** of **14**.

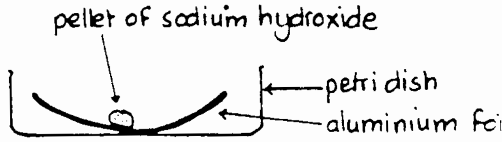
Substances with a low pH value are acidic, substances with a high pH value are alkaline.

2. THE CORROSIVE EFFECTS OF A STRONG SODIUM HYDROXIDE SOLUTION

Sodium hydroxide is an example of a strong alkali. We are now going to have a look at the corrosive effects of this substance.

a) The effect on Aluminium

*Describe your observations



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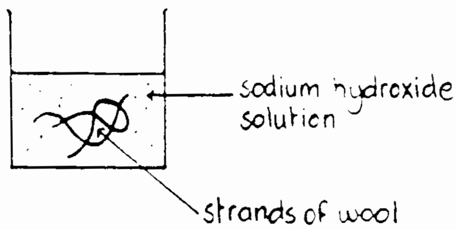
___

___

b) The effect on wool

*Describe your observation



___

___

___

DISCUSSION

Strong alkalis can also be very corrosive

Strong alkalis like sodium hydroxide are found in many household cleaning agents. For example, Jik and Vim have sodium hydroxide in them.
***What must you do if you spill a strong alkali?**

*Imagine that you spill some strong alkali on your mother's new carpet. Try and write a paragraph describing what must be done!

___

___

___

___

___

ACID RAIN

INTRODUCTION

Rain water is always **slightly acidic**. The pH of rain water is about 5.6. Why is this? As rain falls from the clouds, the water reacts with CO_2 in the air to form an acid.

'pure water'	+	carbon dioxide in air	$\longrightarrow$	'rain water' (carbonic acid)
H_2O	+	CO_2	$\longrightarrow$	H_2CO_3
pH 7				pH 5.6

ACID RAIN

Rainfall is called **acid rain** when it has a much lower pH than normal rain water. Rainfall with a **pH less than 5.6** is called **acid rain**. Acid rain is caused by pollution and is found today in different parts of the world. In many countries people are becoming very concerned with problems caused by acid rain.

***Why is acid rain a problem?**

POLLUTION is the **contamination** of the **environment** by substances made by humans. One kind of pollution which is very harmful is **air pollution**.
Air pollution is often caused by the combustion (burning) of fuels.

Figure 1 shows some of the **pollutants** that may be formed when fuels burn.

The amounts of pollutants that are formed depend on the sort of fuel and the way the fuel is burned.

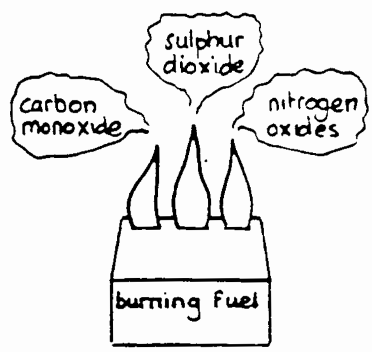


Figure 1

One of the worst air pollutants is **sulphur dioxide (SO_2)**. Chemists believe that **sulphur dioxide is one of the major causes of acid rain.**

***Where does sulphur dioxide come from?**

Many fuels, particularly **coal**, contain **sulphur**. As coal burns the sulphur reacts to make the acidic gas sulphur dioxide.

sulphur in coal	**+**	**oxygen in air**	$\longrightarrow$	**sulphur dioxide**
S	**+**	O_2	$\longrightarrow$	SO_2

Coal-fired power stations use coal to make electricity. When the power station is making electricity large amounts of sulphur dioxide are produced as well. This sulphur dioxide is released into the air above the power station. This sulphur dioxide causes all the problems.
Why is this?

In the atmosphere sulphur dioxide reacts with rain water to form sulphurous acid.

rain water	**+**	**sulphur dioxide**	**⟶**	**sulphurous acid**
H_2O	+	SO_2	⟶	H_2SO_3
pH 5.6				**pH 4**

Figure 2 shows how acid rain is formed.

Some of the sulphurous acid changes into **sulphuric acid.**

Both sulphurous acid and sulphuric acid are found in acid rain.

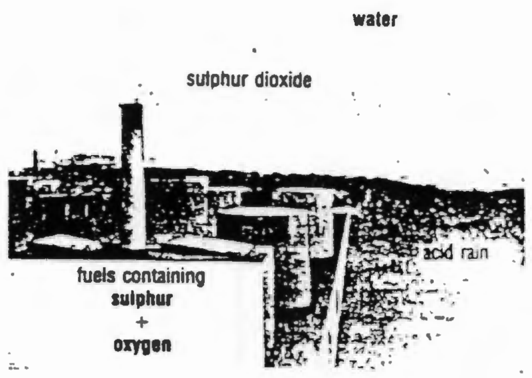


Figure 2

PROBLEMS CAUSED BY ACID RAIN

Acid rain is harmful to living things. Acid rain is harmful to trees, and to living creatures in rivers and lakes. Acid rain can also cause damage to buildings and makes metals corrode faster.

There has been growing concern in Europe and America about the problems of acid rain.

In Germany many forests are filled with dying trees. These trees have been damaged by the acid rain which falls on them.

In Norway many lakes have 'died'. This is because the water has become too acidic. The plants and fishes cannot survive the high acidity and they die.

***What about us here in South Africa?**
***Do we have a problem with acid rain?**

Read the article taken from a local newspaper on the next page. Then answer the comprehension exercise that follows on a fresh page of your notebook.

Acid rains over Eastern Transvaal

Levels of atmospheric pollution and acid rain in the Eastern Transvaal Highveld are as bad as the worst in the northern hemisphere say leading **environmentalists.**

Acid rain is caused by the release of pollutants like sulphur dioxide and oxides of nitrogen into the atmosphere.

The CSIR's Robert Skoroszewski says acid rain damages our environment in two ways:

*By direct contact where damage is caused to trees and the fabric of buildings; and

*By indirect effect as the rain water drains through the soil, affecting soil chemistry and finally causing the **acidification** of rivers and lakes.

More than 1 million tons of sulphur dioxide annually are released into the atmosphere over the Eastern Highveld, mainly from Eskom's electricity-generating power stations, which burn 56 million tons of coal a year.

Other sources of atmospheric pollution include **petro-chemical** plants, coal dumps, fires in townships and car exhausts.

About 80% of SA's electricity is **generated** in the Eastern Transvaal because of the presence of coal and water sources, and the closeness of the PWV area, where most of the electricity is used.

Skoroszewski points out that the million tons of sulphur dioxide released annually into the atmosphere in SA is small compared with the 20 million tons released each year in the US.

In Europe, the acidification of lakes and rivers has resulted in the death of many fish.

In SA tests on streams along the Drakensburg escarpment and in forests have shown conditions probably resulting from acid rain.

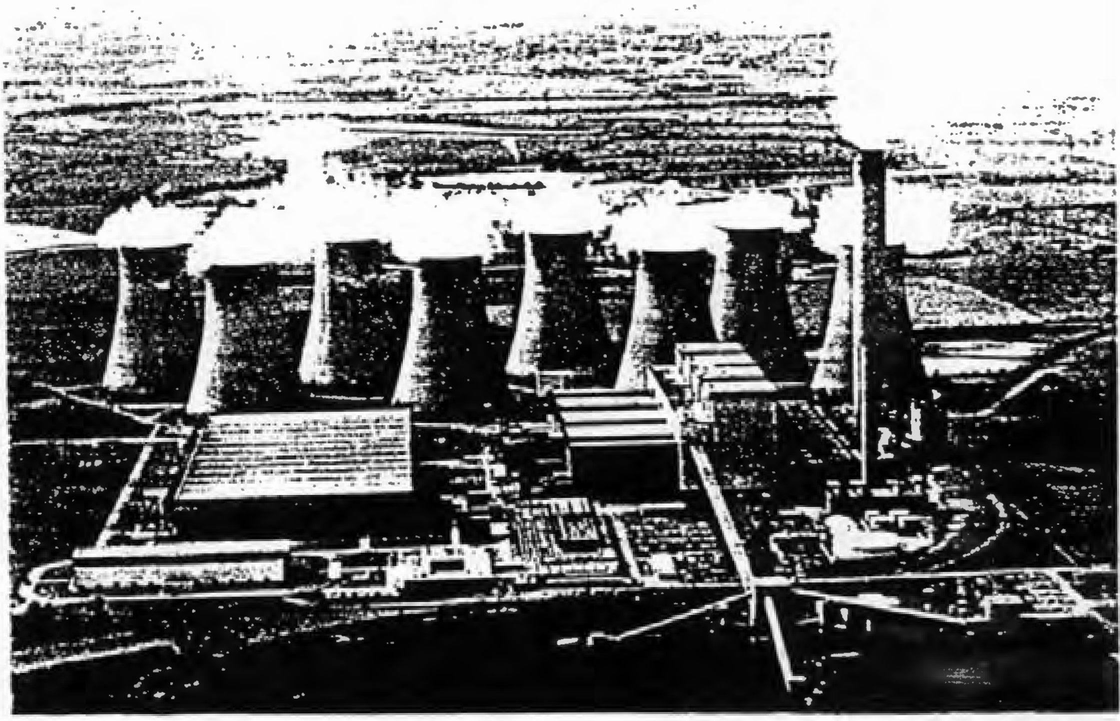
Many European governments have committed themselves to reducing levels of sulphur dioxide by 30% before 1993.

Effective pollution control is extremely expensive, however.

Skoroszweski says the most distressing aspect of the acid rain problem in the Eastern Transvaal is the lack of public awareness.

"It would be a tremendously expensive operation to introduce proper pollution control equipment in our power stations for example, but what price do we put on our environment?"

Eskom counters that the levels of sulphate and nitrates deposited in the Eastern Transvaal are below the highest reported in Europe.



QUESTIONS

1 Which part of the country suffers most from acid rain?

2 What causes this acid rain?

3 Write down a chemical reaction showing how sulphur dioxide makes rain water more acidic.

4 Where does the sulphur dioxide come from?

5 Name 5 sources of atmospheric pollution.

6 If you measured the pH of rain water in the Eastern Transvaal, what pH would you expect to measure?

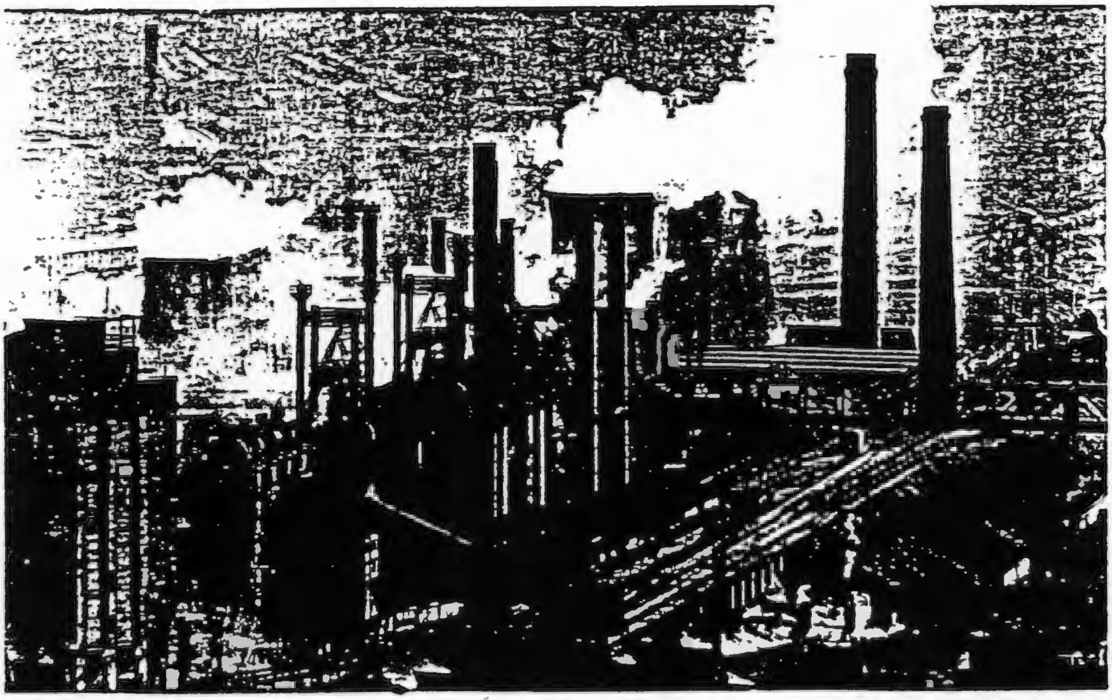
7 Why is 80% of South Africa's electricity generated in the Eastern Transvaal?

