

LEARNING SCIENCE AT THE INTERFACE BETWEEN ZULU AND ENGLISH

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Abstract

Learning science at the interface between Zulu and English

This thesis describes research done between the period 1986 and 1990 with Zulu-speaking teachers and pupils. The aim of the research was not to see how Zulu could be used for the teaching of science. Rather the emphasis was on seeing what difficulties learners, who are familiar with Zulu but only marginally so with English, have in using the constructions and modes of explanation used in English. It is reasonable to suppose that the greater the disparity between the usage of Zulu and the usage of English, the more difficulties learners will encounter.

Zulu-speaking teachers' conceptions in chemistry were probed by audiotaped interviews; this work highlighted the need to explore language issues in more detail.

Zulu-speaking teachers' modes of explanation of basic chemistry in both English and in Zulu were examined by transcription and direct translation of videotapes of several lesson episodes. The study of the transcripts revealed a disparity between the modes of explanation in Zulu and those of English usage. When teaching in Zulu about substances, the teachers used explanations which are functional rather than structural. The Zulu explanations about processes (such as diffusion and osmosis) were interpretive and descriptive (what and how?) rather than in terms of underlying scientific principles (why?). Problems with logical connectives and with the locative construction were also noted.

Free discussions between pairs of Zulu-speaking pupils about practical tasks in chemistry were also recorded on audiotapes. Here the conversations were in both Zulu and English. Two aspects were particularly striking — the amount of time spent on the meanings of words and the growing awareness by some pupils about the value of dialogue.

An English/ Zulu dictionary of problematic scientific terms was also compiled.

The implementation of the findings of this research proceeded in three main ways:

1. Through the development of a science curriculum network (Scisa — Science Curriculum Initiative in South Africa) where new curriculum models for science are being developed.
2. Through the development of the Primary Education Forum which is a grouping of staff who work in science and English projects in the Natal region.
3. Through direct work with authors of textbooks, especially at the lower primary level.

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Chapter 1 Contextual description

Context of black education in South Africa

This research was conducted in black urban schools and a black college of education in Pietermaritzburg, Natal during the period 1986-1990. It will therefore be useful to describe the context of education for black children and teachers in South Africa in the second half of the 1980s. This will be only a brief overview. Writers such as Kallaway (1984), Christie (1985), Nasson & Samuel (1990) give full and detailed accounts of how South African education has evolved to its present pattern and what some of the possibilities for the future are.

There were 5 1/2 million black pupils in school in South Africa in 1983 and over half their teachers had only a junior certificate in academic qualifications. In the 1980s, there were 18 departments of education in South Africa and its neighbouring independent states. All these departments of education were very formalised and bureaucratic and followed very similar, highly content-specific syllabuses.

However, there are enormous differences between the situations in the schools controlled by these departments in terms of funding, teacher support, the security and stability of the local environment, and opportunities for further education and employment. This ensured that there was little resemblance between the curriculum in action in a classroom in a white school and the curriculum in action in a classroom in a black school.

Two quotes from teachers in Soweto schools amply illustrate this point:

It is all very well to talk about African schools having the same syllabus as white schools. But no account is taken of the tremendous difficulties with the language switch from vernacular to English. In deep Soweto — Meadowlands and Phiri — some children in standard three can hardly speak a word of English. And it's supposed to become the medium of instruction! There they are, in biology, learning about carnivores, when they don't even know the words for 'cup' and 'saucer'.

The reading books are all about white middle class children in England. This bears no relation to the culture of black children in Soweto — never mind the rural areas. It has nothing to do with the world they experience outside of school. These kinds of books do nothing to instil a love of reading in black children.

(from Christie 1985 p. 148)

Besides the confusing and alienating nature of much of the school curriculum, the physical facilities in many schools are very poor. Class sizes in many primary and secondary schools are very large — often up to 80 or 90 pupils in a normal sized classroom. The pupil/teacher ratio for black schools in the 1980s was around 1:45; in white schools it was less than 1:20 (SAIRR). While classrooms are crowded, the vast majority of black pupils have very little schooling and drop-out rates are very high. Over half the black children at school are in the first four years of school; throughout the 1980s only 1-2% of black children who were in school were at standard 10 level.

With relatively few teachers being adequately trained, especially for primary and junior secondary science teaching, there is little use of innovative teaching methods. It is common to see what little science equipment a school has, either still in the boxes in which it was delivered to the school, or broken and discarded, even

when only minor repairs are needed. Lessons are almost entirely teacher talk. In upper primary and junior secondary classes a mix of vernacular and English is used by teachers in their explanations; even in upper secondary this is common because of the limited language skills of the pupils. There is relatively little discussion of science between pupils, or between pupils and teachers. In this situation, the only way in which teachers can check on pupils' understanding is by formal written tests, which reward, to a large extent, pupils' ability at rote learning.

While most of the classrooms I visited had a collection of textbooks, they were often older books, written in a formal and inaccessible style which would be difficult even for pupils whose first language was English. In some schools, newer text books are not used because of security issues; I have seen many sets of books locked in the headmaster's office.

- ✓ Written work consists largely of copying down definitions or worked examples. There is little writing about personal ideas or experience and hence no opportunity for science teachers to gauge the written English skills of their pupils and their level of conceptual understanding.

The disruptions to schooling for black pupils due to political unrest are well known. During the 1980s, they increased to a level where, in many schools, pupils and teachers were understandably more concerned about personal security and the devastation of their family lives than they were about learning science.

Under these circumstances, it is not surprising that rote learning is almost the only strategy pupils can adopt when preparing for tests and examinations. Pupils are trapped in a situation where they are passive learners — what Freire (1985) calls a 'banking system' of education. In this model knowledge becomes a fixed commodity which is 'deposited' by the teacher into the 'empty vault' of the pupil.

This rather depressing picture is not meant to convey a hopeless situation. This outline is needed to clearly point out that investigations into the learning of science concepts in KwaZulu schools are within a context which is educationally disadvantaged, and socially and politically unstable. Much of this thesis is about the development of strategies which can be used in this situation to bring about meaningful change. What is essential to understand is that educational change involves working on several fronts at the same time. The work described in this thesis is not about the documentation of educational difficulties as an end in itself in order to explain the current problematic situation in black schools. Rather, the thesis is an attempt to provide a framework of understanding so that desired educational changes have a greater chance of being successfully implemented.

In chapter 3 a model of the interplay between research, curriculum development and day to day teacher-pupil interactions in the science classroom is described. This model has evolved from a joint consideration of critical sociological theory and constructivist learning theory. This thesis examines research into linguistic differences between Zulu and English which appear to impinge on pupil learning, and research into strategies for teacher development which enable issues of language and learning to be addressed by teachers, and in such a way that they can become involved in meaningful curriculum development work.

Chapter 2 Overview of research plan

Exploratory nature of the research

This research was carried out throughout the period 1986-1990.

The nature of the problem being investigated is a complex, multidisciplinary one and a simplistic research plan is unlikely to yield useful results. This research has been consciously conducted as an exploratory piece of research and so the research plan unfolded over time. This is an appropriate strategy for work of this kind. There were conscious shifts in emphasis in the work through a number of cycles of interaction, reflection and action.

The nature of the research is exploratory as this really is new ground in science education. Issues of reliability and validity are of major importance but there are no easy formulas to apply in this situation. The value of each aspect of the research was assessed throughout the research process and the consistency between the data obtained from the various research tasks was constantly examined. Issues in research methodology are explored in chapter 3.

The theoretical framework about learning used in this research is described in chapter 4. Briefly, it is that learning occurs as an internal construction of meaning. Learning is highly contextual and each individual's understanding of any concept is unique. Understanding is not static but is constantly refined and developed with further experience. The task of the science teacher is to negotiate meanings with pupils so that a consensus can be reached about useful, workable models for scientific phenomena. Negotiation requires discussion and articulation, and so the meanings attached to words are crucial.

Further, when one is considering the second language learner, it must be recognized that the structure of a language evolves together with the culture of the people who speak it, and an

analysis of how people explain concepts in a language other than English may well bring greater understanding about how learners operate in a linguistic situation which is at the interface between two languages. Of course, in the urban environment of violence and rapid change in which this research was done, there is no clear cut Zulu culture, nor any way in which a clear relationship between language and culture can be established.

The differences between individual Zulu and English words are obviously important but, in addition, we need to consider much more carefully how the linguistic structures of Zulu influence the nature of concept formation. It is not only the meanings of individual words which are important but also the style in which scientific explanations is given. The ability to follow the separate points in an argument and the way in which these points are linked is also crucial to understanding scientific concepts. Forming basic concepts in chemistry requires much more imaginative, personal, mental picture-making than is often acknowledged. Articulation and discussion are involved in this process and the centrality of language must be recognized.

It is clear that Zulu learners have great difficulty in learning science. Some of this is no doubt due to the chaotic nature of schools at present, overcrowded classes, the poor qualification level of teachers and the scarcity of equipment and text books. However, there are issues which are more closely related to language than to these other problems.

Hypotheses

1. The central hypothesis for this research is that Zulu learners have difficulty forming concepts in science partly because of the process of translating from their Zulu cultural and linguistic experience to verbal formulation of concepts in English.

2. An hypothesis about strategies for overcoming this difficulty is that learners can bridge the differences between Zulu and English if:
 - a. they consciously explore what these differences are,
 - b. articulation and discussion are seen as central to the learning process.
 - c. teachers are involved actively in the curriculum development process.

The need for on-going professional development of teachers is well recognized in all countries. It is clear that this need is more urgent and more crucial in developing countries where the standard of initial teacher qualifications is so low.

It should be noted that the focus of this study is not examining whether English should be the medium of instruction in schools in post-apartheid South Africa. It is almost certain that English will play an important part in whatever educational system evolves. Chick (1990) discusses both macro issues which have led to the current low standard of English in black schools and looks at various language policy options for the future. He argues that *if English is to play the important role envisaged for it in a post-apartheid society and facilitate national unity, educational advancement and economic liberation, among other things, teacher education will need to include courses that will equip all teachers ... with explicit knowledge about the English language.* (p. 21/22)

This study goes further than Chick by suggesting that knowledge about both mother tongue and English is needed if learners are construct bridges which enable them to learn in formal schools in ways which utilise their previous experiences.

Research phases

Table 2.1 Research phases

Year	Nature of work	Reference in thesis
1986	Interviews with student teachers to elicit their alternative conceptions about basic chemistry. This work raised questions that indicated the centrality of language in learning. Data collected by audiotape and research diary.	Chapter 5
1987	Study leave in UK.	
1988	Teachers' explanations in Zulu and English. Data collected by videotape and research diary.	Chapter 6 Appendices 1-6
1989	Pupils' discourse about basic concepts in chemistry. Data collected by audiotape and research diary.	Chapter 7 Appendices 7, 8 & 9
1989-1990	Translation work on an English/ Zulu dictionary of scientific terms and on logical connectives.	Chapter 8 Appendices 10 & 11
1989-	Establishment of the Science Curriculum Initiative in South Africa (Scisa) network.	Chapter 9 Appendix 12
1990	Work of the Primary Education Forum. Work in publishing with Centaur Publications.	Chapter 10

Expected outcomes

Expected outcomes of this multidisciplinary, exploratory research were to:

1. make a contribution to the study of the relationship between language and learning in a bilingual situation such as we find in KwaZulu ✓
2. gain an understanding of learners' difficulties when operating at the interface between Zulu and English
3. develop guidelines for material production
4. provide indicators for teacher development programmes. ✓

Chapter 3 Research methodology

Introduction

It is essential to establish a theoretical base about knowledge, research and learning. The broad framework to be adopted in this work is that of critical social theory and its research application in action research. In order to be able to link the linguistic research in chapters 5-8 with the research on the development of teacher networks described in chapters 9 and 10, one needs a perspective where the ideas of all participants in the research process have value. Having focussed this research on language issues at the interface between Zulu and English, and identified some differences which appear to have implications for learning and curriculum development, it is imperative within a critical framework to engage in action so that knowledge which has been acquired can be of benefit to the people involved. This ethical imperative links the linguistic work with the teacher development work.

Critical theory and action research

Various paradigms exist in the realm of social research. What are often called *traditional*, *interpretive* and *critical* approaches will be briefly explored. The *traditional* approach (often called the empirical-analytical mode, e.g. Popkewitz 1984) is the classic reductionist mode of research. Popkewitz describes the traditional, empirical-analytic approach to research thus: 'Its sole concern is with technical, cognitive, rational procedures for testing, validating or rejecting hypotheses about observable social events' (p. 40). Within this approach it is believed that problems can be defined a priori, that the complexity of social situations can be reduced to a string of variables which are clearly operationalised, and that events can be explained in terms of cause and effect. The need for objectivity is used as the reason for ignoring varying interpretations of questions of value or descriptions of events. There is one 'right' interpretation. Such a

mode of research seems to offer techniques by which social phenomena can be controlled and managed (Deakin University 1984 p. 26). The whole basis of determining causal relations rests on the assumption that variables can be controlled or held constant. However, one cannot control, for example, teacher motivation, community cohesion, or attitudes to science.

This is the trap of false objectivity, which is surprising when, as discussed in chapter 4, page 36, even theories about the nature of science have demolished the myth of objectivity — the observer is an inextricable part of the event being observed. One finds that even now there is a mistrust of any research which is not objective. For example, Opie (1990 p. 3) questions the validity of ‘highly subjective action research models in which the researcher is a participant, and hence a variable within the evaluation process.’ People and the complexity of social interactions cannot be reduced to clearly defined variables. The attempt to do so reduces most traditional social research to arrant nonsense.

This was realised during the 1960s and early 1970s and social research began to focus on exploring the dynamics of interactions with the emphasis on the world as a ‘socially constructed reality’ (Berger & Luckman 1966). The perceptions of all the participants in a situation are needed in order to explore the various interpretations which are possible. The methodology of what is called the *interpretive* approach borrowed extensively from anthropology. In particular, case studies were conducted so the richness of situations could be captured and recorded.

Within educational research, strategies such as responsive evaluation (Stake 1975) and illuminative evaluation (Parlett & Hamilton 1976) arose. There is no doubt that these studies did much to focus attention on the actions and motivations of individuals (both teachers and pupils) within an educational situation, rather than just on summative academic performance. Interpretive research has enriched our understanding of social situations a great deal. The main problem with this approach is that it does not necessarily focus on the areas which need change. Descriptions are

made, often without any form of judgment attached — and this can be an attempt to retain safety for the researcher. But one of the purposes of doing research is to find appropriate ways to improve situations.

However, much valuable research was done and is still being done within an interpretive framework. One important piece of interpretive language research in South Africa which will be discussed in chapter 10 is the Threshold Project (Macdonald 1990a).

What does the *critical* approach add to this situation? Here theory is not prescriptive and the role of theory is not to legitimise and justify practice, but rather to provide an orientation to practice through enabling individuals to 'understand the relations among value, interest and action and, to paraphrase Marx, to change the world, not to describe it' (Popkewitz 1984 p. 45).