8 Imagine you are sent to the Eastern Transvaal and told to report signs of damage caused by acid rain.
What things would you look for?

9 Do you expect us here in Cape Town to have similar problems with acid rain? Give reasons supporting your answer!

10 Do you think anything should be done to try and lessen the problems caused by acid rain?
Make some suggestions.

*Would you like to spend some more time looking at acid rain?
You could choose acid rain as the topic for your **investigation**!



WORKSHEET 4
THE REACTIONS OF METALS WITH AN ACID

INTRODUCTION

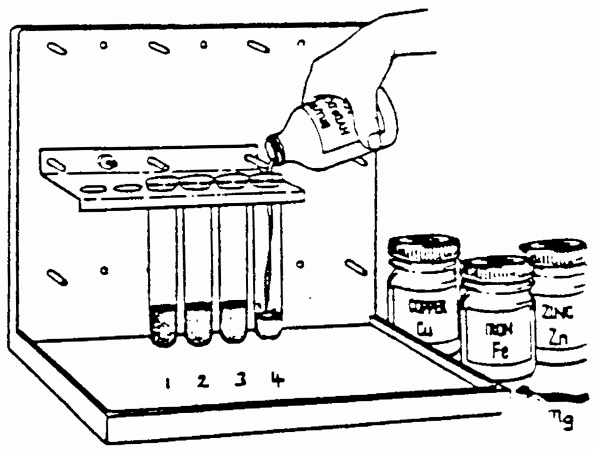
Acids and alkalis can be very **reactive**. A substance is reactive when it can undergo **chemical reactions** with other things. What is the result of a chemical reaction? The substances taking part in the reaction (called **reactants**) undergo chemical changes and turn into new substances (called **products**). In a chemical reaction reactants turn into products.
From work we did in a previous chapter you know that some metals react with oxygen. Also we saw how some metals can react with water.

Do metals react with acids?
How well do metals react with acids?
What is produced when an acid reacts with a metal?

These are some of the questions we will try and answer during this worksheet.

PROCEDURE

*Place 4 test tubes in the test tube stand. Use the felt pen to label the test tubes from 1 to 4.
*Add **dilute hydrochloric acid** to each of the test tubes. Add enough acid to make each test tube a quarter full.
*Use a ruler and measure a 50mm piece of **magnesium ribbon**. Put the magnesium ribbon into test tube 1.
*Add a small amount (tip of a teaspoon full) of **iron filings** to test tube 2.
*Add a small piece of **zinc** to test tube 3.
*Add a small amount (tip of a teaspoon full) of **copper powder** to test tube 4.



QUESTIONS

a) Which of the metals **appears** (seems) to be **reacting** with the hydrochloric acid?

____

b) Write down the four metals in **order** of **most reactive** to **least reactive.**

most reactive least reactive

THE REACTIVITY SERIES OF METALS

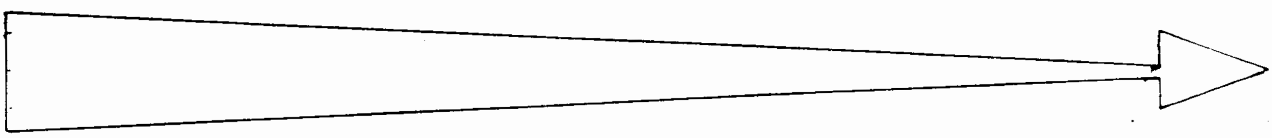
In a previous chapter of chemistry you were introduced to something called **'The Reactivity Series of Metals'**.

Can you remember how you came to draw up the Reactivity Series of Metals?
Firstly, you investigated the reactions of different metals with oxygen. Then you had a look at the reactions of different metals with water.
What you did was get an idea of how **reactive** the different metals are. Just remember, the the reactivity series gives you the **order of reactivity** of a number of different metals.

We have just looked at the reactions of metals with dilute hydrochloric acid. We can now add this information to our knowledge of the reactivity series.

THE REACTIVITY SERIES OF METALS

decreasing reactivity

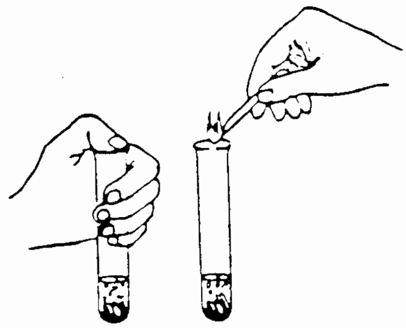


Metals reactions with	**K Na I**	**Ca Mg**	**Al**	**Zn Fe**	**Cu**	**Ag Au**
AIR/OXYGEN	rapid	slow	slow	slow	very slow	none
WATER/STEAM	very rapid with water	rapid with water	seems low	only with steam	none	none
DILUTE ACID		**RAPID**		**SLOW**	**NONE**	

LET'S GET BACK TO THE EXPERIMENT

*Take test tube 1. Add some more magnesium to the test tube.
*Hold your thumb over the mouth of the test tube for a few seconds.

*Light a match. Take your thumb away from the mouth of the test tube. Quickly hold the burning match near to the mouth of the test tube.



*What happens? ______________________________

*Identify the gas which was given off during this reaction.

____

*We say that a gas was **liberated** during the chemical reaction.

*Try to finish the equation for the reaction between magnesium and dilute hydrochloric acid:

write the formula of the gas here

Mg + HCl ⟶ .... + ...

can you think of a name for this substance?

____

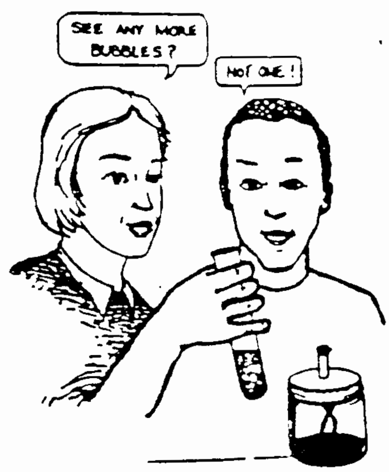
Now you must try and collect some of this other substance.

*Continue adding magnesium to the test tube until no further reaction takes place.

*How can you tell that the reaction in the test tube is finished?

*Heat the test tube gently over the spirit lamp.

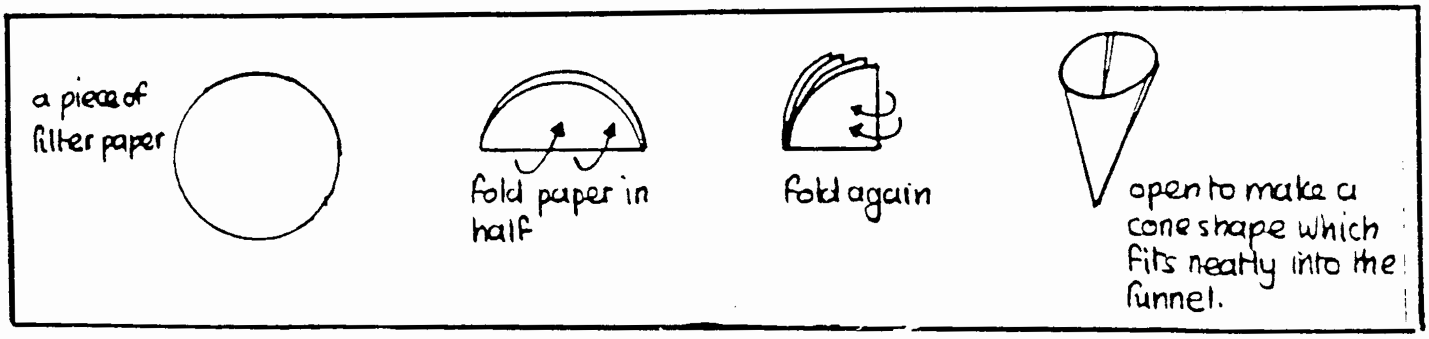
If no more bubbles of gas are seen, the reaction is finished.

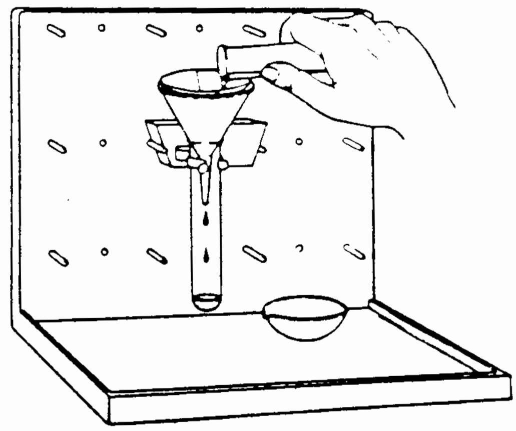


If you look in the test tube what do you see? At the bottom of the test tube lies some of the extra magnesium that you added.
You need to **filter** the solution to get rid of this extra magnesium.

*You will have to fold a piece of **filter paper** so that it fits neatly into the **filter funnel**.

*Ask your teacher to show you how to fold a piece of filter paper. Or better still, try to do it yourself!



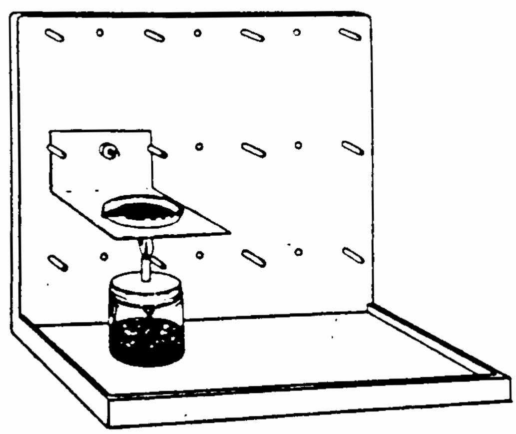


*Place the filter paper in the filter funnel.

*Pour the solution from test tube 1 into the filter funnel. The liquid which passes through the funnel is called the **filtrate**.

*Collect this filtrate in a test tube.

*When you have collected the filtrate pour about **half of the filtrate** into an **evaporating basin**.



*Place the evaporating basin on the heating stand.

*Heat the evaporating basin gently until all the liquid has **evaporated**.

<u>Be careful! The evaporating basin is going to be very hot!</u>

*Have a look in the bottom of the basin.
*What do you see left over in the bottom of the basin?

____

____

*Write down again the equation for the reaction between magnesium and dilute hydrochloric acid.

*Underneath the **chemical symbols** write down the **names** of each substance.

Mg	+	....	$\rightarrow$	......	+	H_2
magnesium	+	....	$\rightarrow$	......	+	hydrogen gas

We can write a **GENERAL REACTION**

METAL + ACID $\rightarrow$ SALT + HYDROGEN GAS

NOTES

HOMEWORK

The following chemical equations show the reactions between different metals and a number of dilute acids. Try and finish the equations.

1.	Mg	+	....	$\longrightarrow$	$MgSO_4$	+	H_2
magnesium			....		....		hydrogen gas
2.	Fe	+	HCl	$\longrightarrow$	......	+	....
	....		....		....		....
3.	.....	+	....	$\longrightarrow$	$FeSO_4$	+	H_2
	....		....		....		....
4.	Zn	+	H_2SO_4	$\longrightarrow$	......	+	....
	....		....		....		....

5. What is the Reactivity Series of Metals?____________________________________

____

6. If some sodium metal was added to dilute sulphuric acid what would happen?

____

____

7. If some silver metal was added to dilute hydrochloric acid what would happen? Try and explain your answer.

____

____

8. Arrange the following metals in order of **increasing reactivity**.

Au I Al Cu Na Ag Ca Zn K Mg Fe

least reactive **most reactive**

WORKSHEET 5
THE DANGERS OF STRONG ACIDS AND ALKALIS

THIS WILL BE A TEACHER DEMONSTRATION

Strong acids and alkalis can be very **corrosive**. Because they are corrosive strong acids and alkalis are very dangerous and must be handled with care.
Many household substances, for example Jik, Handy Andy and Vim contain strong acids and alkalis.