As Lakomski (1988 p. 54) points out, critical theory aims to transcend the positivism of the traditional approach and the relativism of the interpretive approach by placing the process of critical reflection at the centre of the research process. The research embodiment of critical theory is action research. Kemmis (1988 p. 42) defines action research as:

a form of self-reflective enquiry undertaken by participants in social (including educational) situations in order to improve the rationality and justice of (a) their own social or educational practices, (b) their understanding of these practices, and (c) the situations in which the practices are carried out. It is most rationally empowering when taken by participants collaboratively.

What distinguishes action research from more interpretive strategies is the concept of praxis. Praxis is action which is informed by theoretical ideas (for example, about how children learn science) and by the process of reflection on existing practice.

Theory and reflection feed into the formulation of new practice.

Active participation is an essential part of the research process.

The spirals of action research are shown here diagrammatically in

figure 3.1. A more specific diagram developed together with teachers is shown in figure 9.5 on page 129.

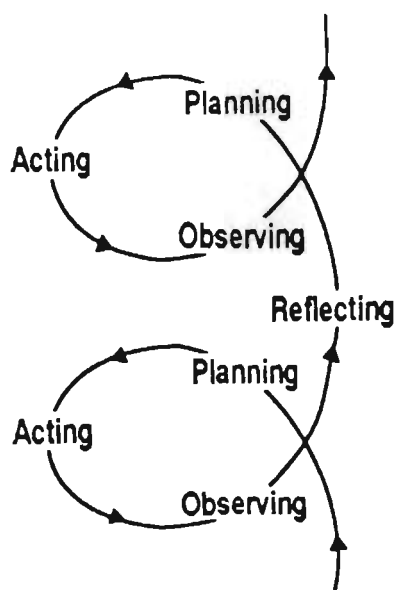


Figure 3.1 Spirals of planning, reflection and action within action research (from McNaught & Raubenheimer 1991, p. 4)

A theoretical framework for research

So, critical theory represents a situation where social theory has moved away from a reductionist perspective towards a more open, inclusive framework. It is essential that any theoretical perspectives on learning and knowledge which are adopted in this research are congruent with this critical perspective outlined above. A constructivist view of learning is explored in chapter 4 and it is argued there that this is an appropriate theoretical perspective. It is also argued in chapter 4 that modern ideas on the nature of science have developed in a similar way to those in social theory and constructivist learning theory. ✓

Within a critical research framework the context needs to be thoroughly explored. In the situation in which this research has been conducted it is necessary to explore the dilemmas posed by the disjuncture between so-called 'western' and 'traditional' educational patterns of thinking, values and priorities.

Once one begins to examine and question the overall structure of the education system in any country, one steps outside what is often seen as the 'safe' territory of science education. The title of Goonatilake's (1984) book speaks for itself: 'Aborted discovery. Science and creativity in the Third World'. Largely using Asian examples, he examines how the structure of the original colonial education systems still has a stranglehold on meaningful curriculum change in the school. Schools are not places for seeking meaning about the world, but rather they are processing places for niches in society. What Dore (1976) calls the Diploma Disease appears to remain virulent when political independence arrives. This is a salient lesson in South Africa.

How does all this assist a clearer understanding of science concept development in general and in a developing country context in particular? For too long we have been concerned with the specific cognitive content of science — an empirical-analytic view. There is no doubt that most physical scientists agree not only on a particulate structure of matter and the idea of identifiable forces explaining the behaviour of matter, but also that this view of physical science is a productive one.

But surely the reason research into conceptual models, alternative conceptions, etc. has been done is to seek better strategies for curriculum development both at school level and in teacher education institutions? These strategies should be ones which allow pupils and students to use science to make meaning of their lives — to see science as a process of examining the physical world and not as an immutable set of facts. Science education can only be successful to the extent that the participants (pupils and teachers) in schools identify with the course content, can use the knowledge practically and see the link between school science and the wider society at large. This orientation is in line with the tenets of critical theory.

All of school science must be embedded in the lives of the pupils and this means much more research into actual cultural settings.

✓ This research concentrates on black teachers and pupils in an urban environment. In that context the ideas of writers like Horton (1967) on clear-cut differences between traditional societies with 'closed' thinking patterns and western societies with 'open' thinking patterns are just too simplistic. The situation is not a straight dichotomy. Horton's work was valuable in that the existence of different modes of rationality was pointed out. People do have different attitudes to causality, time, experiment, prediction, etc. (e.g. Ingle & Turner 1981). But it is also clear that the cultural patterns of people in developing countries are changing rapidly as western influences become more pervasive. Especially in an urban environment in a developing country there is a great deal of cultural accommodation which needs to take place. Four possible modes of cultural accommodation can be used. Traditional beliefs can be rejected, western ideas can be rejected, both can exist together in some sort of confused coexistence or some process of mutual adjustment can occur. It is this last possibility of cultural growth and adaptation for the enrichment of all groups in society (McNaught 1993 p. 163) which is clearly the most desirable and the one we as science educators must aim for. It is the dynamics of this complex social environment which needs to be incorporated into a theoretical research framework. This requires the techniques of ethnography to be central to the development of research strategies (Goetz & Le Compte 1984).

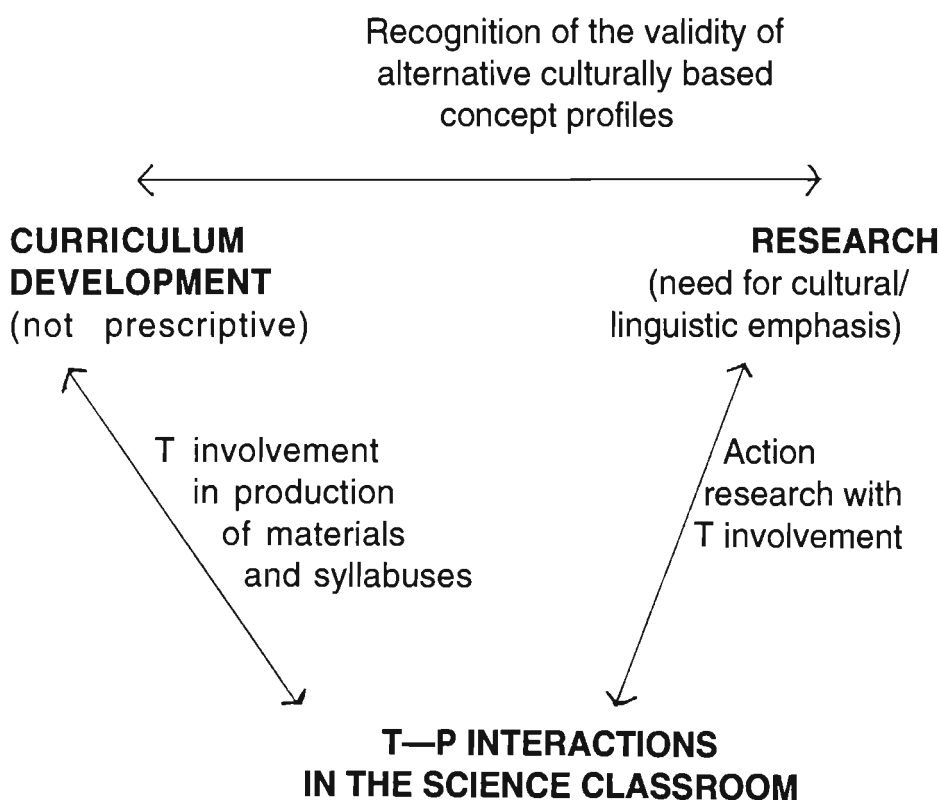
The structure of a curriculum is both an educational issue and a political issue, and the maintenance of power in society can be engineered by the denial of the value of alternative cultural perspectives. In South Africa apartheid was constructed to maintain Afrikaner values. The well-known 1948 policy on Christian National Education states: 'We want no mixing of languages, no mixing of cultures, no mixing of religions, and no mixing of races' (SPROCAS 1971 p. 74). The heritage of this policy must be worked through as we create more meaningful school curricula.

Perhaps the following diagram (figure 3.2) can summarise some of the various factors which must be considered in looking at the

learning of science at the interface between Zulu and English in South Africa. The interdependence of the points in the triangle of curriculum development, research and teacher-pupil learning interactions must be recognised, as must the interdependence of education with the societal context in which it is embedded. The interaction between teacher and pupils cannot be viewed as a one-way $T \rightarrow P$ flow of fixed knowledge. The teacher's scientific conceptions should interact with those of the pupils in a dynamic construction of meaning for all participants. For pupils to learn (i.e., to construct worthwhile meanings), discussion and articulation are essential and for teachers to be able to foster this sort of learning environment, some process of ongoing teacher development is necessary. Ajeyalemi & Maskill (1982) stress the need for fresh research perspectives to be used in developing countries; they also point to the dearth of research on language issues.

Critical sociological theory

- For a given learner, meaning is internally constructed within a social context using language which has developed within a particular culture.
- Conflict is inherent in society. This is especially clear in South Africa.



- T development is the crux of successful curriculum development and research.
- Ps need to engage in discussion for useful learning to occur.

Constructivist theory

- We need to consider whether Ts and Ps share the same scientific conceptions.
- In what way does conceptual change require cognitive conflict?

Figure 3.2 A model for the impact of critical constructivist theory on teacher development and curriculum development

Selecting appropriate research strategies for each research phase

Table 2.1 is repeated here as table 3.1 for ease of reference.

Table 3.1 Research phases

Year	Nature of work	Reference in thesis
1986	Interviews with student teachers to elicit their alternative conceptions about basic chemistry. This work raised questions that indicated the centrality of language in learning. Data collected by audiotape and research diary.	Chapter 5
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1988	Teachers' explanations in Zulu and English. Data collected by videotape and research diary.	Chapter 6 Appendices 1-6
1989	Pupils' discourse about basic concepts in chemistry. Data collected by audiotape and research diary.	Chapter 7 Appendices 7, 8 & 9
1989-1990	Translation work on an English/ Zulu dictionary of scientific terms and on logical connectives.	Chapter 8 Appendices 10 & 11
1989-	Establishment of the Science Curriculum Initiative in South Africa (Scisa) network.	Chapter 9 Appendix 12
1990	Work of the Primary Education Forum. Work in publishing with Centaur Publications.	Chapter 10

Interviews in 1986 with student teachers to elicit their alternative conceptions about basic chemistry

The problems of doing research into concept development are highly complex. Schuster (1983) has discussed many of the difficulties. He does not refer specifically to second language/ culture situations but the points he makes are even more crucial in a cross-cultural context. A few of the issues he raises are:

1. The possible effects of the theory-base, assumptions, expectations, prejudices and subjectivity of the interviewer
2. Semantic difficulties
3. The need for sufficient breadth and depth of probing in elucidating cognitive frameworks
4. Concept modification and learning during the investigation
5. Effects of the mode of presentation.

These five issues seem especially pertinent to the work I have been doing.

The major research strategies which are used both for finding out about learners' alternative conceptions and also how to assist learners in building up more helpful conceptions can be grouped as follows:

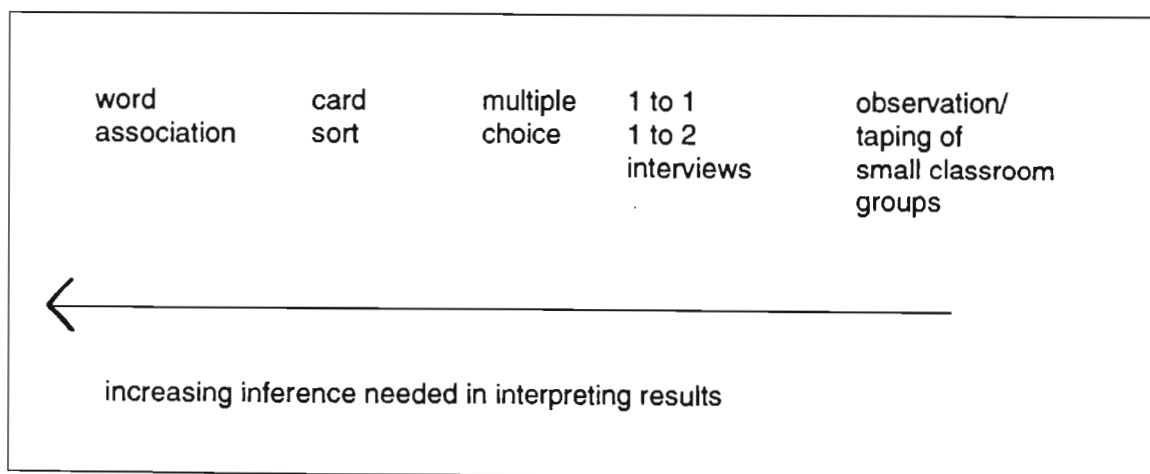


Figure 3.3 Research strategies for mapping learners' alternative conceptions (after Pope & Gilbert 1983)

A more detailed description of research strategies is given by Fensham, Garrard & West (1981). They include sentence writing, essay writing, descriptive writing and solution articulating as well as those listed in figure 3.3. They also discuss methods of data analysis such as various ways of presenting networks, maps, categories and case studies. For the purposes of this exploratory research into a complex, bilingual situation, the strategies in figure 3.3 are sufficient.

There is value in all of the above strategies in an appropriate context and, indeed, the use of a variety of strategies seems essential. The problems of validity that arise from the need to infer meanings in this type of research cannot be overlooked and are a major consideration in this research. Word association tests have stimulated much useful debate about learner's understanding and some convincing evidence exists about the existence of a relationship between performance on word association tests and academic achievement in science for first language speakers of English (e.g. Johnstone & Moynikan 1985). However, as Stewart (1979) points out, there are theoretical difficulties with word association tests in that there is no framework by which to ascribe or explore meanings to the relationships between the concepts noted by learners.

In order to collect data that required a lower degree of inferential interpretation only interviews and observations were used in this research. It was decided that the problems of constructing word association tasks, card sorting tasks or multiple choice tests without cultural bias, and which could indeed allow a reasonable idea of the respondents' conceptions, would be very difficult and the level of validity would be too low in this context. Schuster's points 2, 3 and 5 are particularly relevant here. The additional labour of collecting and interpreting tapes was considered essential.

For the research tasks I have outlined below, it was essential to have bilingual Zulu/ English speakers and so older learners were involved. The move to young school pupils can only occur later; the

problems of reliably communicating with pupils are immense at present both from a language point of view and because of the unrest situation in schools at present.

The interviews I structured in 1986 with thirty students at Indumiso College of Education are described in detail in chapter 5. They involved watching water boiling and examining several substances; the student teachers did not do any practical tasks themselves. In order to discuss terms such as 'particle', 'element', 'compound' and 'mixture', sample tubes of sand, salt, syrup, flour, iron nails, iron filings, air and water were used. When discussing 'chemical reaction', iron, sulphur and iron sulphide were used. Pictorial representations of chemical structures and reactions were explored using diagrams from text books.

All interviews were in English; all were audiotaped with students' permission; this presented no difficulty at all. I kept a research diary which was completed after each interview, noting any feature of the interviews which I considered to be important. This strategy of a research diary is invaluable as it enables one to capture the immediacy of one's reactions and compare them with results from a detailed and careful analysis of the audiotapes.

It should be noted that I made no attempt to conduct 'objective' interviews. The situation was as much a teaching one as a data collection one. In this respect, Schuster's point 4 noted above is totally disregarded, and intentionally so for two reasons. The first is that in order to probe students' understanding more fully (Schuster's point 3), I needed to help students bridge some of the gaps between their knowledge fragments (Reif 1985 — see chapter 4, page 49). Secondly, I wanted students to experience a situation where discussion was used to refine the meaning of a concept, as this type of dialogue is a relatively unfamiliar learning situation for them.

For these interviews transcripts were made of the tapes. These transcripts were then studied in order to record students' alternative conceptions and also to study the nuances of the

language used by the students. As the format of each interview was essentially the same, the alternative conceptions could have been recorded just by playing the tapes a few times and noting the relevant data. If this had been done, a wealth of data which changed the direction of this research would have been lost. As the transcripts were being read, I was able to reflect on whether the students' errors were due to having a poor understanding of chemistry, or due to insufficient ability in English to express their answers, or in what ways their problems with chemistry might be due to language issues. I was also able to realise how much my own prompts were needed by the students in order to provide answers. This situation of passively waiting until almost the entire answer is provided was one of the problems mentioned to me by the science staff at Indumiso College. The depth and richness of the transcript data allowed me to develop insights which would not have been possible with a less labour intensive strategy.

Overall, this work highlighted the centrality of language in learning and led to the linguistic work which was done in 1988 and 1989.

The period of study leave in the UK in 1987 was especially valuable because of the opportunity it provided for reading, reflection and consultation. The disciplines of anthropology, sociolinguistics and cross-cultural psychology were very valuable for building a framework for this research. Understanding the formation of concepts in various learning environments demands an overall study of the sociological and cultural determinants of the learning environments, a study of how learners access, organise and utilise knowledge (psychology), and a study of the structure of the language(s) used in the process (linguistics). The sort of research in such a complex field of study must study and adapt the techniques of several disciplines in order to progress. The problem of shallow interpretation from several disciplines is a real one and time to reflect on reading and discussion was essential.

Given that one wishes to research language differences and issues, just how does one do it? Interviewing Zulu-speaking teachers did

not yield much clear information in this area. This is perhaps not surprising because, essentially, I was asking teachers and student teachers to give me metacognitive analyses of how language influenced their formation of a given concept. This is an extremely difficult task. Interviewing Zulu school pupils is even more difficult. Shyness and an increasing level of distrust of anyone who asks questions (in any language) mean that working directly with pupils is very difficult at present. I decided to use structured exercises with teachers and with pupils and also examine the implications which problematic translations of words seem to have. However, the research is tentative. It is the response to a need; because the need is so great and yet so nebulous, the response has been a hesitant and exploratory one. Perhaps, however, this caution is essential in this area of research.

Teachers' styles of explanations in Zulu and English (1988)

It must be clearly stated that the focus of this aspect of the research was not to see how Zulu could be used as a medium of instruction for teaching science. This research is not concerned with an overall language policy for South African schools. A pragmatic viewpoint has been adopted in that English is likely to be of importance in future schooling and that the interface between Zulu and English is likely to be a significant one. The issue of language policy is complex. There is a body of research which supports the teaching of science in the home language, e.g. McKinley *et al.* (1993) on the use of Maori in New Zealand, Fafunwa (1975), Bamgbose (1984) and Okonkwo (1985) on the use of Yoruba in primary schools in Nigeria, Collison (1974) on the use of Ga and Twi in primary schools in Ghana. The primary/ secondary divide is, of course, an important factor in this debate.

The research in this thesis does indicate that the differences between home language (in this case, Zulu) and English may be such as to make the use of the home language difficult as a medium of instruction but does not consider cultural factors such as cultural identity, value of traditional beliefs and practices, and issues of

social affirmative action (Gudykunst 1988), and so is not a holistic language policy assessment. Clearly, as Brown (1988/9) points out, there is an urgent need to address the language policy question in South Africa.

Also, this research does not address whether western science is the most appropriate science in an African context. This is also a complex issue (e.g. Bajah 1985, Ogunniyi 1986, McNaught 1993). There are few examples of major curriculum shifts, though some case studies of innovation (e.g. George & Glasgow 1989, on street science in the Caribbean) are exciting. Some discussion of this is made peripherally in chapter 4. However, this research is focussed on the pragmatic situation that for the foreseeable future, western science will be the pervasive influence on science content.

During 1988, the main research focus was on analyzing teachers' explanations of science in both Zulu and English. In this part of the research, I studied the differences between teachers' explanations of basic chemical ideas in Zulu and in English. The teachers were final year students Indumiso College of Education, preparing to be secondary school science teachers. The work was done with final year Biology students rather than final year Physical Science students for two reasons; it was logistically easier in terms of the college program and the class size was larger — 22 Biology students but only eight Physical Science students in 1989. Five topics were chosen — diffusion, osmosis, proteins, carbohydrates and lipids. These topics were in the biochemical part of the syllabus and so closer to the earlier research work in 1986 on basic chemical concepts.

Some students gave their lesson explanations in Zulu and some in English. Each topic was taught separately by two students; one taught in English and one in Zulu. Each lesson was about 30 minutes long, so five hours of videotapes were obtained. The teaching was done to peers at Indumiso College. This activity was linked to an assignment in practical teaching skills in Biology and so was taken seriously by the students. Permission was obtained from the Department of Education and Training. The rector of

Indumiso College of Education and the science staff were very cooperative and interested. As with the work in 1986, a research diary was kept.

It was hoped to obtain data in schools with the same student teachers using a portable video system but teaching practice did not occur in schools that year. Instead students had limited teaching practice experience with pupils who were brought to the college for short periods. It was felt that any disruption to this tense and artificial situation with observation equipment would have been unfair on the students.

The English tapes were transcribed. The Zulu tapes were transcribed and directly translated word for word (that is, without interpretation) by Zulu-speaking research assistants. This is described as a literal translation. During 1989 and 1990 I had funds from the University of Natal Student Internship Scheme for two university students to do the translation work. While I had completed Zulu 1 at the University of Natal with a good mark (81%) and have a working knowledge of the language, it was essential to have translators whose first language was Zulu. These students were third year B Sc students; one was majoring in chemistry and one in biochemistry. Both completed their degrees successfully. So, the translators were Zulu-speaking and well qualified in science as well. It was indeed an excellent arrangement.

Under the University of Natal Student Internship Scheme black students acted as research assistants. They obtained research skills and experience and had a mentor on the academic staff. This was a valuable and productive scheme from both sides and I am still in contact with my two assistants (1994).

Sections of two tapes from each translator were checked by Zulu-speaking science teachers. The agreement was very high. Issues relating to translation work are described below.

A comparison of the overall quality of the images conveyed by the lessons in the two languages was then carried out. By 'quality' I

do not mean a superior/ inferior evaluation but more an exploration of the qualitative differences between the lessons in the two languages. This is described in detail in chapter 6 and appendices 1 to 5.

There are several research problems in this approach. While the actual translation of individual words was reasonably straight forward, the interpretation of the meaning of a whole passage was much more difficult. I was looking for overall styles of explanation and this sort of holistic assessment can only be subjective. The teachers planned their own lessons and there were obviously differences in competence between them. There were differences in scientific understanding and also in general teaching ability. In no way can this be seen as controlled definitive research (if such a thing exists), but rather some exploratory work to give guidelines for the future.

The following comments should be made about the differences between the teachers. It was interesting to observe that the differences between the Zulu and the English lessons were not particularly related to differences between the teachers in general teaching ability, by which I mean fluency, ability to engage with the group of learners, use of audiovisual aids, good time management, etc. However, differences in scientific understanding could well have contributed to the differences.

I had originally planned to have the same teacher prepare a lesson involving both an English and a Zulu section. However, the content would have been somewhat different for the two languages. Also, while teachers in a natural classroom situation switch between Zulu and English quite naturally, they felt very inhibited in doing so during a class at College. I tried one video session with a third year Physical Science student who was bright and a good teacher. However, he just felt he couldn't switch between languages mid-stream in a lesson in a contrived manner. Hence, this structured allocation of students to tasks was devised. Perhaps a little surprisingly, the students who were allocated the Zulu lessons did not mind this. I had spent a great deal of time at Indumiso College

and was well known to the students; I found them cooperative at all times. I suspect they found an Australian interested in learning about and struggling with Zulu to be an interesting phenomenon!

All the students who presented lessons prepared written responses in Zulu to aspects of their lessons which I had identified during the lessons. This enabled me to check up on points which I had noted as being problematic during the lessons. This also provided me with some data to see if there were any really noticeable differences between styles of explanation in written and spoken Zulu. (This data is in appendix 6.) This was really an incidental aspect of the research as I had to choose questions for the student teachers to answer while I was listening to the lessons and also operating the video camera. This was not difficult when the lessons were in English; it was more demanding when the lessons were in Zulu. This is mentioned in this chapter on research methodology because of the need to try out ideas in a new field of research when the opportunity arises.

Issues in the translation procedure

It is almost certain that for the foreseeable future, we will still be including 'conventional' science concepts such as force, energy, particle, reaction, chemical bond, etc. in any science curriculum we construct. Many languages do not, at present, have the linguistic capacity for western scientific explanation but have a richness about some ecological concepts, social relationships and spiritual values. So, difficulties in explaining the science concepts used in school science curricula do not in any sense indicate that a language is deficient, just that it there has not been a need for certain understanding or using certain concepts in former times.

Straight translation of curriculum concepts from one language to another is rarely satisfactory. Nida (1964 p. 3) defines language as 'a public system of symbols constantly, if slowly, being remade to fit the exigencies of a changing world'. The issue with respect to the language of science is the pace at which languages can accommodate new concepts. The meanings attached to words are

not only linguistic; they also have emotional and cultural meanings. Nida discusses translation as a process which needs to be embedded in current cultural meanings. Understanding the cultural symbols or signs of a society is part of this process (semiotics), as is understanding the links one can find between these symbols, their embodiment in language, and behaviours in the society (pragmatics).

The normal process of translation is an interpretive process. The translator removes some of the ambiguity in the original work by deciding what a particular section of language is meant to portray. This fixes the meaning in the frame of reference of the language into which the work is being translated. Minimizing the reduction in freedom for the original linguistic symbols is one of the challenges and responsibilities which the translator undertakes and this is done by a process where the translator brings the two languages as close as possible — s/he minimizes the linguistic distance between the two languages, rather than highlighting it.

Wilkinson (1975 p. 36) describes three levels of language: the words themselves (lexis), the rules for arranging them and adjusting them (grammar) and the rules for using them in speech (phonology). All of these levels combine to make meaning which can be called the fourth level. It is the relation between meaning and the three basic levels that can be problematic for the translator and where interpretation enters the process.

In this piece of research, I was not interested in seeing whether Zulu can be used to teach science. I was interested in trying to see if one can get some understanding of the 'linguistic distance' between Zulu and English in the context of explaining basic concepts in western science. I was interested in trying to capture the world of a child who comes to learn science through the medium of English when most of her/ his previous experience has been in a Zulu cultural/ linguistic environment. What mental processes does this child need to go through in order to make sense of a teacher's explanation about such ideas as 'particles', 'states of matter', 'chemical reaction', 'bonding', etc.? What 'distance'

does the child have to travel in terms of the language as well as the new ideas?

These questions cannot be answered by an interpretive translation where the translator takes on the responsibility for minimizing linguistic distance. Questions such as these prompted me, in consultation with members of the Department of Zulu at the University of Natal, to develop this method, of literal rather than interpretive translation. It was not a straightforward decision and the transcripts seem unnecessarily clumsy in many ways. If the translations had been interpretive, I would have obtained information on whether Zulu can be used to teach science. As I stated above, this was not my purpose.

The process of interpreting the literal translation was done as outlined in appendices 1-5. Comments were made beside sections of the transcripts. These were reflected on and, after many readings, reflection and discussion with teachers, Zulu lecturers and my student translators, the generalisations described in chapter 6 emerged.

Pupils' discourse about basic concepts in chemistry (1989)

As Gilbert (1983, p. 2) comments, 'the most naturalistic setting for the study of conceptions must be the classroom, particularly where students are engaged in practical work'. The interviews I structured in 1986 involved student teachers watching water boiling and examining several substances, but they did not do any practical tasks themselves. In this phase of the research I decided to give pupils some practical tasks to do and record their group discussions about they approached the tasks. These would be simple problem-solving tasks but ones they had hopefully not encountered before.

In order to get natural discussions about science from learners doing science practical work, I tried placing audiotape recorders with small groups of students (usually four or five students in each

group) at Indumiso College during practical work. The resultant mix of English and Zulu was interesting to listen to but really too complex to analyze without the visual assistance provided by video-recordings.

A more structured process was needed. It was decided to audiotape dialogues between pairs of learners who are school pupils at Edendale Technical College. The pupils were willing to do the work but were not confident about it. Two simple exercises on standard 6 (year 8) chemistry were constructed. One was on particles where pupils could discuss the meaning of the word as it is used in chemistry and also do two exercises to gain some idea about the sizes of particles. The other was on classifying substances into elements, compounds and mixtures where pupils could discuss the meanings of the words and classify samples of various substances. They were also asked to classify by the state solid, liquid or gas. These exercises involve key conceptual areas in chemistry. As with the earlier data collection activities a research diary was kept.

The design of the activities was assisted by studying work done with Group Practical Tasks (GPTs) in Indonesia (Eggleston *et al.* 1984). GPTs are carefully structured problem-solving tasks together with a detailed assessment protocol covering specific questions and points which can be observed.

The decision to use audiotapes was influenced by the work of Gorodetsky & Hoz (1980). They encouraged pupils to use a 'think aloud' technique during problem solving exercises. They were able to use audiotapes to identify conceptual leaps or transitions for both solvers and non-solvers. This potential value for the audiotapes was exciting, though I realised that in the disadvantaged and linguistically complex situation in which I was working I was unlikely to be able to produce such an elegant analysis. That certainly was true.

Pupils were told they could discuss the work in either Zulu or English — whatever they wished — and all the tapes contained a

mixture of both languages. As with the videotapes of teachers, transcription and direct translation of the Zulu to English was done. Four discussions were obtained for each of the two exercises.

Comments noted on the transcripts relate to

- The science ideas articulated by the pupils
- The linguistic structure of their discourse — language clues which may have resulted in or reinforced any unhelpful alternative conceptions noted
- The flow of dialogue — pupils' ability to pose questions to each other and resolve issues.