1. THE CORROSIVE EFFECT OF A STRONG SULPHURIC ACID SOLUTION

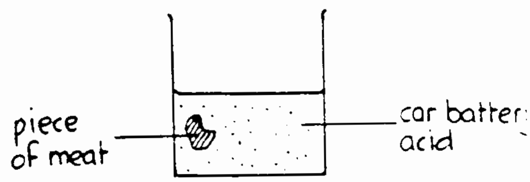
A strong sulphuric acid solution is used in a car battery. Sometimes it is just called 'car battery acid'.

a) **The effect on a piece of meat**

*Describe your observations

____

____

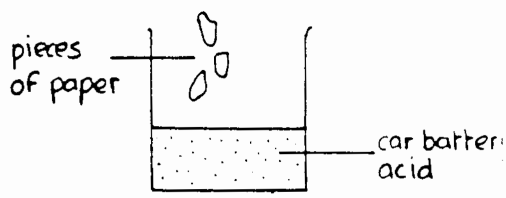


b) **The effect on pieces of paper**

*Describe your observations

____

____

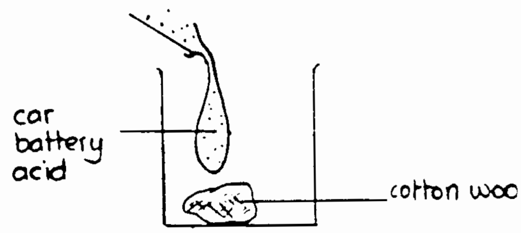


c) **The effect on cotton wool**

*Describe your observations

____

____



DISCUSSION

STRONG ACIDS CAN BE VERY CORROSIVE.

What must you do if you spill a strong acid?
ACT QUICKLY!

*Remove as much of the acid as possible with a wet cloth. Wash the place where the acid was spilt with a **dilute alkali.**
*How can you make a dilute alkali? **Mix some bicarbonate of soda in water.**
*Wash again with water the place where the acid spilt.

3. THE DANGERS IN MIXING HOUSEHOLD CHEMICALS

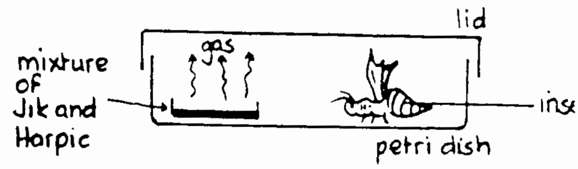
Your teacher will add some **Jik** to some **Harpic lavatory cleaner**. The Harpic has been placed in a **petri dish**. There is also a live insect in the petri dish.

a) What do you see happening to the mixture of Jik and Harpic?

____

____

____



b) What happens to the poor insect!?

____

____

c) What do you think this tells us about the gas being formed?

____

____

This experiment shows us the dangerous effect of mixing household chemicals. Cleaning agents like Jik and Harpic should <u>NEVER</u> be mixed together!

NOTES

COMPREHENSION EXERCISE

BLEACH

In Worksheet 5 you saw a demonstration of the dangers of mixing together household chemicals.
Bleach is perhaps the **most dangerous** chemical found around the home.
*Look carefully at the pictures below. The pictures are taken from the label on a bottle of bleach.

*Look carefully at the warnings on the bleach bottle label.
*On a page in your notebook answer the following questions:
1)What does it mean to say that bleach is an **irritant**?
2)What is the main chemical found in this bottle of bleach?
3)**'Contact with acids liberates toxic gas'**
Try and explain this statement in simple words. Explain clearly the meaning of the words **'toxic'** and **'liberates'**.
4)Why would it be a mistake to mix some bleach with a toilet cleaner like Harpic?
5)Why do you think they tell you **not** to remove the label unless the contents are completely used and the bottle rinsed out?
6)**'If inadvertently swallowed...'** What does the word **'inadvertently'** mean?
7)Nolundi's baby brother swallows some bleach. What would you tell Nolundi to do?

You might have noticed that the labels are not taken from a South African bleach bottle. They come from a British bleach bottle.
*Do South African bleach bottles carry warning labels?

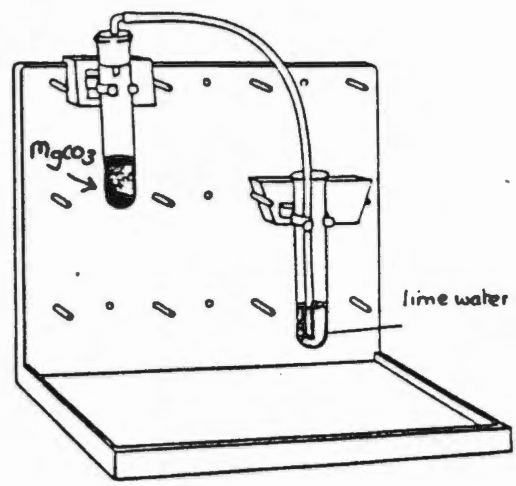
***If you are looking for a topic for you group investigation here's something to think about!**

WORKSHEET 6
THE REACTION OF CARBONATES WITH AN ACID

Carbonates are compounds which have a carbonate ion (CO_3^{2-}).
For example, **magnesium carbonate** has a chemical formula **$MgCO_3$**
calcium carbonate has a chemical formula **$CaCO_3$.**

***What happens whan a carbonate is added to an acid?**

PROCEDURE



*Add half a teaspoon of **magnesium carbonate** to a test tube. Quarter fill another test tube with **lime water.**

*Look at the drawing. Set up the **apparatus** just like this.

*To the test tube with magnesium carbonate add some dilute **sulphuric acid.**

*Let the gas which is given off bubble through the lime water.

QUESTIONS

a) What did you see happening in the test tube of magnesium carbonate when dilute sulphuric acid was added?

____

____

b) What happened to the lime water? ______________________________

____

c) Lime water is used in the test for which gas? ______________________

The reaction between sulphuric acid and magnesium carbonate can be written like this:

$$H_2SO_4 + MgCO_3 \longrightarrow MgSO_4 + H_2O + CO_2$$

***REPEAT** the procedure but this time use **calcium carbonate** and **dilute hydrochloric acid.**

*Write down your observations for this reaction: ______________________________

____

____

____

Complete the chemical equation for the reaction between dilute hydrochloric acid calcium carbonate.

$HCl \quad + \quad CaCO_3 \quad \longrightarrow$

ALL CARBONATES REACT WITH AN ACID TO MAKE A SALT, WATER AND CARBON DIOXIDE.

We can represent this as a general reaction:

ACID + CARBONATE $\longrightarrow$ SALT + WATER + CARBON DIOXIDE

NOTES

1. HOW CAN YOU MAKE A CAKE RISE?

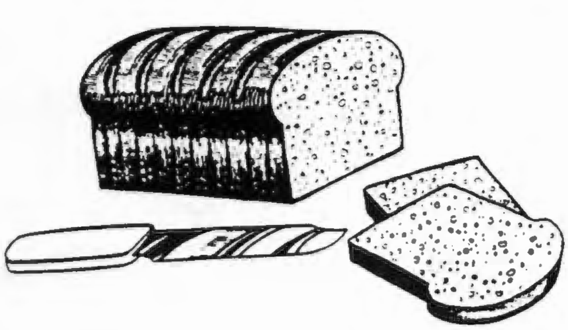
Have a close look at the piece of fresh white bread the teacher gives you.

*How does the bread feel?
Does the bread feel **light and airy** or does the bread feel **hard and solid**?
In English we would say that a fresh loaf of bread has **risen** nicely. The bread feels light and airy.
Not eveyone eats bread like this. Some people eat a different kind of bread which is **unleavened.**

*Have a close look at a piece of unleavened bread. This kind of bread is called a pappadam.
*Compare the pappadam to the piece of fresh white bread.
*Do the two pieces of bread feel the same?
*Taste a piece of pappadam, which bread do you think tastes the best?

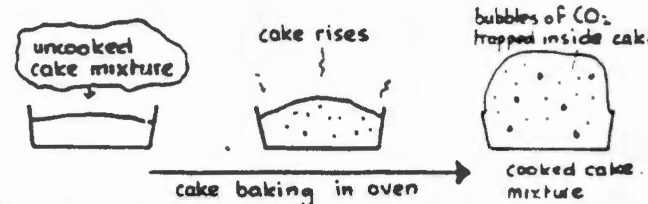
Food usually tastes nicer if it is light and airy. Many people find bread much nicer to eat if it has risen.

Both kinds of bread were made with flour. But something must have been added to the white bread to make it light and airy!



Cooks make food light and airy by mixing together ingredients which will make tiny bubbles of gas in the food. The gas produced is usually **carbon dioxide**. The carbon dioxide gets 'trapped' inside the food as the food is cooking.

The drawing below shows how this works inside a cake.



HOW A CAKE RISES

Can you now understand why we say in English 'a cake rises'?

The question we must now ask ourselves is
"As the cake bakes how does this carbon dioxide get made inside the cake?"

There are two chemical reactions which can be used to produce this carbon dioxide:

***reacting sodium bicarbonate with an acid.**

***heating sodium bicarbonate.**

We haven't looked at **bicarbonates** yet but you have used **carbonates** before. In **worksheet 7** you looked at the reaction between an **acid** and a **carbonate**.

What then is the difference between a carbonate and a bicarbonate?

*Carbonates are compounds having the **carbonate ion** (CO_3^{2-})
for example:
sodium carbonate is Na_2CO_3.

***Bicarbonates** are compounds having the **hydrogencarbonate ion** (HCO_3^{-1})
For example:
sodium bicarbonate is $NaHCO_3$
this is also called
sodium hydrogen carbonate.

The reaction of an acid with a carbonate and an acid with a bicarbonate is the same.

If you add an acid to a carbonate or add an acid to a bicarbonate, it fizzes and gives off carbon dioxide.

Sherbet contains a mixture of sodium hydrogencarbonate and citric acid. When these substances dissolve in the liquid in your mouth, they produce carbon dioxide - they FIZZ!

ALL CARBONATES AND BICARBONATES REACT WITH ACID TO GIVE CARBON DIOXIDE, WATER AND SALT.

Sodium bicarbonate is also called **baking soda.**
Baking powder is a mixture of **baking soda** and **tartaric acid.** One way to make a cake rise is to add baking powder to the cake mixture.

When you add baking powder to a cake mixture bubbles of carbon dioxide are made inside the cake.

Why is this?
The sodium bicarbonate and tartaric acid in the baking powder react together to make carbon dioxide.
Fortunately both sodium - bicarbonate and tartaric acid are safe to eat!

When you heat sodium bicarbonate it **decomposes** (breaks up) to give carbon dioxide, water and a carbonate.

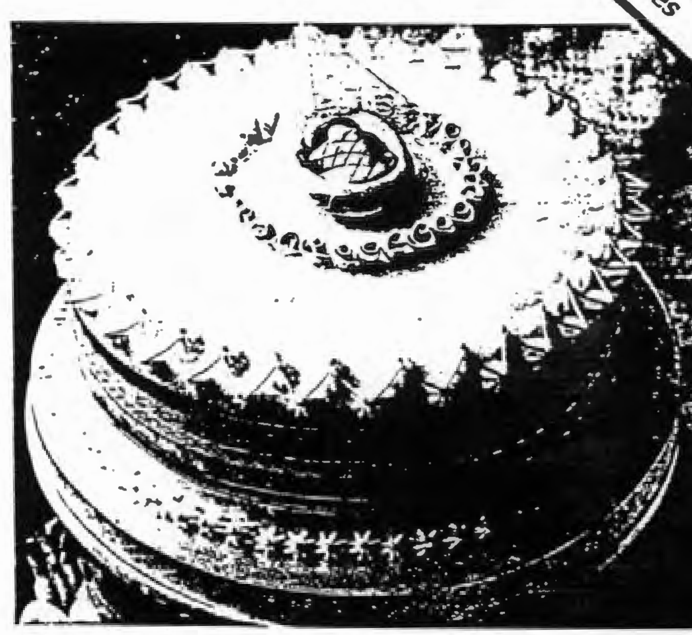
sodium bicarbonate ⟶ carbon dioxide + water + sodium carbona

$$2NaHCO_3 \longrightarrow CO_2 + H_2O + Na_2CO_3$$

So, another way to make cakes rise is to add sodium bicarbonate (baking soda) to the cake mixture. When the cake is cooking, the sodium bicarbonate decomposes.

The decomposition of sodium bicarbonate produces bubbles of carbon **dioxide gas.**
The bubbles of carbon dioxide gas make **the cake mixture rise up.**

Cakes



MAKING SHERBET

Sherbet is a mixture of sodium hydrogen carbonate, citric acid and sugar. When these powders dissolve in the water in your mouth, the sodium hydrogen carbonate and citric acid **react** together. These two chemicals **fizz** and give off **carbon dioxide.**

*Do you remember the other name for sodium hydrogen carbonate?
It is also called sodium bicarbonate.

If you follow this simple recipe, you can make some sherbet yourself.

RECIPE

Put the following ingredients into a bowl and mix well together.

* **9 teaspoonsful of icing sugar**
* **2 teaspoonsful of citric acid**
* **1 teaspoonful of bicarbonate of soda**

*Can you make sherbet at home and make some money selling it to you friends? Here is a possible topic to **investigate**.

APPLICATIONS OF THE ACID-CARBONATE REACTION

*What else fizzes in the home?
'When you're feeling low Eno' is a popular advertisment. If you get a stomach ache, then Eno is a medicine which may help you feel better.
How do you take Eno?
You would normally mix some of the Eno with water. As you mix togehter the Eno and water it **fizzes**. In science we use the word **effervesce** to describe this fizzing.

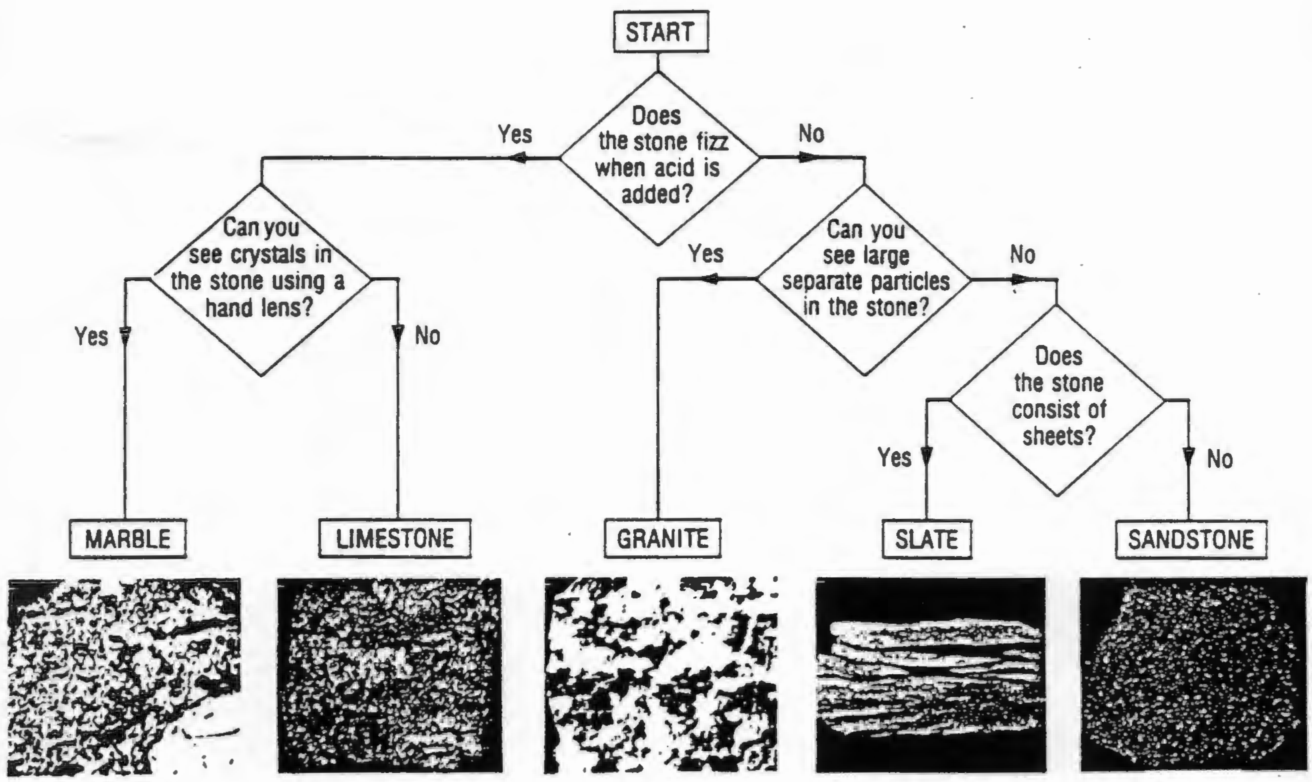
As the Eno **effervesces** millions of tiny bubbles of gas are being made.
*Can you guess what gas is being produced? How could you check your idea?
Eno is called an **effervescent** medicine.
*Why does Eno effervesce when it is added to water?
*What chemicals are in Eno?
This is a possible topic for **investigation!**

Most **fire extinguishes** produce **foam** that contains **carbon dioxide.** If this is sprayed on the fire no oxygen can get to the fire. The fire will then go out.
Old fire extinguishers used to contain an **acid** and a **bicarbonate.** When these two chemicals came into contact, they produced the carbon dioxide sprayed on the fire.

WHAT STONE IS THAT?

We can use the effect of acids on stone to help us identify some common types of rock. You will use what is called a **'key'** to help you identify 5 different kinds of rock.

STONE IDENTIFICATION CHART



SAMPLE	TYPE OF STONE
A	
B	
C	
D	
E	

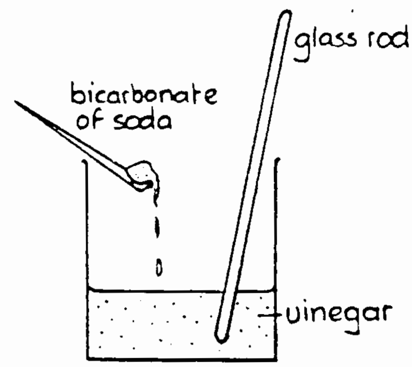
WORKSHEET 7

NEUTRALISATION PART 1

Think back to Worksheet 5 'The dangers of strong acids and alkalis'. You were told that if you spill a strong acid you can clean it up using an alkali. Remember what you decided to do if you spilt a strong alkali?
In those examples the acid and the alkali cancel or **neutralise** each other. It should be of no suprise to hear that **neutralisation** reactions are very important in the study of acids and alkalis.

1. NEUTRALISING VINEGAR AND BICARBONATE OF SODA

Vinegar is acetic acid solution. When vinegar is tested with universal indicator paper, the indicator turns _______ in colour.
Dissolve bicarbonate of soda in water and you make an alkali solution. If you put a piece of universal indicator paper into a solution of bicarbonate of soda, the paper would turn ______ in colour.



*Now you can do an experiment in which you mix together vinegar and bicarbonate of soda.

*Pour about 25ml of vinegar into a 100ml beaker.

*Slowly add bicarbonate of soda to the vinegar.

*Stir the solution in the beaker with a glass rod.

*How can you tell that a reaction between the vinegar and the bicarbonate of soda is taking place?

____

____

*Test the solution in the beaker with a small piece of universal indicator paper.

*You must continue adding small amounts of bicarbonate until you think a reaction is finished.

*When you think the reaction is finished what colour will a piece of universal indicator paper turn?

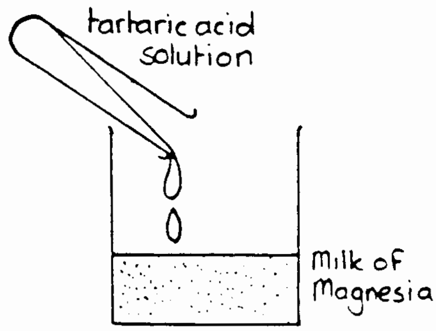
____

The vinegar has been neutralised by the bicarbonate of soda. The reaction between the two substances is called a neutralisation reaction.

2. NEUTRALISING TARTARIC ACID AND MILK OF MAGNESIA

Here you can use a procedure similar to that used in part 1 of the experiment.

*Pour some tartaric acid solution into a test tube.



*Add some Milk of Magnesia to a beaker.

*Slowly add the tartaric acid to the Milk of Magnesia.

*How can you tell that a reaction between the tartaric acid and the Milk of Magnesia is taking place?

____

*Keep adding the tartaric acid until the solution in the beaker goes clear.

*Test the solution with a piece of universal indicator paper. What do you find happens to the indicator paper? ______________________________

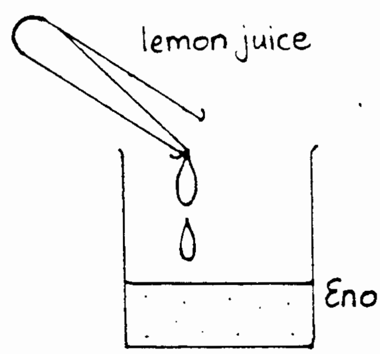
*Is the solution acidic, neutral or alkaline? ______________

The Milk of Magnesia has been ______________ by the tartaric acid solution.

3. NEUTRALISING LEMON JUICE AND ENO

Lemon juice contains citric acid. ENO contains sodium bicarbonate and a small amount of citric acid.

*Pour some water into a 100ml beaker until the beaker is about 1/4 full. Add a little ENO to the water. Stir the solution until the ENO dissolves.



*Pour some lemon juice into a test tube.

*Add lemon juice a little at a time to the ENO.

*How can you tell that a reaction is taking place?

____

____

*Stop adding lemon juice when you think the reaction is finished.

*Test the solution with universal indicator paper.
*Is the solution acidic, neutral or alkaline? ____________

*The ENO has been neutralised by the ____________________

In general, an acid and an alkali neutralise each other. This process is called NEUTRALISATION.

STOMACH TROUBLE?

Rushing to her science lesson after break one day Nolundi came across her friend Xoliswa. Xoliswa looked very unhappy.

"What's wrong with you?" asked Nolundi "Why are you groaning and holding your stomach like that?"

"Oh sissi, I've got this terrible pain in my stomach!" Xoliswa groaned loudly.

"I'm not surprised" said Nolundi "I saw you at the tuckshop. You were very greedy. I saw you eat 3 vetkoek, a packet of chips and a Bar one! And to make matters worse, you were eating all that food very very quickly."

"Please Nolundi, don't be cross with me. You are always saying that you want to be a doctor one day. Can't you recommend something I can take to ease the pain?"

Nolundi thought for a while. She tried to look serious and even asked Xoliswa some more questions about her sore stomach. Suddenly a big smile appeared on Nolundi's face.

"Xoliswa, you are in luck. I've just remembered something from a biology lesson. Often when you have a sore stomach it is because too much stomach acid has been produced. I think the teacher said there is a weak solution of hydrochloric acid in our stomachs. Too much acid causes indigestion. Yes, that's my feeling, you've got too much acid in your stomach. Here's what Doctor Nolundi suggests that you do..."

*What do you think Nolundi told Xoliswa to get hold of? Explain your answer.

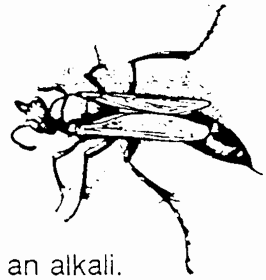
____

____

____

____

____

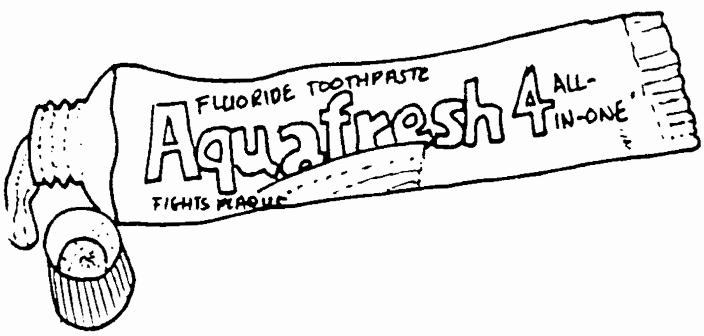


NEUTRALISATION AND EVERYDAY LIFE

We all have **hydrochloric acid** in our stomachs. We need this acid to help us digest our food. Sometimes there is too much acid in our stomach. This may happen when we eat the wrong food. Or, like Nolundi, when we eat too much food too quickly.
In order to **neutralise** the acid in the stomach, we take an alkaline medicine. **Milk of magnesia** and **Eno** are alkaline medicines. They help to neutralise the acid in our stomach.
Remember, acids are neutralised by just the right amount of alkali. When acid solutions react with alkali solutions to make neutral solutions, it is called **neutralisation**.