All these three aspects operate together which makes analysis tentative and complex.

These were much more difficult tapes to try to understand than the teacher videotapes but do give some clear images of pupils struggling with unfamiliar words and constructions. These tapes were collected in 1989. In 1990 the escalating violence in the Pietermaritzburg area precluded further research along these lines.

A full discussion is in chapter 7 and appendices 7, 8 and 9.

Translations of specific words — dictionary of scientific terms

While the bulk of the research has focused on the overall use of a language in the formations of key concepts, it is clear that difficulties arise for learners when the word(s) used in English is/are quite different from those used in Zulu. It is reasonable to suppose that the greater the disparity between the usage of Zulu and the usage of English, the more difficulties learners will encounter.

An English/ Zulu dictionary of scientific terms with 760 entries was compiled from the two English/ Zulu dictionaries which exist (Dent & Nyembezi 1969, Doke *et al.* 1958). A literal translation

was done of the Zulu translation of the English term. The results are given in chapter 8 and appendix 10.

Translations of specific words — logical connectives

It became clear from reading the transcripts of teacher explanations and pupil discussion that certain logical constructions in English are not matched in Zulu. It is well known that scientific language relies heavily on the use of logical connectives. The list of 220 logical connectives which Gardner (1977) identified as being difficult for mother tongue English speakers were examined. Those which do not translate easily were noted. The results are given in chapter 8 and appendix 11.

Development of teacher networks — the Science Curriculum Initiative in South Africa and the Primary Education Forum

The theoretical framework for action research is central to the way in which these initiatives were set up. Some basic features of action research projects in education are:

- A research group where all members act as co-researchers
- Intersubjective dialogue between members of the research group on issues in the philosophy of science, human learning and the social context in which the research is embedded
- Intersubjective dialogue between members of the research group on evaluating research techniques, teaching methods and curriculum materials
- A conscious use of internal and external moderating mechanisms. O'Donoghue & McNaught (1991 p. 402) discuss the need for 'consultants who play devil's advocate and a healthy scepticism that things are not always as they seem'. The danger that an action research group reduces its level of interpretation to the reinforcing of each other's maxims is very real and the rigour of a critical perspective demands that both internal and external checks need to be constantly in place to ensure adequate validity.

The difference between a development project and an action research project lies in this element of reflective evaluation. Action research goes beyond the implementation of an innovation — setting up communications, running workshops, disseminating materials, etc. It is essential that an ongoing critical dialogue be established from the beginning of the project.

The two action research projects associated with the enactment of this research are discussed in chapter 9 (the Science Curriculum Initiative in South Africa) and in chapter 10 (the Primary Education Forum).

It is important that my contribution to these networks be clearly stated as the work is being examined in the light of my suitability to obtain a PhD degree. Action research precludes the concept of totally individual research. By its nature a participatory approach is required. I was deeply involved in the initial conceptions of both projects and had substantial involvement throughout their development. The linguistic work described in chapters 5 to 8 was one impetus and focus in the networks; there were others which arose from the work contexts of other participants. The initial theoretical framing of the projects was my responsibility but, as both projects developed a more coherent sense of networking, the reflective insights and new ideas came from a range of participants. This is exactly the strength of a network — the ownership of knowledge and products is joint and no individual can or should claim sole credit for any advances.

As far as this thesis is concerned the essential link in the research design is the establishment of appropriate networks whereby research, such as the research into interface language issues, can become known to teachers and hence accessible to essential actors in emerging curriculum patterns.

In conclusion, it must be stressed that the insights gained from this research would not have been possible if the focus of the research had not shifted to one where the problems of learning chemistry

were seen as being more than the conventional clarification of concepts. The importance of seeing language, and culture, as central to concept formation requires a research methodology and ethical perspective which sees the ideas of the learner as of equal value to those of the researcher. The usefulness of certain ideas may then be negotiated, and it is this negotiation through dialogue which constitutes good educational practice and useful educational research.

Chapter 4 Language and learning science

Introduction

This has been a century of amazing growth and change — in the depth and range of scientific knowledge and the use of this in technology, in social research into the functioning of human societies, and in our understanding of how individuals learn. In this chapter an integrated theory of the relationship between epistemological aspects of scientific knowledge, theory about how individuals come to understand scientific knowledge, and social theory about individuals can act to use scientific knowledge to bring about change is presented. In this study I was interested in change, in the context in which science curricula are constructed and implemented in a situation where learners are working at the interface between two languages.

In chapter 3 a critical perspective on social theory was presented. Its congruence with modern ideas in the philosophy of science and constructivist learning theory will now be explored.

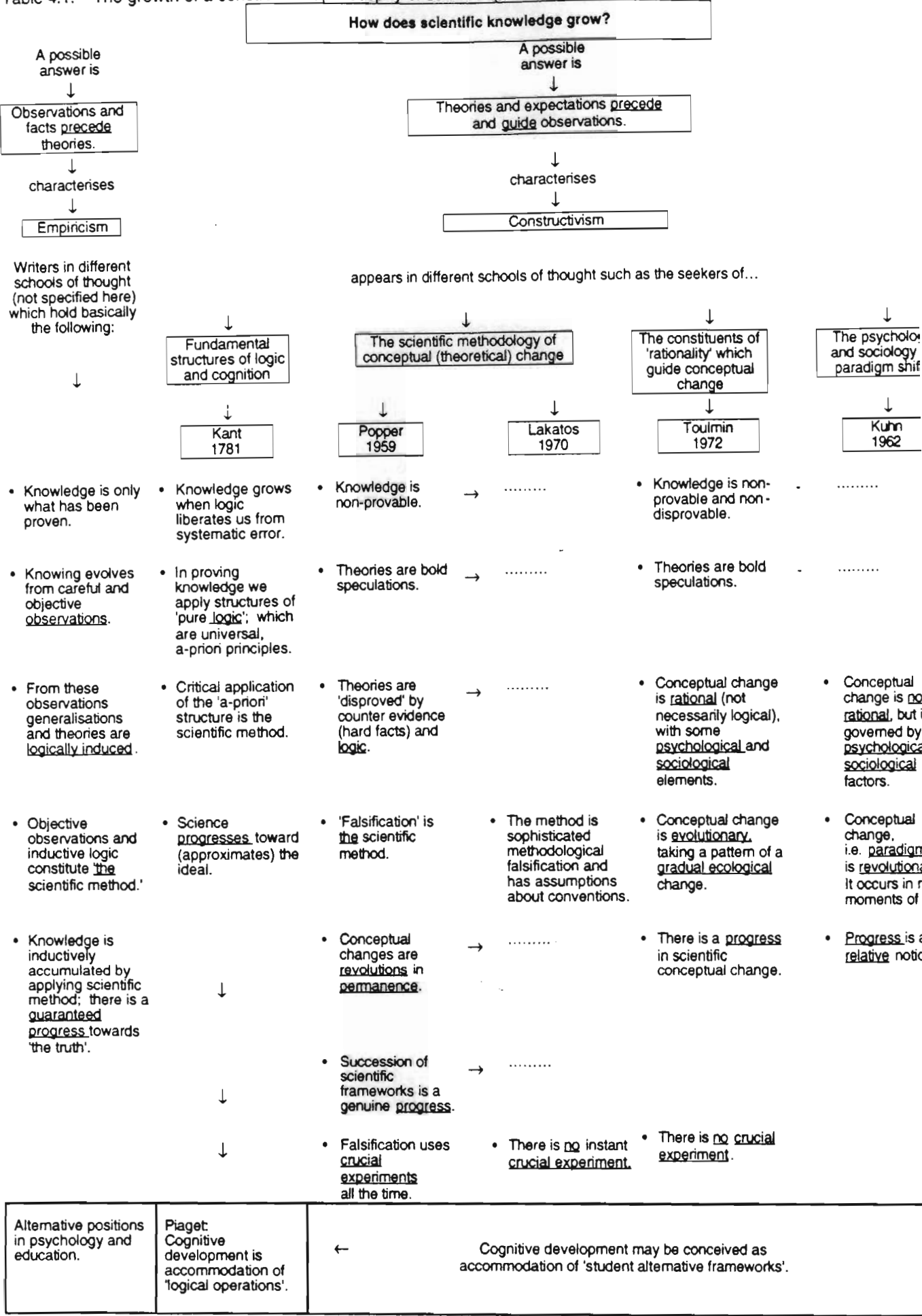
The nature of science

Has science really changed so fundamentally this century? What are the ideas about the nature of science that have resulted in authors like Capra (1983a, 1983b) having such enormous appeal (though I suspect more people talk about Capra than have read his books!)? Three issues have emerged from the exploration of the atomic world which have transformed views about knowledge:

- The role of the observer. Einstein's theory of relativity has taught us that the observer (the scientist) is inextricably part of the process being studied.
- The meaning of certainty, of truth. Heisenberg's Uncertainty Principle has taught us that our measurements are not absolute.
- The need for considering context. The enigma of the wave/particle duality can only be understood when we realise that the context is part of any phenomenon being studied.

Of course the exciting times in physics early this century did not come in a social vacuum. The classic Baconian view of the world as a machine which can be dissected and understood through experimentation was questioned throughout the eighteenth and nineteenth centuries. Nussbaum (1983) cites Kant (1781) as one of the first philosophers to see scientific theories as being an aid to the growth of knowledge and not being absolute statements of truth at any time. The growth of a constructivist philosophy of science is summarised in table 4.1 (from Nussbaum 1983 p. 3). The issues of relativity, uncertainty and context are clearly being progressively incorporated into a general philosophy of science.

Table 4.1: The growth of a constructivist philosophy of science (from Nussbaum 1983 p. 3)



So, is all well? Is science acceptably accommodating to the results which come from scientific work? The answer is both Yes and No. Yes, the rigidity of a totally reductionist outlook is lessening; No, there are still unquestioned myths about the practice and scope of science. Woolgar (1988 p. 68) discusses how scientific work can practice the unconscious deceit of 'splitting and inversion'. He portrays this as a six-stage process:

- (1) observation
- (2) observation → object
- (3) observation object
- (4) observation ← object
- (5) deny or forget about stages 1-3
- (6) feel safe as an observer!

In this process the relationship between observation and object is reversed, so that it appears that the external phenomenon has a reality and existence which is independent of the observer and that the observer is a passive recipient of signals. This model is significant because it portrays the lack of engagement with and responsibility for scientific problems (such as those associated with environmental degradation) which still characterises much scientific and technological work today.

This 'inversion game' in science has another twist as well. Only the sorts of phenomena which fit this process are studied, i.e., those involving discrete objects or concepts. Broad interdisciplinary studies cannot be easily treated in this way because of the large number of interrelated observations and objects involved. So one finds a lot of seemingly trivial scientific work being done when pressing problems are largely ignored. Surely science, as one of the most significant forces in our world society, should be above the pastime of 'rearranging deck chairs on the Titanic'.

What, then, are possible ways in which science can preserve and develop the gains made in technology, medicine, agriculture, etc. but also develop a more interdisciplinary focus for problems such as over-population and environmental degradation ?

Woolgar suggests that we look into anthropological methodology, especially ethnography, for ways of unpacking our preconceptions. He discusses the example of a pipette giving it 'relentless anthropological attention ... Such mundane objects encapsulate and sustain the culture of the laboratory, its beliefs, results and decisions from the past embodied in material artefacts' (p. 85). The scientist's (pre-pipette fillers!) and ethnographer's descriptions of a pipette are, in respective order:

A pipette is a glass tube with the aid of which a definite volume of liquid can be transferred. With the lower end in the liquid, one sucks the liquid up the tube until it reaches a particular level. Then, by closing the top end with finger or thumb to maintain the vacuum the tube can be lifted and the measured volume within it held. Release of the vacuum, enables the liquid to be deposited in another beaker, etc.

Here and there around the laboratory we find glass receptacles, open at both ends, by means of which the scientists believe they can capture what they call a 'volume' of the class of substance known as a 'liquid'. Liquids are said to take up the shape of the vessel containing them and are thought to be only slightly compressible. The glass objects, called 'pipettes', are thought to retain the captured 'volume' and to make possible its movement from one part of the laboratory to another.

Woolgar (1988 p. 85)

While much of this sort of activity seems rather pedantic to scientists, something like this is essential if we are to uncover the assumptions made about the content and methodology of science.

Knudtson & Suzuki (1992) go much further. Not only do we need to try to see science as someone outside might see it, but also assert that we need to look at other forms of knowledge in order to seek answers, particularly for the vexed questions concerning the eco-crisis and the survival of many forms of life on Earth. For too long

many scientists have continued in the arrogant assumption that classical science can solve all problems. Knowledge has existed for centuries in many indigenous cultures about how to live in harmony with other living creatures and how to wisely harness the natural resources of the Earth. We need to tap into that knowledge for our very survival. Capra (1983) showed how similar modern physics is to the wisdom of the East. Traditional wisdom and a constructivist view of science are not so far apart. Knudtson & Suzuki are suggesting that we need to spend more energy on looking for the links where they exist and thus finding ways to incorporate more of the balanced values of traditional cultures into our own western frameworks. The breadth of what knowledge might usefully be included in our 'western' perspective is illustrated by Wang & Bedford (1985) who discuss the validity of divination as a scientific process. Scientific explanations do not exist for the success that many water diviners have. 'It is clear that the breakdown of the universality of mechanical causation robs science of the power to deny out of hand the validity of some alternative conceptions of the world' (p. 437). Quite a challenge.

So, both science and social research have moved away from a reductionist perspective towards a more open, inclusive framework. Are our views on learning moving in the same direction?

Constructivism as an appropriate learning theory

I was motivated to begin this research by the increase in recent years of literature which has focused on the problems of learning science in terms of how pupils perceive the science they interact with at schools. The growing awareness of the fact that children bring to their science studies already well-formed frameworks of ideas about many of the topics they study in science has had a real impact on many science education projects. The distinction between scientists' science, teachers' science and children's science is a vital one. And the fact that the interaction between children's science and teachers' science may not result in anything

resembling scientists' science is becoming more clearly recognized.

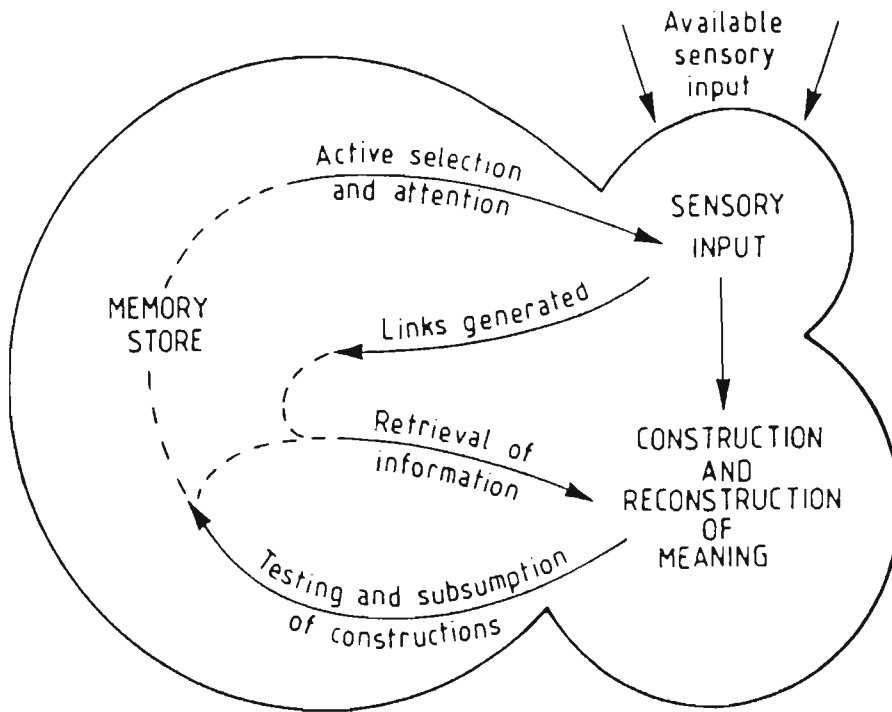
Current constructivist views of learning see individual learners as building up personal, internal conceptual maps as a result of interactive processes between each learner and her/his environment. Learning outcomes are dependent not only on the environment but also on the state of the learner with her/his existing conceptions and motivations. Learning occurs as an active construction of meaning as a result of reflection on experiences (e.g. Driver & Bell 1986). 'Reflection' is one of those concepts embodied in critical theory which deserves to be reflected upon. It does not just mean thinking over an experience, but implies a conscious integration of experience into an existing framework. Our frameworks embrace our sociocultural environment as well as our physical environment. The process of reflection is not purely rational. West & Pines (1983 p. 37) state that 'non-rational components are intrinsic to conceptual change in the individual'. They discuss elements such as power, simplicity in complexity, aesthetics and personal integrity as being central to learning.

Earlier views of learning were within a behaviourist or a developmental mode. A behaviourist view sees educational problems as being centred around designing the most efficient transmission systems for fixed packets of knowledge. While this may be a useful strategy for teaching certain skills, there is no room for considering individual differences between learners (which we all know are there) or the issue that differing expressions or forms of knowledge can be equally valid. A developmental perspective does see learners as being the architects of their own knowledge but prescribes the order in which increasingly complex cognitive operations become available to the learner (Driver 1984). The linearity of this model is at variance with many studies, especially about human creativity.

This is a very sketchy comment on developmental psychology. The work of Jean Piaget has had enormous influence on constructivist thinking. His concepts of assimilation and accommodation fit in

with the idea of individuals being active learners. His concepts of equilibration, of achieving a greater degree of reversibility, are foundational to the idea of learners integrating new knowledge into existing frameworks. A good overview of Piaget's basic theory is given by Donaldson (1978 appendix). Driver & Easley (1978) refer to much of Piaget's work and suggest that his work, especially that dealing with causality (e.g. Piaget 1974) 'should be read for the indications they give of the content of children's ideas and explanations, rather than as ways of assessing the development of underlying logical structures' (p. 79).

Often constructivism is seen as being in opposition to the behavioural learning theory, where the emphasis is on information processing and management (e.g. Posner 1989) with a set of clearly defined outcomes at the end of a learning experience. The determinism of this objective view of learning has been criticised by constructivists, who see the individuality of learners and the uniqueness of their previous experiences as being ignored. However, as Cole (1992) argues, it is not helpful to debate theories and ideas of learning in a confrontational fashion. She proposes that objectivism and constructivism can be seen as applying to the ends of a spectrum of learning types. At one end is learning basic knowledge in a very structured context with narrowly defined, immediate objectives; and at the other end is acquiring advanced knowledge of complex issues in uncharted contexts, where the objectives may be numerous and ill-defined. The danger of taking such an eclectic viewpoint about learning is that our approach to learning may lose focus and rigour. A more convincing approach is taken by Osborne & Wittrock (1985) who have formulated a model which incorporates aspects of both the constructivist and information processing traditions of cognitive psychology. They call this the generative learning model.



THE ACTIVE CONSTRUCTION OF MEANING

Figure 4.1 Schematic representation of the generative learning model (from Osborne & Wittrock 1985 p. 67)

If we use this idea of the active construction of meaning and focus on what sorts of mental models learners construct and how we can encourage them to frame suitable questions in order to consciously explore and refine these models, we may be developing a valuable eclectic approach. Everyone uses models everyday. For example, when you pull out from an intersection, you must have a mental model of how fast an approaching car is going and where that car and your car will be at any instant in the near future. We constantly add to our existing knowledge base to make new predictions and generalisations. By constructing an explicit model, based on one's knowledge of a system, one finds out how much is already known and how much must be guessed, or how much new information needs to be sought. Then one changes the guessed parts gradually to see what guesses are reasonable because they make the model do things in a way which is similar to the

behaviour of the system as it is perceived. In this way you find out more about how well you know the system and what aspects are crucial to know more about.

The terms 'concept' and 'conception' appear frequently in educational writings. Markle & Tiemann (1970), in their discussion of the term 'concept', emphasize that 'to really understand a concept is to be able to generalize to all possible instances that might be presented and to be able to discriminate all possible non-instances' (p. 43). Another way of describing a concept is through the realisation that we experience events or objects and that we build up a concept as a 'regularity in events or objects designated by some label' (Novak & Gowin 1984 p. 4). Thus a concept is something which can be fairly clearly defined and about which explicit measurements can be taken. On the other hand, the term 'conception' is less clearly defined; it is a set of ideas linked with a concept which enable a learner to make sense of the concept — to fit it in with her/his existing view of the world. It is the recognition and identification of these frameworks into which children must fit the concepts they learn about at school which has produced the proliferation of exciting new research in science education.

This perspective enables a greater understanding of the problems of teaching science. It also raises the interesting questions about whether unhelpful conceptions can be modified and, if so, how this should be done. The use of the word 'unhelpful' places a value on western science as it is currently understood and, as I will discuss later, this really is a problematic assumption. The implications for curriculum development which this notion of altering conceptions brings, are far-reaching and much work remains to be done in this area.

So, there are clear parallels between a behaviourist learning perspective, classical reductionist science and traditional modes of social research. And there are also clear parallels between a constructivist learning perspective, an open and inclusive view about science and a critical social perspective. There are no clear

divisions between these descriptions. Techniques and materials developed within a more reductionist framework may well be useful transformed to use in a situation where people are trying to establish an open view of learning. It is important in developing an appropriate theoretical framework to maintain the rigour of a critical perspective. The criteria listed in chapter 3, page 32, enable one to devise research programmes which are valid.

This research adopts a framework where knowledge (in this case scientific knowledge) is negotiated and individually constructed within a social context. Education action should be participatory with as many stakeholders as possible involved in the process.

Some studies on learners' problems in learning science

To date, the majority of the work has been, understandably, in the area of identifying just what children do think about the scientific concepts they meet. Osborne & Gilbert (e.g. 1980) refined an interview strategy — Interview About Instances (IAI) — which they used to investigate children's understanding of concepts in basic physics such as work and electric current. Shayer & Adey (1981; also Shayer, Adey & Wylam, 1980) are well-known for their Science Reasoning Tasks which were designed to allow the gathering of data a class at a time rather than on a one-to-one basis by a combination of practical demonstrations with answer sheets. The Science Reasoning Tasks were constructed using a classical Piagetian stage model rather than a broader constructivist approach. Thus, there were clear expectations about what performance outcomes should be. However, the Science Reasoning Tasks themselves have been used by researchers working in a constructivist framework to seek understanding about learners' understanding of science. I myself have used the chemical combinations task (Adey 1977 & 1979) with Higher Diploma in Education (HDE — one year post-graduate teacher education course) General Science method students as a stimulus to a workshop where students identify their own difficulties.

There is some evidence that learners' alternative frameworks are consistent across different task contexts (Clough & Driver 1986) and that unhelpful alternative conceptions may be quite resistant to even quite carefully planned instruction (Nussbaum & Novick 1981).

Studies on conceptions within physical science have largely been in physics. My own interests are in chemistry where fewer studies have been undertaken. Most of this work has been done on learners' understanding of the particle nature of matter; this is not surprising as this is the basis for building conceptions about bonding, structure, stoichiometry and equilibrium. The brief literature discussion here will therefore focus on the particle nature of matter. General reviews on alternative frameworks in chemical education confirm this (Osborne & Schollum 1983, Fensham 1984). There is some evidence that increased instruction on (and hence more understanding of ?) the particle nature of matter results in improved performance on some chemistry problem solving tasks (Gabel 1990). Johnstone (1988) reports on a teaching scheme which does result in improved understanding of the particle nature of matter.

Early studies about children's conceptions about particles were done by Piaget & Inhelder (1974) and Pella & Carey (1967). One very thorough investigation into Scottish children's understanding of the particle model of matter is that by Dow *et al.* (1978). Mitchell & Kellington (1982) have also researched the ideas about particles held by Scottish children. Pfundt (1981) and Kircher (1981) have done research with children in Germany. More recently, Nussbaum (1985) and researchers in the Children's Learning in Science Project have investigated secondary pupils' ideas about particles and basic chemical concepts (Brook *et al.*, 1984; Briggs & Holding, 1986). It is interesting that the confusions about this area of chemistry found by these workers are similar to those found by myself in South Africa (chapter 5). These can be summarized as:

- Confusion about the nature of particles themselves.
Many learners have problems in appreciating the shape and size of particles themselves. The word particle itself can cause confusion; particles of sand, for example, being seen as similar to atoms and molecules. If this is true for first language speakers of English, it is not surprising that the problem also exists for Zulu learners.
- Attributing macroscopic properties to particles.
Learners may use everyday experiences to interpret ways in which particles might behave, often attributing bulk properties such as melting, expanding, contracting, floating and even exploding to them.
- Confusion about the motion of particles.
Commonly held ideas include the following:
 - Particles only move when they are heated (i.e., they need something to keep them moving).
 - Particles stop moving at 0°C.
 - Air particles always move upwards.
- Confusion about bonding/ forces between particles.
Many learners have problems in conceptualising bonding and the way in which it changes from solids to liquids to gases. For example, many learners associate evaporation with bond breaking.
- What is in the space between particles?
Learners often find the notion that a vacuum exists between particles very difficult to accept, particularly when considering liquids and gases. Air is the most commonly mentioned candidate for filling the gaps ("because air is everywhere").
- Attributing animistic properties to particles.
Learners may consider that particles are alive.

One delightful example of how learners can construct confused understandings is given by Arnold (1983) who reports that a new entity called the 'molecell' exists. The cell is a small part of living matter. The molecule is a small part of matter. The cell has a nucleus. An atom in a molecule has a nucleus. It is not surprising that learners may not clearly distinguish between the concept of the cell and the concept of the molecule — hence the molecell.

Karplus (1980) classifies scientific concepts into various levels in terms of their abstractness. These are:

- First level (specific), e.g. force, electric charge, wave length, temperature
- Second level (intermediate), e.g. particle, motion, inertia, elasticity
- Third level (general), e.g. object, property, interaction, reference frame.

As an intermediate concept, it is likely to be more difficult for pupils to be able to define and construct mental models about particles.

The key to understanding how different alternative conceptions such as these arise appears to me to lie in coming to terms with how language is used by learners in storing and processing scientific concepts. Both the descriptions briefly outlined below describe cognitive hierarchies and in both studies the role of language in building up an effective cognitive system is stressed.

Champagne *et al.* (1983) describe the way knowledge is stored in memory as a hierarchy of concepts, propositions, microschemata and macroschema. They contend that learners' 'naive macroschema', derived from their previous experience in the world, affect all other levels of the hierarchy. Also, frequently there is a lack of integration between various microschemata and this means that contradictions between pieces of knowledge are not identified by the learner. The two notions of the influence of previous experience and of fragmented knowledge are central to

understanding how children build up alternative frameworks in science.

Reif (1985) describes five modes of concept interpretation. These are knowledge fragments, standard cases, types of cases, feature specification and procedural specification. Only in the last two does the learner actively seek an overall system for storing and processing knowledge and thus avoiding contradictions in the memory store.

It is valuable to consider research on how learners store and process information. Johnstone's Chemical Education Group at the University of Glasgow have produced evidence that individual learners have a remarkably stable cognitive 'space' in which to hold data and perform thinking operations on that data (e.g. Johnstone & El-Banna 1986). This space is often described in terms of the number of totally unrelated pieces of information which can be independently manipulated at the same time. If the cognitive demand of any problem exceeds the limits of this space, the learner fails to solve it. However, if one can reduce the level of demand by combining several steps in the solution sequence, then the problem may become feasible.

Of course, one must distinguish between an analysis of what mental operations and knowledge are needed to successfully perform a task and an analysis of how individual learners actually go about performing a task. Data must be collected on learners' actual strategies and there is an increasing understanding that differing linguistic/ cultural backgrounds lead to differing concept profiles and problem-solving strategies.

In summary, learners form unhelpful alternative conceptions because:

- They are not aware of, and cannot use, the rich background of experience they bring to their science studies.
- They cannot adequately process the information being presented to them during their current schooling.

Language, culture and learning

How can one access a child's rich language and cultural background when a westernised model of science is being taught, largely through the medium of English? All children bring a great deal of cultural experience and knowledge with them to school. This is implicitly used and valued when the child's language and culture more or less match that of the school system but when the child is learning in a second language/ second culture situation, the richness of her/his background is often largely ignored. This mismatch between children's linguistic and cultural background has been well documented (e.g. Maddock 1981, Prophet 1990). This section will attempt to explore how this situation might be improved.

Let us explore the following two questions:

- How is language related to thought?
- How does the cultural context of an individual relate to the planning and implementation of an educational context which will allow that individual, and hence the society, to develop wisdom and creativity?

These are both very complex and controversial questions. There are no fixed solutions but there is the possibility for broadening our own frameworks on these issues.

- ✓ Language is heard, spoken and written. Language to Vygotsky (e.g. 1986 translation) is a 'psychological tool'. His discussion of dialogue as a mediating process in the blending of intuitive or 'spontaneous' concepts with formal taught 'scientific' concepts to form coherent conceptual frameworks is entirely consistent with a constructivist view. The uniqueness of an individual's conceptual structure comes partly from the way in which social, interpersonal communication links with the intrapersonal dialogues one has with oneself. Vygotsky describes the dialogical character of learning as occurring within the zone of proximal development (ZPD). Here the weaknesses of personal spontaneous reasoning are compensated by

the strengths of scientific logic. This meeting of one's inner and outer worlds is essential for learning and is mediated by language. To Vygotsky, language influences the nature of inner speech by giving a culturally based order to our memories; as we also use language (asking ourselves questions) to recall memories back to mind, this cultural order is reinforced (McCrone 1994). In this sense, learning is cumulative; as one's rich store of psychological associations with a particular concept grows, so does the understanding of the concept. Vygotsky distinguishes between 'word meaning' which is like that of a dictionary, and 'word sense' which is this personal sum of psychological associations.