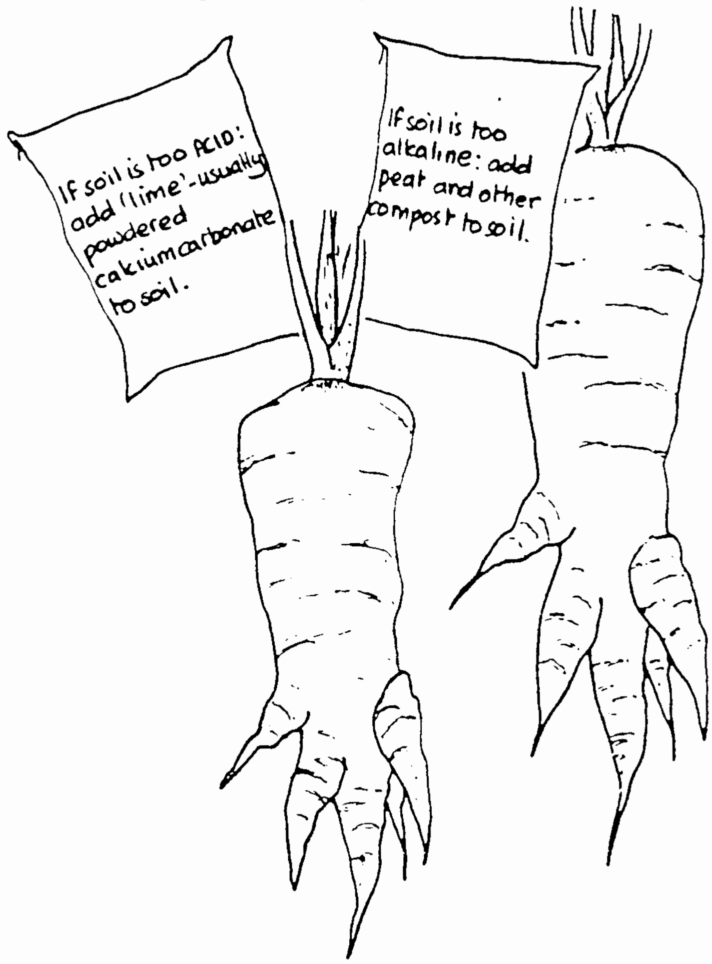
We use neutralisation in many ways.

*There is a lot of acid in our food. This acid causes tooth decay. We should brush our teeth every day to keep them clean. **Toothpaste** contains an alkaline solution. This alkali will neutralise any acid from food which has collected on our teeth.



*A bee sting can be very painful. When you are stung by a bee, the acid in the bee sting causes pain.
To take away the pain you must put an alkaline solution on the sting. Put some bicarbonate of soda on a bee sting. The alkali will neutralise the acid from the bee sting. The pain should go away!

*The sting of a wasp contains an alkali. The alkaline sting of a wasp is very painful. An acid such as vinegar will neutralise the alkaline sting of the wasp.



*A farmer always tests the soil before planting a crop. Some crops like the soil to be acidic, other crops like the soil to be alkaline.
A slightly acidic soil is said to be 'sweet'. A more alkaline soil is 'sour'.
Most crops, especially vegetables grow well in a sweet or neutral soil.
Sometimes there is too much acid in the soil. What do you think a farmer does?
If there is too much acid in the soil, a farmer adds an alkali. Calcium hydroxide is an alkali. Calcium hydroxide is also called slaked lime. If you add slaked lime to soil it will reduce the acidity of the soil.

WORKSHEET 8

NEUTRALISATION PART 2

In the previous worksheet we saw how an alkali and an acid neutralise each other. In this worksheet we want to look at two different things.
Firstly, we want to see if there are any **energy changes** during neutralisation.
Secondly, we must have a look at what are the **products** of a neutralisation reaction. We must have a look at what is formed when an acid and an alkali neutralise each other.

1. ARE THERE ANY ENERGY CHANGES WHEN NEUTRALISATION TAKES PLACE?

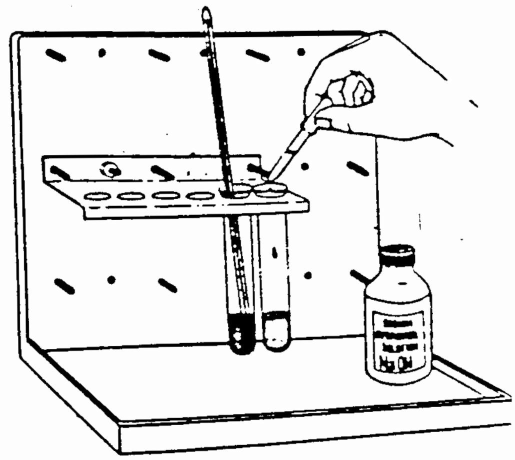
PROCEDURE

*Add about 10ml of dilute hydrochloric acid to each of 2 test tubes.

*Take the temperature, using a thermometer, of the dilute hydrochloric acid.

*Add to <u>one</u> test tube about 10ml of sodium hydroxide solution.

*After adding the sodium hydroxide take the temperature of the solution in the test tube.



*Fill in your measurements of temperature below:

Temperature of HCl	Temperature of HCl + NaOH	Change in temperature

QUESTION

Was there any temperature change during this reaction? ______________

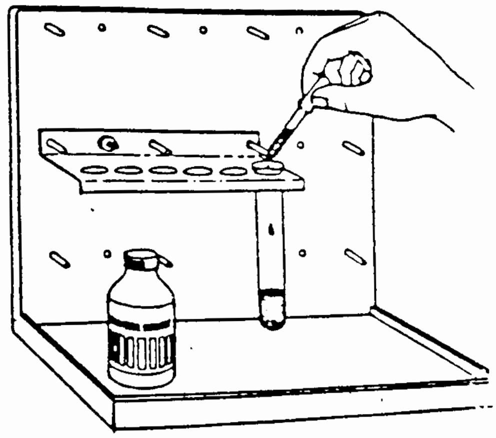
*Your teacher will discuss with you what you have just seen.

*There is space below to write a short note.

2. WHAT SUBSTANCES ARE PRODUCED WHEN AN ALKALI NEUTRALISES AN ACID?

To collect the **product** of a neutralisation reaction, you must make sure that a **complete neutralisation reaction** takes place. What do we mean by a complete reaction?
A complete neutralisation reaction is one in which just the right amount of alkali has been added to the acid. If we add just the right amount of alkali to the acid we will be left with a **neutral** solution. If the solution is neutral we know that a complete reaction has taken place.

PROCEDURE

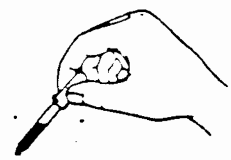


*Take the second test tube with it s 10ml of dilute hydrochloric acid.

*Add 3 drops of universal indicator solution to the test tube.

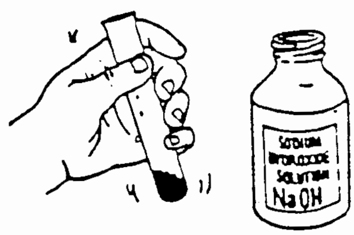
*Take a clean eyedropper. Squirt 3 droppersful of sodium hydroxide solution into the test tube.

*Shake the test tube gently to mix the two solutions.



*Continue adding sodium hydroxide drop by drop, shaking the test tube gently.

*When the solution turns **yellow,** now's the time to go slowly!



*Slowly add sodium hydroxide until the solution turns **green**.

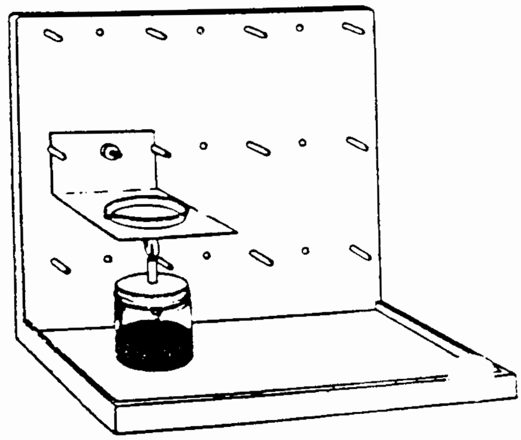
QUESTIONS

a) Is the solution now acidic, neutral or alkaline? _____

b) What is the pH of this green coloured solution? ______

You have reached with this solution what is called the **endpoint**. The alkali has successfully **neutralised** all of the acid. The solution is now **neutral.**

If you added **too much** sodium hydroxide the solution would have turned **blue**. We would say that you have '**gone past the endpoint**'. If you have gone past the endpoint the solution is now **alkaline** and of no use to us here!
If this happens, start again. Learn from your mistakes. Maybe you added sodium hydroxide too quickly, this time add the alkali slowly..



*From the test tube take about 1/3rd of the neutral solution and pour it into the evaporating basin.

*Place the evaporating basin on the heating stand.

*Carefully heat the evaporating basin until all the liquid has evaporated.

QUESTIONS

c) What do you see left behind in the basin?

____

____

d) Can you **identify** this substance? (**You may taste a** <u>little</u> bit)

____

You have **recovered** one product of this neutralisation reaction.

e) What do you think was the liquid which evaporated from the basin?

____

f) Can you think of a way of testing to see if your guess for the name of the liquid

is correct? ____________________________________

____

Try to put your answers together.

*What are the names of the products formed when sodium hydroxide neutralised hydrochloric acid?

____

Try to finish off the chemical equation for this reaction:

$$HCl \quad + \quad NaOH \quad \longrightarrow$$

We can represent neutralisation reactions by the following general reaction:

ACID	+	ALKALI	$\longrightarrow$

NOTES

EXERCISE
NEUTRALISATION USING OTHER ACIDS AND ALKALIS

You now know that **salts** are formed during **neutralisation** reactions. But how do we name these salts?
This exercise will show you how to name salts.

1. NAMING SALTS

*A salt takes its name from the acid and alkali that were used to make the salt.
*Salts have two parts to their names eg. **sodium chloride**

Let's look and see how this salt got its name.

*The first part of the name, **sodium**, comes from the **alkali** that was used. The alkali that was used was **sodium** hydroxide.
*The second part of the name, **chloride**, comes from the **acid** that was used. The acid that was used was **hydrochloric** acid.

hydrochloric acid + **sodium** hydroxide → **sodium chloride** + water

*Notice how the **metal** is always written first in the name of the salt. The metal always comes from the alkali.
*If the salt is made up of only **2 elements**, the name of the salt ends in **-ide**
eg. **NaCl** is called sodium chlor**ide**

*If the salt is made up of **3 or more elements**, the name of the salt ends in **-ate**
eg. **$CuSO_4$** is called copper sulph**ate**

*The names that come from the acids are as follows:

ACID	NAME OF SALT
hydrochloric	chloride
sulphuric	sulphate
nitric	nitrate
citric	citrate
acetic	acetate
tartaric	tartrate

2.NEUTRALISATION

ACIDS	ALKALIS
hydrochloric	calcium hydroxide
sulphuric	potassium hydroxide
nitric	sodium hydroxide
citric	
acetic	
tartaric	

Use the above acids and alkalis to complete the following equations. The first equation has been finished for you.

a) **hydrochloric acid + potassium hydroxide → potassium chloride + water**

b) sulphuric acid + ... → calcium sulphate + water

c) .... + potassium hydroxide → potassium acetate + water

d) citric acid + sodium hydroxide → .... + water

e) tartaric acid + ... → calcium tartrate + water

f) .... + ... → sodium nitrate + water

g) acetic acid + calcium hydroxide → .... + water

COMPREHENSION EXERCISE
RENNIE

*Look carefully at the pictures on the next page. The pictures are taken from a packet of Rennie tablets.
*On a clean page in your notes answer the following questions:

1a) What do you think is meant by the expression 'active ingredients'?
b) Write down the chemical formulae of these 'active ingredients'.
2) What are the names of the 'active ingredients' in Rennie tablets?
3) Simpiwe has taken an **overdose** of Rennie tablets! What did Simpiwe do?
4) 'If your digestive troubles ... are **recurrent**, it is wise to consult your doctor'. What does the word **recurrent** mean?
5) Most warnings and instructions are found on the slip of paper inside the packet. What warning is given on the packet itself?
6) Why do you think they tell you on the packet to 'Store in a dry place'?
7) Write down a **general equation** to represent the chemical reaction which takes place when a Rennie tablet reaches your tummy.