Solomon's (1983) work on children's concepts of energy led her to see children as learning in two domains — everyday notions and scientific explanations. She comments that 'the deepest levels of understanding are achieved neither in the abstract heights of 'pure physics', nor by a struggle to eliminate the inexact structures of social communication, but by the fluency and discrimination with which we learn to move between these two contrasting domains of knowledge' (p. 58).

A great deal has been written about the links between a learner's personal conceptual network and the external environment. Clearly the learner's perceptions about cultural patterns and values form part of that environment. As does her/his shared experience with others about previous experiences. That shared experience relies heavily on language.

One can contrast Piaget and Vygotsky, though straight contrasts are somewhat simplistic. Piaget is concerned with maturation, i.e., with internal generative mechanisms of development. Vygotsky focuses on social mediation, i.e., on external generative mechanisms of development. This is a useful distinction provided it is used to focus on the need to consider both individual and social influences on learning.

There is a continuum of possible hypotheses about the relationship between language and ideas. One extreme end of the continuum is

the proposition that language shapes thought very closely and that individuals who speak different languages actually differ in how they think. This is the celebrated Sapir-Whorf hypothesis (named after Edward Sapir (1884-1939) and his pupil Benjamin Lee Whorf (1897-1941), e.g. Whorf 1941). Proponents of the other end of the continuum propose that ideas determine language and there is a universality about human cognition and capacity for language (e.g. Chomsky 1968). Most modern linguistic ethnographers would take up a position somewhere in the middle. For example, Hudson (1980 p. 84) has produced a model showing interrelations between thought, language, culture and speech which is shown in figure 4.2. In this model, thought is the large box. Within thought, the range, scope and emphases of a language (and its embodiment as speech) are linked to its cultural setting. His model depicts language as being formed by conceptual thinking, rather than by propositions. The articulation of propositions in speech is seen as arising from both the language store and cultural experience. My own image of the process would involve a feedback process whereby the experience of speech, often shared and refined with others, alters and enriches language capability and the cultural patterns in which language is embedded. Perhaps the arrows should be two-way.

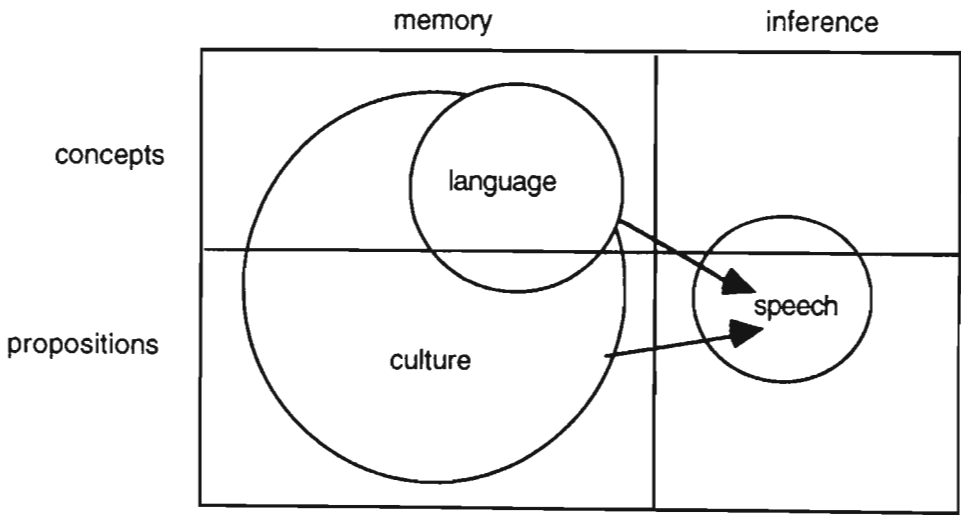


Figure 4.2 The relations between thought, culture, language and speech (from Hudson 1980 p. 84)

Hewson (1988) takes a relativistic position similar to that of Levi-Strauss (1966). This is that there is a universality about human strategies for seeking knowledge about the world. All cultures order, classify and systematize information. However, different cultures select different materials on which to operate, 'that is the operations are the same although the content is different' (p. 320). The way in which language has developed is a key factor in the selection of materials.

Wilkinson (1975 p. 66) summarises this well. 'There is general support for the 'weak hypothesis' that language influences thinking, but less support for the 'strong hypothesis' that it determines thinking.'

No simple model is adequate. Kaplan (1984) describes literal knowledge as a focussing or mediating mechanism in 'the rich interplay between the open concrete world and the open world of intelligence' (p. 76). Much of this mediation is at an unconscious level. A huge number of questions present themselves about how this mediation process might occur. What are the links between mental images or representations and language? How do metacognitive processes relate to language? Are the links between language and thought different for thinking at different levels of cognitive complexity?

A valuable way to consider several of these issues is to examine the role of metaphors in the formation of concepts. Hesse (1963) considers that models or analogies are essential to the process of developing scientific theories. The process of matching mental models with experimental observations can involve positive, negative or neutral analogies. Collins & Gentner (1987) have produced a elegant description of how individuals select and combine analogies in quite different ways to produce their own unique working explanations of evaporation.

Language metaphors are an integral part of our way of understanding the world. They are the way in which we use

language to express the mental analogies we are playing with as we think. Sutton (1981) analyses many scientific metaphors used in English, showing how they arise as learners attempt to make meaning. Biology has many examples — ‘messenger’ ribonucleic acid, ‘cells’ and the ‘lock and key’ explanation for enzyme and substrate. Such metaphors enable the scientist to develop testable predictions and thus gradually to develop and refine useful models.

Modelling often involves the construction of mental images — of internal visual metaphors. External visual metaphors (graphical or visual ways in which links are made between existing and new knowledge) can also trigger the production of useful questions which enable the learner to progressively explore, predict, test and refine models. [The relationship between spoken and written language and visual material such as pictures and diagrams in text books, slides, video and film material is another dimension of this complex situation. This research focuses on spoken and, to a lesser extent, written language, though some exploration was done with diagrammatic material in 1986 (chapter 5).]

Solomon (1986) illustrates how difficult it is for many students to construct explanations which develop and formalise their metaphors to the level of theoretical modelling. She advocates more conscious attention to language activities in the teaching of science. Pope & Gilbert (1983) also point out the importance of examining how metaphors are constructed by learners in order to make meaning of new knowledge. Sutton (1980) discusses how, for a child particularly, the meaning of a word is not its definition; it is rather the sum of all the connections that the child makes with the word. He describes work with burr diagrams which indicate how children’s concepts develop as they make more connections between ideas, objects and experiences. In later work, Sutton (1992) focuses not only on individual exploration of meanings; he examines the need for the learner to move towards some accepted, precise scientific meanings. This tension between facilitating individual exploration and yet insisting on scientific correctness is a challenge for teachers.

Forming basic concepts in chemistry requires much more imaginative, personal, mental picture-making than is often acknowledged and this process involves talking with one's own self as well as with others. Language is intimately tied to this process and hence to concept formation. The common use of metaphorical language may be more essential to concept formation than has usually been recognised; learners need to construct metaphors to enable them to fit new knowledge into existing mental frameworks.



It is this framework of progressively developing models through a process of metaphorical association, asking questions and testing ideas, that is central to understanding how learners form and use scientific conceptions.

Most of the studies mentioned above are based on work with first language English-speaking students learning in an environment where English is the acknowledged medium of instruction. What other factors need to be considered when talking about learning science in a language/ cultural setting which is other than one's first language/ cultural setting? The discussion above points to the importance of considering the distance between the learner's previous and ongoing experience outside school (which includes linguistic, cultural and physical activities) and the formal activities of learning western science in a school environment.

There are now many reports of cross-cultural work in science education. Wilson (1981) provides an excellent bibliography for further reading in this field, although little of the work he cites involves a specific analysis of learners' first language. Much of the literature (e.g. Stevens 1976, Curtis & Millar 1988) which addresses problems of learning in a language other than one's first language considers this distance problem from the perspective of how to assist learners to accommodate to the western perspective of the school. The metaphor of two-way traffic does not apply to any significant degree.

Adey (1982) discusses learning studies conducted within a cross-cultural Piagetian framework. While there are serious research design problems with many of these studies, he supports the general validity of such cross-cultural studies. The notion that learners all the world over go through more or less the same stages of cognitive development is not surprising; what do appear to vary significantly are the ages at which various stages of development are reached. As Hewson (1981) suggests, the translation of these differences in level of cognition in terms of various theories of deprivation is of highly questionable validity. A more fruitful line of investigation has been to link the ideas mentioned above of children having previously formed conceptions which may inhibit school learning to examinations of how this problem is exacerbated by a school environment which is largely based on a western model of education and ignores the knowledge that children bring with them to school.

In the work being done in the UK (and elsewhere) with learners who have English as a first language, the kinds of alternative conceptions in science are similar to the sort of results I obtained with the students at Indumiso College of Education in 1986 (chapter 5). This is really not surprising because of the similarities of western science curricula world wide. What is interesting are the subtleties in the differences between results for first and second language speakers of English. When speaking about particles with me in 1986, the Indumiso students frequently said that "Zulu doesn't have the right words". The differences in vocabulary between English and Zulu are obviously important but there is much more, I believe, to consider. We need to consider much more carefully how the linguistic structures of a language influence the nature of concept formation.

The discussion above focused on the centrality of metaphors in the construction of meaning. This idea is important in English but much more so in African languages which lack specific words for specific scientific concepts. The structure of a language evolves together with the culture of the people who speak it and a sociolinguistic analysis of how people describe phenomena and

explain concepts in a language other than English may well bring greater understanding about how learners operate in a linguistic situation which is at the interface between two languages. ✓

A simple example about linguistic structures in the Shona language in Zimbabwe may be useful at this point. In Zimbabwe English is the main medium of instruction with the home language only being used in lower primary classes. In many respects Shona and English are very different. For example, in Shona the category system is quite explicitly built into the language and requires the speaker to use classification criteria other than those common in English. Consider:

shiri inobururuka	a bird can fly
mhashu inobururuka	a locust can fly
nhungi inobururuka	a fly can fly
but	
gonola rinobururuka	a vulture can fly
gunguwo rinobururuka	a crow can fly
hwata rinobururuka	a secretary bird can fly
and	
muremwaremwa unobururuka	a bat can fly

(Robson 1974 p. 25)

According to this classification, a bird, a locust and a fly are grouped together; a vulture, a crow and a secretary bird are part of another group, while a bat is assigned to a class of its own. There is a clear logic to this classification — one based on a rich mythology. However, a Shona child learning science will discover to her/his dismay that a bat will be classified along with other mammals and that a bird cannot be assigned to the class of insects. The traditional classification system is ignored and devalued.

It is useful to note here that Zulu does not exhibit such a clear classification system. There are 15 noun classes in Zulu, though classes 12 and 13 are no longer used. While one can see some classification logic in some of the decisions about assignment of

nouns to classes, the noun classes are basically phonetic and do not reflect cultural classification systems.

Investigations in Israel (Stavy & Wax 1989; Stavy, Wax & Erickson 1992) have found links between Hebrew children classification of plants as being non-living and linguistic factors. The Hebrew word for 'animal' is very close to the word for 'plant'. In contrast, the word for 'plant' does not include the word for 'life' or any of its cognates. They conclude that the English language supports the development of the conception of plants as being living things while the Hebrew language inhibits this process, and that Hebrew science educators needs to engage with this aspect of the language.

Cain *et al.* (1989) describe the Zulu child's understanding of lightning and how there are many points in this spiritual understanding which can interface with the an explanation based on electricity. Quinn & Holland (1987) discuss studies in several communitites which link people's explanations of domestic heating to family relationships in the community.

Cross-cultural linguistic studies have shown different conceptual profiles across a range of cultures. Szalay & Brent (1967) used simple word association techniques in their studies on social concepts with American, Columbian and Korean students. Isa & Maskill (1982) also used word association techniques in their study of Scottish and Malaysian children's understanding of science concept words. The existence of differences between different cultural groups is not surprising.

Some more recent work of interest in this area has been done by Ross (1982, 1987). He used word association techniques and translation exercises in his work on his work on heat, fuels and burning with Nigerian pupils and teachers. He managed to elicit various concept profiles and has shown that learners not only have distinctly different profiles but also that many differences can be traced to linguistic sources. His short translation tasks appear to be more reliable than the earlier verbal association strategies.

However, all his tasks were written ones and there is clearly a need to collect data by taping spoken language.

The main point being made by these and other studies is that knowledge about cultural differences in concepts can be used as a valuable starting point for science teaching. These studies do provide valuable information about how to link learner's previous experiences with the science they learn at school. The situation needs to be two-way and the value of cultural links seen as important in the construction of appropriate curriculum activities.

Implications for curriculum development

Research has shown that pupils in all countries have unhelpful alternative conceptions in science. These they may bring with them to school or develop while studying formal science at school. Schooling is successful when children manage to convert their everyday ideas about science into scientific knowledge which helps them understand their environment more fully. However, often schooling is inadequate and this transition does not occur. One of the essential tasks of science educators is to use the information on alternative conceptions and levels of concept development, incomplete though it certainly is, to improve science teaching strategies, curriculum materials and teacher education programmes. As Hewson (1981 p. 199) puts it: 'If alternative conceptions are overlooked, they inhibit learning, but if they are explicitly dealt with, they facilitate learning.'

There seems to me to be two main requirements for curriculum development work:

- That articulation and discussion become central activities in science lessons

Practical work is more than the manipulation of equipment by pupils or, as happens in many South African schools, by teachers only. It is a waste of time unless pupils are allowed to explore the meaning of what they have done and seen through a process of

conscious articulation. How much of this discussion should be in English is a difficult issue but it should probably be more than occurs at present.

Viennot (1985) supports this idea, and perhaps goes further, when he discusses how to enable students to become aware of their own ways of reasoning. Teaching learners some strategies of analysis and problem-solving is also advocated by Reif (1985). My own feeling is that in many schools in developing countries getting children to talk about science is the first step and that conscious articulation of specific learning strategies is somewhat further off in time. In the work described in chapters 9 and 10, the production of curriculum materials which build discussion activities about practical work and around diagrams will be outlined.

- That teachers must be involved actively in the curriculum development process

The need for on-going professional development of teachers is well recognized in all countries. It is clear that this need is more urgent and more crucial in developing countries where the standard of initial teacher qualifications is so low. Science education upgrading projects which concentrate on the professional growth of teachers are much more successful than those which concentrate on the provision of curriculum materials alone. O'Donoghue & McNaught (1991) describe the success of an environmental education curriculum project when it changed its focus from materials dissemination to collaborative production of resources with teachers. The Science Education Project in South Africa (Gray 1985) is another example. In this project well-designed equipment and worksheets are provided together with an ongoing programme of in-service courses and school visits. However, the real strength of the project lies in the setting up of what is called a zonal support programme for teachers. In this aspect of the Science Education Project's work, teachers are assisted to set up their own groups for mutual professional support. Regular meetings to discuss day-to-day science teaching

problems, the production of a newsletter, organisation of outings and lectures, etc. are taken on as a responsibility of these zonal groups.

The sheer numbers of poorly-qualified teachers involved in education systems in developing countries means that a commitment to teacher involvement in the design and writing of curriculum materials is a huge task but through teacher networks, responsibility for this work can be effectively handed to teachers. It is a long-term goal but not an unrealistic one.

In education systems where teachers are more highly qualified, several different models of teacher involvement have been suggested. For example, Erickson (1981) has suggested a system whereby the analysis of classroom questionnaires can lead to teachers being able to select specific teaching manoeuvres. The combination of well-researched strategies for identifying individual learner's conceptual profiles together with well-tested teaching strategies and materials is a marvellous goal but sounds rather Utopian to me in the context of black schools in South Africa. However, the notion of groups of teachers discussing their pupils' performances and then having several possible strategies to use in planning lessons is a realistic possibility. Ziervogel (1993) describes such a project with Biology teachers in KwaZulu.

Summary

Near the beginning of chapter 3 a model for the impact of critical constructivist theory on teacher development and curriculum development was presented (figure 3.2 page 17). This framework espouses a constructivist learning perspective, an open and inclusive view about science and a critical social perspective. It integrates research, teacher development and curriculum development within an action research methodology. This model has influenced the research²⁵ to consider issues which confront learners at the interface between Zulu and English which is presented in the following chapters. Four points from chapter 3 and 4 are especially important in the following chapters:

- Research on language and learning suggests that effective learners use a process of metaphorical association, asking questions and testing ideas, in order to form and use scientific conceptions. Articulation and discussion are central to this process.
- ✓ • Learners form unhelpful alternative conceptions partly because they are not aware of, and cannot use, the rich background of experience they bring to their science studies.
- ✓ • Learners form unhelpful alternative conceptions partly because they cannot adequately process the information being presented to them during their current schooling.
- Teacher development is essential in any programme which attempts to address language and learning issues.

Chapter 5 Teachers' alternative conceptions about basic chemistry

Indumiso College of Education

In this chapter work done at Indumiso College of Education at Imbali near Pietermaritzburg in Natal/KwaZulu in 1986 will be described. Indumiso College is a black college of education. In 1986 I interviewed all the Physical Science students at the college; these students were training to be physical science teachers at secondary schools. The interviews were about some basic chemical concepts in junior secondary science and about teaching strategies for this level.

Indumiso College is a fairly new black college of education (opened in 1981), training both primary and secondary teachers. In 1986 there were over 1 000 students at Indumiso. The Science Department is well-equipped and the staff are enthusiastic and competent. In 1986 all the staff were English-speaking. The academic quality of the intake of students is better than at many other colleges of education in South Africa. Even so, many students have very poor school science results and almost all the students will have been taught at school by rote-learning techniques with little or no experience of practical work in science.

There were thirty students in 1986 training in the Physical Science stream at Indumiso, more or less equally spread over the three years of the diploma course. The diploma is called the Secondary Teachers' Diploma (STD). The interviews were conducted after a period of time when I joined classes at the college and felt known and accepted by the students. The interviews were largely with two or three students at a time (Table 5.1). Fourteen interviews were conducted. This decision was made in order to make students feel more relaxed and secure. The students' level of spoken English was high (their first language is Zulu) but the richness of the interviews was greatly increased

by the interchanges between students as well as the direct answers to myself. Obviously, with this technique, individual student profiling is not possible; in this exploratory situation, the group interview strategy which was chosen was felt to be the most appropriate one.

Getting all the interviews done was difficult because of the security situation at the time. Seven interviews had to be rescheduled because of a particular problem which had flared up on that day. On four of these occasions, I could not be contacted and travelled to the college in vain.

Table 5.1 Grouping of students for interviews in 1986

No. of students in each group	No. of STD 1 students. (No. of groups in brackets)	No. of STD 2 students	No. of STD 3 students	Total no. of students (and groups)
3	3 (1)	3 (1)	6 (2)	12 (4)
2	8 (4)	6 (3)	2 (1)	16 (8)
1		2 (2)		2 (2)
				30 (14)

The structure of the interviews

There were two main aims for these interviews. The first was to explore students' understanding of the particle model of matter and basic chemical reactions. The second was to explore their ideas on teaching strategies for these topics in terms of pictorial representations and discussion strategies. The interviews varied in length between 40 minutes and an hour, the longer ones being because of students' questions. All were audiotaped. There was

little difference in the overall quality of understanding between the students at different stages of their diploma and no explicit breakdown will be given here. The science staff at the college were not surprised (though somewhat disappointed) by the fact that unhelpful alternative conceptions about very basic ideas in chemistry persisted throughout the entire three-year college course. They felt constrained by the rigid syllabuses used at that time; they experienced great difficulty (as I did) in engaging students in much debate about scientific ideas; and they were aware of the increasing gulf between college life and the reality of the surrounding townships.

The experience of boiling water

The interviews began by considering what happens when water is boiled in a mug using a small immersion heater. The steam is allowed to condense on a tin lid. The advantage of the immersion heater over a bunsen burner or spirit burner is that the immersion coil provides a readily observable nucleation site for bubble formation. Only half the groups could distinguish between the expulsion of dissolved air and the formation of bubbles of steam. There was confusion between the terms 'boiling' and 'evaporation' in all the groups. Indeed the first occasion when I began consciously to consider how my research could focus more on language was when one student asked me about the difference between 'steam' and 'water vapour'. He said that different words are used in Zulu — *umusi* or *umhwangulo* for 'steam' and *umoya* or *umhwamuko* for 'water vapour'. It was clear that whatever images his Zulu words conveyed were not the same as the contextual distinctions we use in English.

Incidentally, detailed research by Bar (1986) with children in Israel has found that many children find it difficult to develop a useful model for evaporation.

Half the students believed firmly that water breaks into hydrogen and oxygen on boiling and that these fragments recombine on condensation. It should be noted that it is difficult to give exact

numbers of students who held any given alternative conception because, in some groups, students were unwilling to dissent from a firmly held belief of a peer in front of me. The general descriptive style I am using here seems to be most valid. In any case, it is the overall pattern which is important.

Most of the students understood that the temperature of the water increased until the water boiled and then remained constant; and that after that added energy went into changing water from the liquid to the gas phase. Only three students were really unsure about this.

What is a 'particle'?

Students were then shown sample tubes of sand, salt, syrup, flour, iron nails, iron filings, air and water. On the use of the term 'particles', all the students were certain that all substances are composed of particles. They were sure that the particles moved in air and vibrated (though few knew the term) in solids but about one-third of the students were very hesitant about the nature of particle movement in liquids. Half the students were unsure about classifying syrup as a liquid. All were certain that the particles in iron filings and iron nails were the same (though see a quote below on page 68) but many thought that they were more tightly packed in a nail than in a single filing.

I purposely allowed a lot of discussion using the term 'particle' before asking what I thought was the critical question:

"We have been talking a lot about particles. Look at the samples of flour and salt. Tell me which has the smaller particles in terms of what scientists mean by particle."

Only one student could identify that, in scientific terminology, salt has smaller particles than flour. The others could after discussion about the chemical composition of salt and flour and after looking at a diagram of a starch molecule (figure 5.1). (Many students did not know that flour was a carbohydrate.) The confusion between

'particle' and 'grain size' is a common one but it was interesting that many students commented on the difficulty they had with English words for which there is no Zulu equivalent. *Izinhlayiya* is the Zulu word for 'particles' but has no connotation of being unseen, of being too small to be visible.

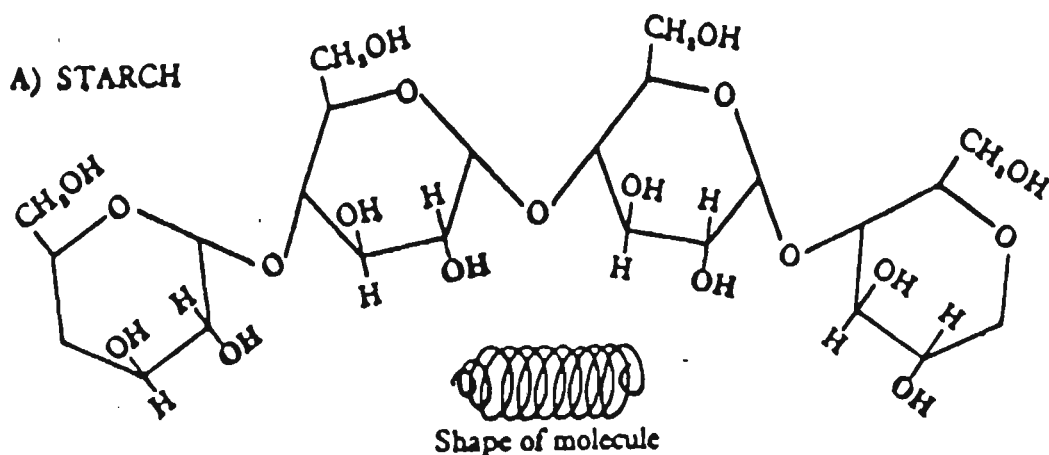


Figure 5.1 Diagram of a starch molecule used in interviews in 1986 (from Roberts 1976 p. 67)

As noted in chapter 3, page 21, I made no attempt to conduct objective interviews. The situation was as much a teaching one as a data collection one. While the interviews were exploratory and therefore fairly general in design, I did focus on some aspects of students' understanding of the particulate nature of matter. Alternative conceptions found in the research literature are listed in chapter 4, page 47. Four of these confusions are clearly shown in these interviews. They are reproduced here with some appropriate quotes from the interviews.

- Confusion about the nature of particles themselves

"The bubbles are bigger particles."

"The molecules of flour are large and the particles are small."

“The particles in iron filings and iron nails are the same.”

Later, the same student ... “The particles in iron filings are shaped more like rods.”

“Particles are just smaller than what we see. So particles of flour are smaller than particles of salt.”

- Attributing macroscopic properties to particles

“The particles are expanding as the electricity makes them hot.”

- Confusion about bonding/ forces between particles

“It breaks into hydrogen and oxygen.”

Carmel “What is the steam made of?”

Student “It is oxygen.”

Carmel “Where is the hydrogen?”

Student “It has disappeared.”

- Attributing animistic properties to particles

“Molecules are excited.”

“The molecules want to get out of the hot water.”

“The hydrogen and oxygen are now free from each other.”

One must be careful not to read too much into these quotes. Some of them will be due to firmly held alternative conceptions about the particulate nature of matter; some will be due to casual, colloquial use of language. What is of concern is that the way in which teachers express themselves has profound implications for the way students will learn the concepts.

It is worth noting that a study of predominantly English-speaking South African secondary science teachers (33) and student teachers (26) revealed that the majority of these teachers had serious misconceptions about chemical bonding. Bradley, Gerrans & Matthee (1989) conclude that 'one source of pupil misconceptions about chemical bonding is likely to be the teachers' own misconceptions' (p. 641).

Elements, compounds and mixtures

Students were asked to classify the samples of sand, salt, syrup, flour, iron nails, iron filings, air and water into elements, compounds and mixtures. They only had problems with syrup and flour, which most students thought were compounds. The concept of mixtures of compounds was clearly very confusing.

However, all students could give clear definitions of the terms element, compound and mixture — a clear demonstration of the fact that learnt definitions do not necessarily imply conceptual understanding. This confusion was also clear when the reaction for the formation of iron sulphide was discussed.

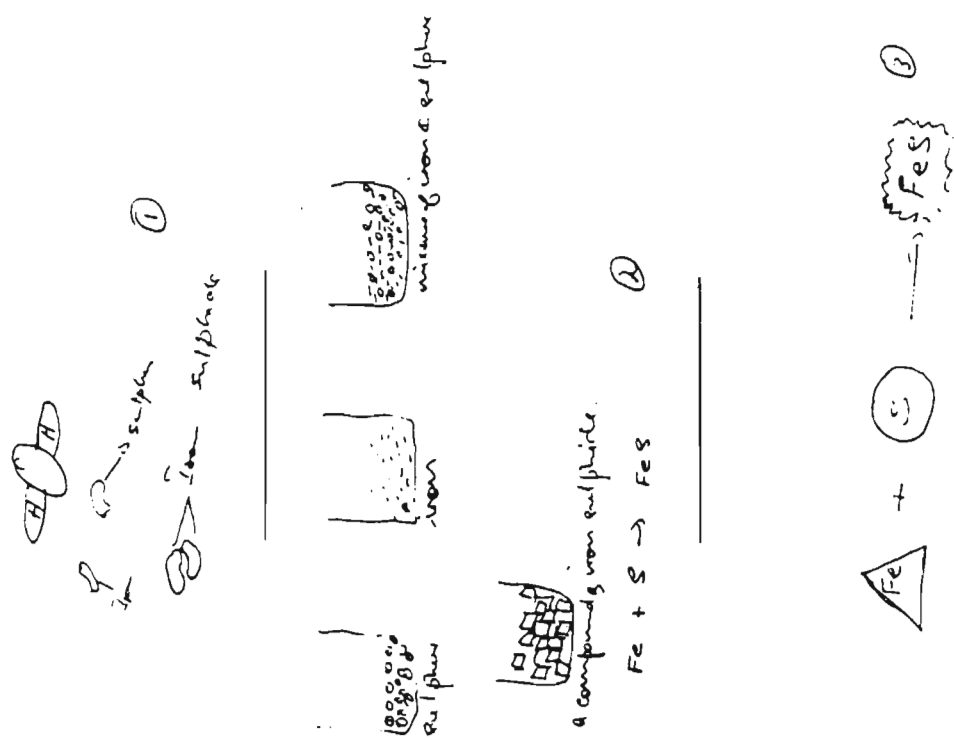
The reaction, iron + sulphur \rightarrow iron sulphide

I then showed students sample tubes of iron filings, sulphur powder, two different mixtures of iron and sulphur and of iron sulphide lumps. The reaction, iron + sulphur \rightarrow iron sulphide, is explicitly taught as the introduction to chemical reactions in South African schools. Yet, only half the students (14) could write the chemical reaction easily. Three students tried to use S_8 rings in their equations; eight students wrote a formula which was closer to sulphate than sulphide. None of the students could identify the lumps of iron sulphide, even though many of the students said they had actually done the experiment. The importance of the fact that I could show two mixtures of iron and sulphur was not clear to the students, though they could identify which one had more sulphur, and most of the students knew that the mixture could be separated using a magnet.