Digestif Rennie

Scheduling Status: Not scheduled.

Proprietary Name (and dosage form): Digestif Rennie Tablets.

Composition: Each tablet contains Calcium Carbonate 680 mg and Magnesium Carbonate Levis 80 mg.

Pharmacological Classification: 11.4.1 Acid Neutraliser.

Pharmacological Action: Antacid.

Indications: When an antacid is indicated, such as indigestion and heartburn.

Contra-indications: Hypermagnesaemia, hypercalcaemia or alkalosis.

Warnings: Do not continue usage for longer than 2 weeks except on the advice of a doctor. Do not give to children under five years of age except on the advice of a doctor.

Dosage and directions for use:

Adults: One or two tablets to be sucked half hourly as required. Not more than twelve tablets to be taken in 24 hours.

Children 5-8 years: Half to one tablet half hourly as required. Not more than four tablets to be taken in 24 hours.

8-12 years: One to two tablets half hourly as required. Not more than eight tablets to be taken in 24 hours.

Side effects and special precautions: Calcium Carbonate, like other calcium salts, may cause constipation. However the Magnesium Carbonate may affect the latter tendency since magnesium salts are known to be mildly laxative in action.

Digestif Rennie tablets should be used with caution when a state of debility, renal insufficiency or a predisposition to kidney stones exists.

Enough calcium may be absorbed to cause systemic and renal effects in certain cases. Some of the magnesium may be absorbed and it is usually excreted rapidly in the urine. If the renal function is impaired, hypermagnesaemia may result.

Calcium salts may enhance the cardiac effects of digitalis glycosides, and the absorption of tetracyclines as well as iron preparations may be reduced as the result of a medicine interaction.

Known symptoms of overdosage and particulars of its treatment: Hypercalcaemia and alkalosis which may occur with excessive doses of Calcium Carbonate respond to withdrawal of tablets. If renal function is impaired, hypermagnesaemia may result which is rapidly reversed with calcium salts given intravenously. *IN THE EVENT OF OVERDOSAGE, CONTACT A MEDICAL DOCTOR OR THE NEAREST HOSPITAL.*

Conditions of registration: None.

Identification: White to cream square shaped tablet with rounded corners, concave surfaces engraved "Digestif Rennie".

Presentation: Available in packs of 2's, 25's, 50's and 100's individually wrapped tablets. Available in peppermint and spearmint flavours.

Storage Instructions: Store in a cool (below 25°C), dry place, out of the reach of children.

Registration Number: E/11.4.1/533.

Name and Business Address of Applicant:

Nicholabs (Pty) Limited
15 Trotter Road
PINETOWN 3610
Reg. No. 05/09890/07

Date of publication: July 1990.

PLF 004

WORKSHEET 9

SAFETY WITH HOUSEHOLD CHEMICALS

During the past few weeks you have been learning about acids and alkalis. You have seen how many household chemicals contain strong acids and alkalis. These acids and alkalis are CORROSIVE, TOXIC and IRRITANT.
If you mix acids and alkalis the wrong way they can produce poisonous gases.
When used carelessly, they can cause blindness, sickness and death.
The proper use and proper storage of household chemicals is very very important.

1. WHAT ARE THE DANGERS?

On the next page there are some examples of labels taken from the containers of household chemicals. Read these labels carefully and look for any warnings printed on the labels.

*Next to the name of each household chemical write down any possible dangers of that chemical.

____

____

____

____

____

____

____

b) **Do you know of any accidents in the home that have been caused by household chemicals?**

*In your group spend 5 minutes discussing any accidents that you know of.

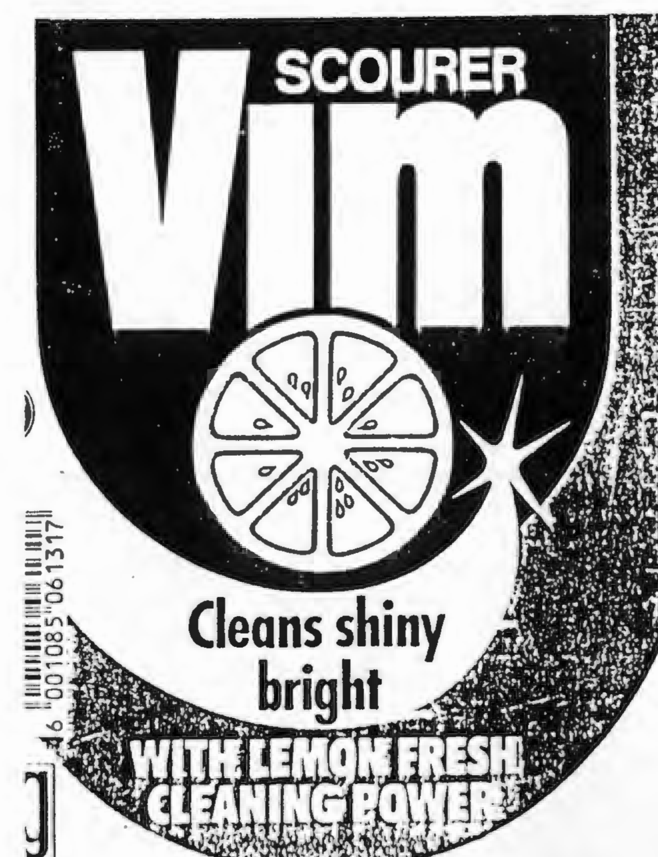
*Each group will then contribute to a general class discussion on the dangers of household chemicals.

*From this discussion we need to draw up together a list of **safety precautions to be followed in the home.**


Harpic
powder toilet cleaner
Used regularly, Harpic Powder Toilet Cleaner's unique power disinfectant action kills germs, removes ALL stains and deodorises in both the bowl and the trap behind – a place no other method reaches. Safe with septic tanks.
CAUTION: Harpic Powder is made specially for the toilet. Do not use for anything other than toilet bowls nor with any other chemical cleaners or liquid bleach. Keep container closed (audible "click") and out of reach of children.
Indien gereeld gebruik, kragreinig Harpic Poeier met sy unieke kragtige ontsmettingsaksie, dood kieme, verwyder ALLE vlekke en verfris in beide die bak en die afsluiter daaragter – daar waar geen ander metode bykom nie. Veilig in rottingstenks.
WAARSKUWING: Harpic Powder is spesiaal vir latrines gemaak. Moet vir geen ander doel of saam met enige ander chemiese reiniger of bleikmiddel gebruik nie. Hou houer dig toe (hoorbare "klik") en buite bereik van kinders.
1 Flush bowl
2 Flick open lid
3 Sprinkle Harpic Powder around sides and into water
4 Leave as long as possible
5 If badly stained sprinkle generously and leave overnight.
6 Brush well and flush.
7 Safe with septic tanks
750 g
GREEN
Reckitt
ACTIVE INGREDIENT


750 ml
IT SANITISES
Reckitt
JIK
Whitens, removes stains and kills germs
CONTROLLED STRENGTH
Hou buite bereik van kinders. Indien ingeneem, ontbied dadelik 'n geneesheer. Klere en vel spoel dadelik uit.
Keep out of reach of children. If swallowed call a physician immediately. Rinse skin and clothing immediately after contact.
GEKONTROLEERDE STERKTE


HANDY ANDY
Real LEMON Juice
Guaranteed to Powerclean even tough dirt without scratching
A LEVER PRODUCT
Baths, Stoves and Sinks: Use straight from the bottle on a damp cloth – rinse. Floors, Walls and Paintwork: Dilute 25 ml with 3 litres of warm water – no need to rinse.
Baddens, Stowe en Opwasbakke: Gebruik net so uit die bottel op 'n klam lap – spoel af. Vloere, Mure en Verfwerk: Verdun 25 ml met 3 liters warm water – afspoel onnodig.
Lever Brothers (Pty) Ltd
73 Maydon Road, Durban


SCOURER
Vim
Cleans shiny bright
WITH LEMON FRESH CLEANING POWER
6 001085 061317

*We must also think about **safety and first aid**.

*For **homework** your group must draw up a list of **first aid suggestions** to deal with accidents involving household chemicals. You will have to ask yourselves questions like this:

- What should be done if my baby sister swallows some bleach?
- If my mother splashes some toilet cleaner in her eyes, what should I tell her to do?

*To help you with ideas, read through the articles on the next page. These articles have been taken from local newspapers.

*Write down your suggestions below:

*From the newspaper articles make a list of what you think are the most important phone numbers to keep in mind.
*Write these phone numbers in the space below:

***Maybe you should take these phone numbers and keep a list of them at home!**
REMEMBER: SAFETY FIRST!!

Protect them from poison

A DREADFUL story was doing the rounds a few years ago.

The couple had two children: a boy of 18 months and a girl of three.

One morning the little boy, exploring his world, opened the kitchen cupboard, grabbed a bottle of cleaning fluid and swallowed the contents. His mother found him unconscious.

She picked him up and raced to her car — the hospital wasn't far away — forgetting her daughter. She reversed over the little girl in the driveway. Both children died.

The story may be apocryphal, or exaggerated, but it spells an awful warning.

The appalling tragedy should never have happened. It was preventable.

So were all the accidents that led to the 3 018 telephone calls received in 1989 by the Poisons Information Centre at the Red Cross Children's Hospital at Rondebosch.

BECAUSE the centre has amassed a wealth of information on poisons, the doctor on duty can give you vital advice when you phone to say you've had an accident and somebody has been poisoned.

The hospital's emergency room stands ready day and night. This room also houses the computer which stores the poisons data and the telephone that will bring your call straight through.

The telephone rings.

A frantic mother from Strandfontein: *"My little girl has drunk a bottle of bleach. She's ~~never opened any cupboards before~~..."*

A terrified grandmother from Edgemead: *"My grandson has taken my heart pills. I just put them down for a second while I answered the phone..."*

A frightened father from Knysna: *"I was painting, and I tipped a little turps into a jam tin..."*

A doctor from Durban: *"The poisons centre at Addington has just closed for the night. Will you check some toxic ingredients for me?"*

If it comes from the Cape Flats, it's likely that the caller will cry: "When I got home I found that the baby had drunk the paraffin!"

On the computer, the doctor calls up the poison, probably by trade name if it's a household product. He checks its composition and poisonous ingredients, the symptoms, antidotes, and treatment — which might not be simple. Only two percent of poisonous substances have a specific antidote; some products contain two or three poisons, needing different treatments; the nature of the poison might not even be known.

Whatever the case, you'll be told what to do. "Give her a drink of milk."

"Bring her into hospital immediately"

"He's eaten half a cigarette? Don't worry ..."

Of last year's 3 018 calls, 628 led to outpatient treatment and 243 to hospital admission. Poisons included detergents, painkillers, plants, fungi, polishes, cleaners, rat poison, shampoo, anti-depressants, mercury, paraffin, fertilisers and insecticides.

WRITING in *Pedmed*, the SA Paediatric Journal, Professor P M Leary emphasises that with adults, poisoning is usually deliberate. With small children it's almost always accidental.

"A baby of six months puts everything into its mouth. A 12 to 24-month-old will open every container within reach. A two-year-old will drink any bottled fluid and open unlocked drawers and cupboards, and a three-year-old will climb on a chair to reach high places."

Every year 400 containers of potentially toxic substances arrive in the average home.

"Only in its fifth year will a child reject ingestable substances which don't look or taste very nice," says Professor Leary.

So every case of poisoning below that age must be attributed to an adult's carelessness. Don't let it be yours.

IN First World countries, paraffin hardly figures in poisoning cases but it has a very high incidence in greater Cape Town, reflecting poor situations in areas where paraffin is used — and often sold in old beverage bottles.

Marion Glasstone of the Poisons Information Centre mentions some poisons that are less common than drugs, paraffin and cleaners: Mercury from thermometers ("Some children chew them!") and plants."Berries from syringa trees are toxic and can cause paralysis. Oleanders are poisonous too."

This centre is one of two in our area. The other is at Tygerbery Hospital.

Of the 10 centres in other parts of the country, some close at five, so late calls often come to the Red Cross from as far away as Natal and Namibia — concerning adults as well as children. Many adult cases are suicide attempts.

"Some people," says Marion Glasstone, "think we have a whole staff simply dealing with poisons. But we don't. Doctors have other duties too. A doctor may be alone one night, trying to save the life of a badly injured child, when a poison call comes through — what is he to do?

"People must try to be patient. They will be helped as quickly as possible.

"We would love to have a special poisons staff but we don't have the money. With so many current demands, other things are considered more urgent and important, I suppose."

IF you are a parent with a young family at home, or somebody who cares for other people's children, there is *NOTHING* you could be doing at this moment that's more important than locking up the medicines, cleaners and other hazards that threaten children.

Do it NOW.

POISONS INFORMATION CENTRE

Red Cross Hospital: ☎ 689 5227

What you can do:

- When you phone, be specific about the poison, the child's age, and the time the poisoning occurred.
- Try to be patient.
- Start a lobby to persuade Province, industries or clubs to finance or sponsor a unit dealing only with poisons.
- Best of all: Prevent poisoning.

Poisoning: Do's and dont's

23 MAY 1990

Staff Reporter

AT least 50 poisonings a week are referred to Tygerberg Hospital's Poison and Drug Therapy Consultation Centre.

Although victims are not usually treated there, the centre provides valuable information to hospitals, private practitioners and the public.

Based at the University of Stellenbosch's Department of Pharmocology and Toxicology, the centre specialises in plant and animal toxicology.

It is the only 24-hour laboratory service in the region. It is also the only after-hours laboratory service in the Peninsula. NORTHERN ED.

According to staffer Dr Gerbus Müller, about 45 percent of the consultations are drug-related. The other 55 percent deal with non-drugs such as industrial toxins and household products like bleaches and detergents.

Non-drug poisoning usually occurs accidentally in children, whereas adults, committing para-suicide (an attempt to gain attention without actually resulting in death), usually swallow drugs.

Paracetamol poisoning is the most common in this case. This drug is closely followed by Benzodiazepines and other anti-depressants. According to Dr Müller this is because of the accessibility of these drugs.

Poisoning of children by household products could be avoided if these were kept out of their reach.

He also cautions parents not to transfer these poisons into unlabelled bottles as this usually hampers the elimination process when the victim is taken for medical attention. The poison should also be taken along in such cases.

The following rules should be followed if poisoning is suspected:

- Phone your nearest poison centre (there is also one at Red Cross Hospital);
- Keep the container in which the poison came, (or the plant or animal which caused poisoning);
- Be able to describe the poison to a medic;
- Try to give the victim water or milk, but avoid this measure if the person is unconscious;
- Don't try to induce vomiting;
- Don't forget that you can also call your doctor.

The Consultation Centre's all-hour telephone number is ☎ 931 6129.

Emergency numbers

Ambulance 511 5151
Flying Squad 10111
Poisoning — children 689 5227
Tygerberg Hospital 938-4911
Tygerberg Hospital poison unit 931 6129
Eskom Power Failure 946 1590
Fire and rescue:
Bellville 948 1777/8
Brackenfell 901 5544
Durbanville 96 3064
Kraaifontein 902 1151
Kuils River 903 3008
Milnerton 52 2222 (fire only)
After hours emergencies 52 3131
Parow emergencies 927 000, fires 92 7050

These numbers are for emergencies only. Consult your telephone directory for inquiries numbers.

GLOSSARY

In this unit of work you find some words which have been highlighted (they appear in bold print). The meanings of these words are explained in this glossary. When you are reading through this unit of work there may be other words whose meanings are unclear. This glossary will explain what some of these words mean as well.

The glossary does not give all the meanings of a word; it gives only the meaning which we use here. If you want to find out about the other meanings of a word you will have to consult a dictionary.
The following abbreviations (short forms) are used here:
(a.) = adjective (n.) = noun (pl.) = plural (v.) = verb

acidification (n.) turning acidic, becoming acidic

activities (n.) different things to do

appear (v.) to seem like

classify (v.) to put things into groups

compare (v.) to look for sameness or difference between two things

contamination (n.) when something has been polluted or poisoned

corrosive (a.) to rust, to eat away, as acid eats into metal

demonstrate (v.) show something happening

deposit (n.) some substance left behind after a reaction

dilute (a.) mix with water to make less concentrated

dissolving (v.) to melt in a liquid

effect (n.) the effect of something is the change it can cause

effective (a.) having an effect, working satisfactorily

effervesce (v.) to give off bubbles of a gas

emphasis (n.) the importance placed on something

enclosed (v.) surrounded by

environment (n.) the world around us

environmentalist (n.)a person who is concerned with protecting the environment

evaporate (v.) to turn a liquid into a gas

extinguish (v.) to put out

fizz (v.) making bubbles, usually bubbles of a gas

flammable (n.) burns easily

generate (v.) to make

identify (v.) to find out what something is

inadvertent (a.) not on purpose, by mistake

inhale (v.) to breath in

investigate (v.) to study, look into something carefully

irritant (n.) a substance which is dangerous to the skin and eyes

liberate (v.) set free

observe (v.) to look at, listen to, to feel or smell something

pollutant (n.) a substance which causes pollution

pollution (n.) the poisoning and destruction of the world around us

procedure (n.) the way to do something

process (n.) the different steps in doing something

products (n.) the substances that are produced (made) during a reaction

properties (n.) a characteristic of a substance

react (v.) to undergo a chemical change, to make new substances

reactants (n.) the substances you begin a reaction with

reaction (n.) when substances react, a chemical change happens

soluble (a.) melts in a liquid

solution (n.) a mixture of substances. Usually a solid dissolved in water

substance (n.) any thing like a solid, liquid or gas

symbol (n.) a sign which stands for the real thing

toxic (a.) poisonous; caused by poison

***Are there other words whose meanings you would like to write down? Use the spaces below:**

APPENDIX 2

Standard 8A and 8B Pretest results

Students' responses to certain key questions are summarised below:

STANDARD 5

Question 1.	8A	8B	Total
1.1 Taught	26	12	38
1.2 Not taught	7	6	13
1.3 Can't recall	1	13	14

Question 2.	8A	8B	Total
2.1 Shown some experiments	17	11	28
2.2 Not shown experiments	15	9	24
2.3 Can't recall	2	11	13

Question 4. Taste of acid?	8A	8B	Total
4.1 Yes	24	18	42
4.2 No	10	13	23

Question 5. Meaning of soluble	8A	8B	Total
5.1 Yes	26	23	49
5.2 No	8	8	16

Question 7. Feel of base?	8A	8B	Total
7.1 Yes	15	4	19
7.2 No	19	27	46

Question 10. What is an indicator?	8A	8B	Total
10.1 Yes	13	14	27
10.2 No	21	17	38

Question 13. Meaning of neutral	8A	8B	Total
13.1 Yes	9	5	14
13.2 No	25	26	51

STANDARD 7

Question 14. Taught in Std 7?	8A	8B	Total
14.1 All of chapter	4	3	7
14.2 Some of chapter	16	15	31
14.3 None of chapter	14	13	27

Question 17. Completed word equation	8A	8B	Total
17.1 Yes	0	0	0
17.2 No	34	31	65

Question 18. Completed chemical equation	8A	8B	Total
18.1 Yes	3	0	3
18.2 No	31	31	62

Question 19. Formula of nitric acid	8A	8B	Total
19.1 Yes	2	0	2
19.2 No	32	31	63

Question 20. Concept of neutralisation	8A	8B	Total
20.1 Yes	2	3	5
20.1 No	32	28	60

Question 22. Meaning of dilution	8A	8B	Total
22.1 Yes	7	11	18
22.2 No	27	20	47

APPENDIX 3

Summary of Questionnaire 1

1. Age Distribution

Age in Years	14	15	16	17	18	19	20	24
Students in 8A		4	8	16	11	3		1
Students in 8B	1	1	9	7	11	5	3	

Average age: 8A 17.2 years
8B 17.4 years

2. "Cape Town is my home" 8A 31 students
8B 26 students

"Cape Town is not my home" 8A 12 students
8B 11 students

3. Place of Birth

	Cape Town	Urban Cape	Rural Cape	Transkei	Elsewhere
8A students	26	2	3	11	1
8B students	20	4	2	8	3

4. Place of Abode

	Khayelitsha	Langa/ Guguletu/ Nyanga	Elsewhere
8A students	32	9	2
8B students	20	16	1

*If they are living in townships other than Khayelitsha, they live at least 15km from the school.

5. Repeating Standard 8 in 1991

8A 11 students
8B 7 students

6. Schooling Background

	Luhlaza Std 6 &7	Other school Std 6 & 7	Different schools Std 6 & 7	At Luhlaza from Std 7
8A students	21	7	2	13
8B students	10	16	8	3

*Out of 80 students who returned the questionnaire, 33 were attending Luhlaza for the first time in Standard 8.

APPENDIX 4

Standard 8A and 8B Textbook Questionnaire

A total of 83 students (44 in 8A and 39 in 8B) filled in and returned the questionnaire. As each student did not necessarily answer each and every single question, the totals for both classes sometimes add up to less than 83. Space was provided on the questionnaire to allow students to reply to Question 5, which asked "What is it about the textbook which you think makes it difficult to understand?". Rather than recording them here, some of the students' responses to this particular question are included in chapter 8. The students' responses to the other questions are summarised below:

Question 1.

"Do you have a science textbook?"

	8A	8B	Total
Yes	38	33	71
No	6	6	12

Question 2.

"Have you tried reading about atoms in the textbook?" (We were busy with this section of work prior to the start of the trialing exercises.)

	8A	8B	Total
Yes	29	27	56
No	15	12	27

Question 3.

"How often do you read a science textbook?"

	8A	8B	Total
*Everyday.	1	1	2
*Once or twice a week.	11	14	25
*Only over weekends.	7	2	9
*Only before a test or before an exam.	24	22	46

Question 4.

"How much of what you read in the textbook do you understand?"

	8A	8B	Total
*All of what I read.	0	0	0
*Most of what I read.	7	8	15
*About half of what I read.	21	16	37
*Not much of what I read.	16	15	31
*Nothing of what I read.	0	0	0

Question 6.

"How do you find the English which is used in the textbook?"
The English is...

	8A	8B	Total
*always too difficult.	0	1	1
*mostly too difficult.	6	2	8
*sometimes too difficult.	32	26	58
*almost never too difficult.	5	6	11
*never too difficult.	1	1	2

Question 7.

"After reading the textbook, how do you feel about the textbook? Choose the statement you agree with most."

	8A	8B	Total
*I feel happy about the textbook, I understand clearly the English being used in the textbook.	0	1	1
*Most of the time I am satisfied that I understand enough of the English being used in the textbook.	7	9	16
*Sometimes I understand the English, but I often stay confused about the work in the textbook.	33	23	56
*The English used in the textbook leaves me confused and frustrated about the work.	3	1	4
*I really don't understand what the textbook is trying to say, I don't like the textbook at all.	1	1	2

Question 8.

"Consider the following statements/suggestions about the textbook."

	8A	8B	Total
*The sentences are often too long and complicated.			
Yes	20	17	37
No	9	5	14
I don't really know	8	5	13
*There are too many big words used in the textbook.			
Yes	21	19	40
No	14	9	23
I don't really know	4	2	6
*New words should be explained more clearly.			
Yes	40	28	68
No	1	1	2
I don't really know	0	3	3
*There should be more pictures and drawings explaining the work.			
Yes	35	21	56
No	3	4	7
I don't really know	4	3	7
*The textbook must be written in Xhosa, so that I can understand it clearly.			
Yes	3	6	9
No	34	17	51
I don't really know	2	5	7

Question 9.

"How do you feel about the drawings and diagrams in the textbook?"

	8A	8B	Total
*They help me to understand the work more clearly.	17	18	35
*They sometimes help me to understand the work.	18	11	29
*I often find them confusing, but I try to understand them.	9	5	14
*I avoid looking at them because they just don't make sense at all.	0	1	1

Question 10.

"If you are reading your textbook and you come across a word that you don't understand, what do you do?"

	8A	8B	Total
*Ignore the word and carry on reading.			
Always	3	5	8
Sometimes	23	15	38
Never	7	3	10
*Ask a classmate (or friend) to explain it.			
Always	4	2	6
Sometimes	33	12	45
Never	2	7	9
*Try to look up the new word in a dictionary			
Always	6	8	14
Sometimes	33	12	45
Never	4	6	10

Question 11.

"Do you own a dictionary?"

	8A	8B	Total
Yes	22	17	39
No	20	17	37

Question 12.

"How do you really feel about science this year?"

	8A	8B	Total
*I find it an interesting and enjoyable subject.	16	14	30
*I find some sections of work interesting, but not everything interests me.	26	20	46
*I occasionally find a section of work interesting, but mostly the work bores me.	1	2	3
*I have discovered that I don't like science at all	1	0	1

Question 13.

The students in both classes were doing 6 subjects in Standard 8: Xhosa; Afrikaans; English; Biology; Science and Mathematics. Here they were asked to rank these subjects in order from "Most enjoyable subject" to "Least enjoyable subject". Science was placed by the students as follows:

	8A	8B	Total
1. Most enjoyable subject	4	2	6
2.	12	4	16
3.	14	6	20
4.	4	10	14
5.	9	9	18
6. Least enjoyable subject	1	4	5

APPENDIX 5

The Group Investigation

ACIDS and ALKALIS
Standard 8 Physical Science

As you can see in the handout there are a number of homework and comprehension exercises to keep you busy. Besides this work, each group will have to choose a topic and then undertake a project on that topic. You are given a reasonable choice of topics to choose from, hopefully one of them will be of interest to you and the rest of your group.

Don't worry! It is too early now to commit yourself to a given topic. Most groups will probably only feel ready to choose their topic after 2-3 weeks of working through the handout.

The most important thing to realise is that it will be a group investigation. Each member of the group will be expect to participate in the preparation of a report. This report in which you describe your investigation will be presented to the class in a 'report back' session. The **due date** for completion of the project is the last Thursday of term - the **19th September.**

Depending on the topic you choose for your investigation you might be expected to make a wall chart, prepare a written report, undertake a pratical demonstration etc. Maybe you will end up preparing a combination of these things.

You can of course expect a lot of support from your teacher. Each topic will have some kind of information sheet available with it, you will get guidance and assistance from this information sheet. You might even be able to think up your own topic! You might wish to modify (change) one of the topics given below. You might come up with an idea for something entirely different. Great! As long as your topic has something to do with 'acids and alkalis' you are encouraged to do what you want.

Please note, you will be assessed on your final presentation to the class. This project is worth the same number of marks as the test which follows completion of this work.

Here is a list (not complete - more topics will probably be added)

1. Making your own indicator
2. Acid Rain - preparing a wall chart for the lab.
3. Acid Rain - preparing information for Geography students.
4. Acid Rain - a problem in Cape Town?
5. Make one up yourself!
6. The pH of 'water in the home'.
7. The pH of soil samples around the townships.
8. The pH of 'water in and around Khayelitsha'
9. Warning labels on household chemicals - how safe are they?
10. Poisoning of children by household chemicals.
11. Making cakes rise...
12. Making money out of sherbet.
13. Fizzy drinks
14. Fire Extinguishers
15. What is the best indigestion tablet?
16. Reaction of acids with metal oxides.
17. Toothpaste.

Information Sheet (2)

Acid Rain – preparing a wall chart for the laboratory

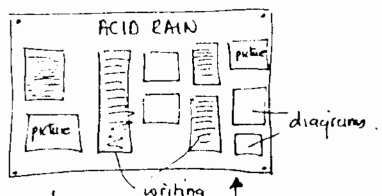
Pages 18 - 21 of the handout introduces to the topic of 'acid Rain'. The comprehension exercise attempts to show you that 'acid rain' is a serious problem even here in South Africa.

As you can imagine the notes only briefly explain about this fascinating topic. Would you like to learn more about it? Well then, this project is for you!

What will be expected to do is to prepare a large wall chart for the laboratory which gives students the opportunity to learn more about acid rain.

What must you start off with doing?

1. Go to the library and look for as much information as possible about acid rain. Also ask your teacher, maybe he can give you some more newspaper articles to read!
2. Collect together this information and then decide how much you need to present on a chart.
3. Ask your teacher to give you a large blank chart, and if you need any other stationary (which you don't have yourself) ask for that as well.
4. HINT: You could ask to use the 'white board' at the back of the class for planning your layout.
5. Each member of the group must contribute, maybe each member of the group could write a seperate article for the chart.



your chart could look something like this
USE YOUR IMAGINATION!

THIS TOPIC IS FOR A GROUP WHICH ENJOYS BEING CREATIVE!

NEED ANY HELP? → SET UP A PLANNING MEETING WITH YOUR TEACHER.

Information Sheet (7)

The pH of soil samples around the townships

You might be surprised to hear that you can have acid, alkaline and neutral **soils**. In standard 5 you might have been taught something about different types of soils. (Read the attached pages from a Std 5 textbook as background reading).

What about the soils around where you live? What you are expected to do in this investigation is gather different soil samples and measure their pH.

- So, is the soil in Guguletu acid, alkaline or neutral?
- What about in Khayelitsha; we can all see that the soil is very sandy! Is sandy soil acid, alkaline or neutral?
- You will have to answer these questions if you choose to do this investigation.

- You will have to set up a practical investigation in which you test soil samples from as many different places as possible around the Cape Peninsula.

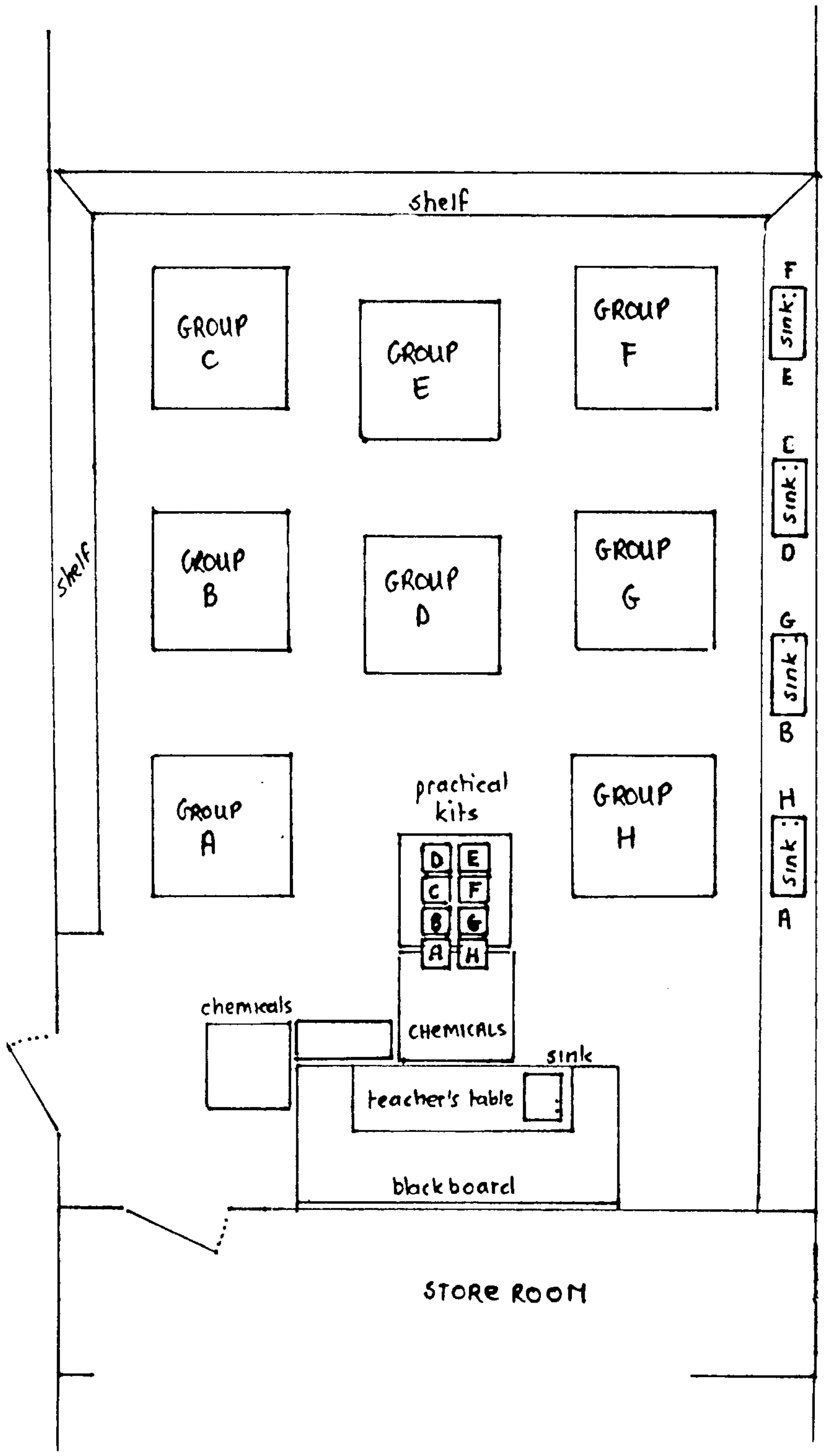
What will you have to decide to do?

- How are you going to collect the soil samples?
- How are you going to find out whether each soil sample is acid, alkaline or neutral?
- How are you going to record your results?
- How are you going to report your results to the class?

If you are keen to try this investigation, set up a meeting with your ~~teacher~~. You may need some help in getting started!

APPENDIX 6

Layout of Standard 8 Physical Science Laboratory



APPENDIX 7

Example of Daily Progress Logsheet

GROUP F

PROGRESS LOGSHEET 8A

What did you work on today?

MONDAY 12/8	TUESDAY 13/8	WEDNESDAY 14/8	THURSDAY 15/8	FRIDAY 16/8
·Introduction ·Laboratory Safety ·Greeting the kits	Finished red indicator' pg2	Finished [illegible] Fished 9 Pg 13	Finished ~~on~~ 2 worksheet Indicator pgs 10, 11 Alkali	FINISHED THE STRENGTH OF ALKALIS AND ACIDS Pg 14
MONDAY 19/8	TUESDAY 20/8	WEDNESDAY 21/8	THURSDAY 22/8	FRIDAY 23/8
FINISHED WORKSHEET INDICATOR [illegible] SOLUTION	FINISHED WORKSHEET ON Pg 16, 17 THE PH [illegible]	FINISHED read pg 18 and 19 Acid rain and pollution Absent Montlhurelo S. and Wendie Jetsie	NO SCHOOL	NO SCHOOL
MONDAY 26/8	TUESDAY 27/8	WEDNESDAY 28/8	THURSDAY 29/8	FRIDAY 30/8
Finished worksheet 4 Pg 22 The reaction of metals with an acid absent: Peggy Finule	FINISHED P. 23 & 24 ~~FINISHED Pg 2~~ THE REACTIVITIES SERIES OF METALS	FINISHED WORKSHEET 6 THE REACTION OF [illegible] WITH AN ACID [illegible] PEGGY [illegible]	Worksheet 5 pg 21 Strong Acid and Alkalis	We had [illegible] worksheet 4, 5, 6
MONDAY 2/9	TUESDAY 3/9	WEDNESDAY 4/9	THURSDAY 5/9	FRIDAY 6/9
FINISH WORKSHEET 7 6 HOW TO MAKE A [illegible] Pg [illegible]	Finish worksheet How to make a Sherbet P. 36	FINISHED WORK SHEET 7 Pg 38 & 39 ABSENT: PEGGY AND THEMBELA	Finished WORKSHEET 8 NEUTRALISATION PAGE Pg 42 & Pg 43 & Pg 44	Finished pgs 45, 46 Neutralisation Part 2

APPENDIX 8

The Practical Kit

KIT 1 CHECKLIST

Lemon Juice	IRON Fe	COPPER Cu	Tartaric Acid	Vinegar
Hydrochloric Acid HCl	Sodium Hydroxide NaOH	ZINC Zn	Citric Acid	Milk of Magnesia
Sulphuric Acid H_2SO_4	Calcium Hydroxide $Ca(OH)_2$	MAGNESIUM CARBONATE $MgCO_3$	Universal Indicator	Handy Andy
Nitric Acid HNO_3	Potassium Hydroxide KOH	CALCIUM CARBONATE $CaCO_3$	Bromothymol Blue	Epsom Salts

KIT 2 CHECKLIST