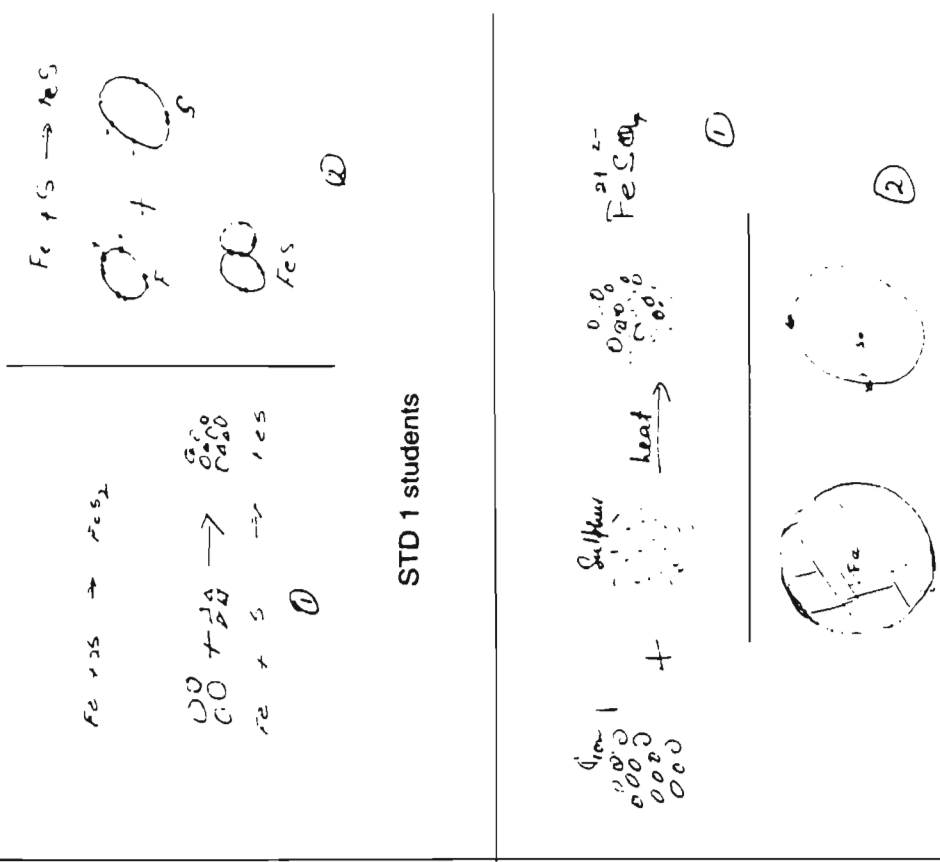
Pictorial representations of reactions

I asked the students to draw diagrams for me which they could use in trying to help pupils in schools understand what was happening to the particles of iron and sulphur when they reacted to form iron sulphide. No students were able to do this at all well; some examples are shown in figure 5.2. The idea of using diagrams in this way was completely foreign. For pupils and teachers to try to express their understanding in pictorial ways was a new idea to these students. I then showed them figures 5.3 and 5.4 (Bavage *et al.* 1985, McNaught *et al.* 1984a). These are diagrams from two South African junior secondary science texts, though figure 5.3 is from an English book which has been adapted for use in South Africa. The discussion about these two diagrams, when they could be used and how they could be used, was lively and enthusiastic. The advantages and problems of various pictorial representations were quite thoroughly explored; for example, the idea of using different sized circles for Fe/Fe²⁺ and for S/S²⁻ entities but not necessarily explicitly bringing this to pupils' attention; or the possible problems of showing iron sulphide as a fusion of iron and sulphur. One student said:

"I have never discussed the learning of chemistry in this way before; this is good."



STD 2 students



STD 3 students

Figure 5.2 Student teacher diagrams of the reaction between iron and sulphur produced in interviews in 1986

- STD 1 students — Secondary Teaching Diploma Students, year 1
- STD 2 students — Secondary Teaching Diploma Students, year 2
- STD 3 students — Secondary Teaching Diploma Students, year 3

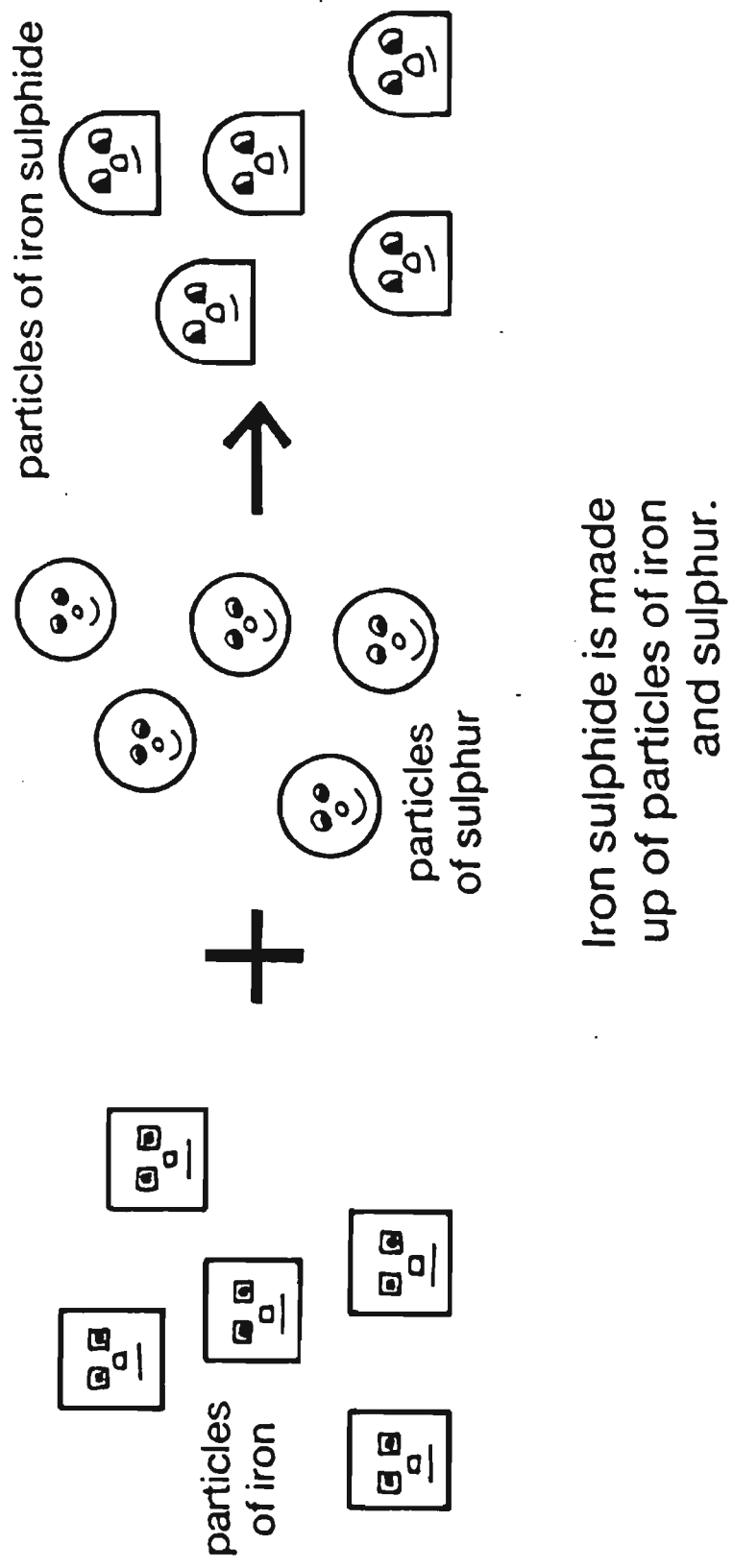


Figure 5.3 Diagram of the reaction between iron and sulphur used in interviews in 1986 (from Bavage *et al.* 1985 p. 52)

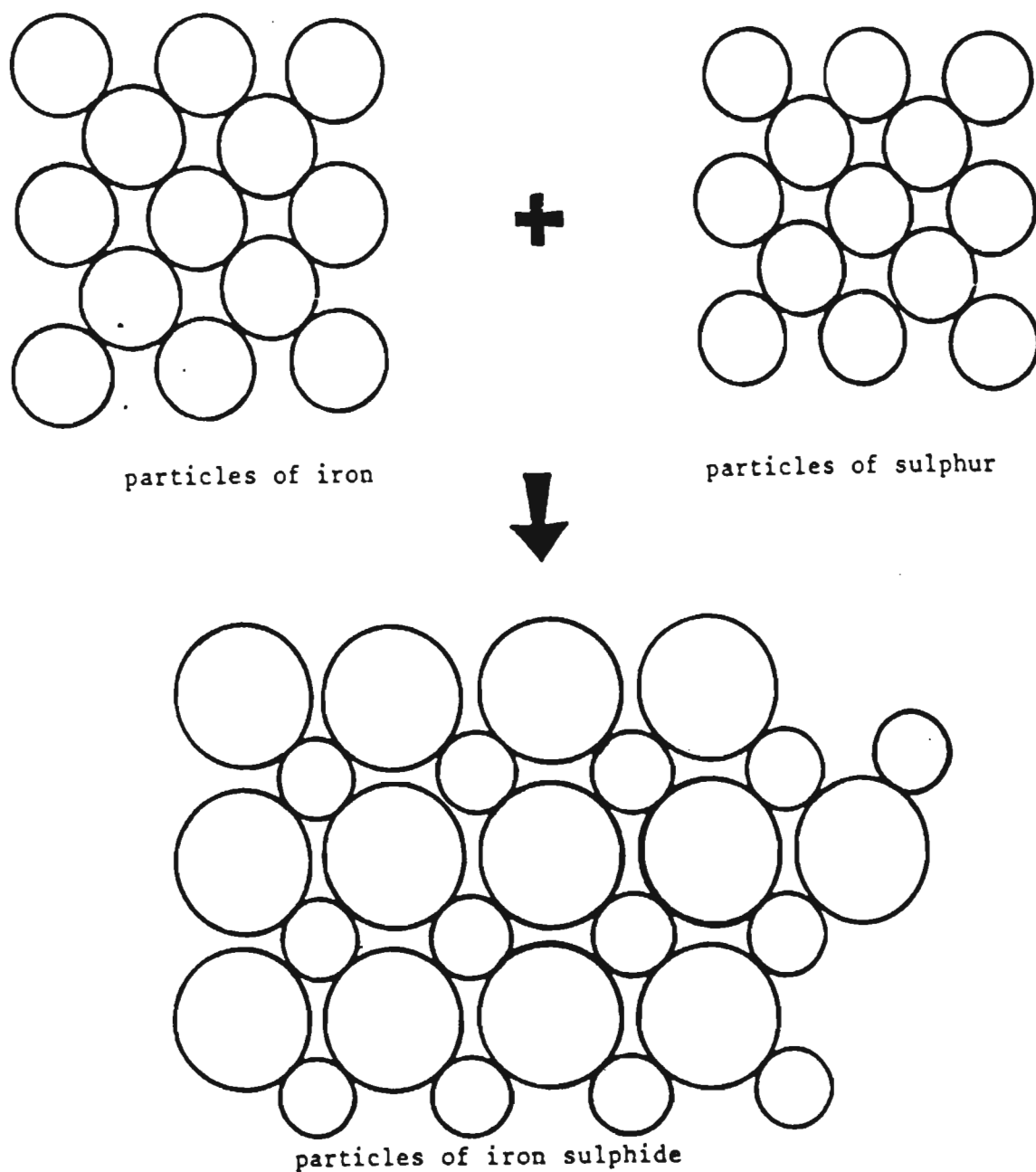


Figure 5.4 Diagram of the reaction between iron and sulphur used in interviews in 1986 (from McNaught *et al.* 1984a p. 93)

(Fe and Fe^{2+} particles shaded in interview diagrams)

In this research in 1986, the students found pictorial representations of the particle model very difficult to work with. I did not pursue this work in the research in 1988 and 1989, though learning more about this difficulty and seeing if it is linked to blocks in learners' own strategies for forming mental images about chemistry would be very valuable. It is worth mentioning that in the years 1987-1990, I devised an activity which was used with Higher Diploma in Education (HDE) General Science Method students. The activity was simply structured along the lines of the interviews described above. I also included three dimensional models which were made with balls with diameters in the ratios shown in figure 5.4. Most of the students were English-speaking South Africans. All the students found discussing how one can use physical models and diagrams to facilitate pupils' development of images of the particle model and chemical reactions to be challenging and useful. The materials produced by the Children's Learning in Science Project (1984a&b) were also used in these classes. This is mentioned because research should impact on one's teaching and the Indumiso interviews were a particularly valuable experience for me.

While I did not pursue the area of pictorial representations any further, it is clearly an area deserving further attention in South African science education. There is some evidence in the literature that pictures may not universally be of value to learners, e.g. Bottrill & Lock (1993) working in the UK and Schollum (1984) working in New Zealand. Pictures used may not be as clear as the text, and may reinforce or create unhelpful conceptions.

Teaching in South African black schools

The interviews concluded with a general discussion about facilities in South African schools. Black schools are poorly equipped and it is common to find 50 or 60 pupils in each class in urban secondary schools. The students do not seem committed to group work for practical work (e.g. with improvised equipment

which is taught at the college) or discussion activities. Most felt overwhelmed by the difficulties of the classroom situations in which they will work. They agreed that discussion was important but most felt unable to implement this idea. This is hardly surprising after the formal teacher-dominated education they have been through and indeed the authority structure within the Zulu culture.

What was most interesting was students' lack of commitment to working in English for their own studies. Even at college level, students discuss science in Zulu unless speaking directly to one of the lecturers. Their own ambivalence about deciding how much of their own formal science studies should be in English does not indicate a likelihood that their pupils will be encouraged to discuss science in English. This is a real problem. It seemed to me to indicate the whole problematic area of school science being divorced from the reality of the pupils' and teachers' lives. In South Africa such a schism is highlighted.

Overall the interviews were fun. All the students agreed that they had refined their ideas and had new thoughts to reflect on. So, the experience was a positive and productive one. But what I became increasingly uneasy and frustrated about was that the students appear to divorce their interest in physical science from the realities of Indumiso College in 1986 with police raids, detentions, suspensions, military presence, etc. At one particular period, on entering the college, the normal procedure was to undergo a car search and then to wend my way through an obvious military presence before reaching the college buildings. There was a definite sense of relief when I reached the 'rational', familiar atmosphere of the Science Department. I suspect that the students felt the same. So what of my belief that science education is involved with the process of individuals making meaning of their lives? At present this is just not happening. Black pupils and teachers feel alienated from the existing system of education and do not hold its knowledge as being relevant to the solution of the problems they face daily. The situation may well be more extreme

in South Africa but such problems of alienation exist in many developing countries.

Summary

This chapter reports some fairly conventional science education research that I did in 1986. During that year I interviewed all the physical science students (30) at Indumiso College of Education about their understanding of basic concepts in chemistry. The interviews were discussions between groups of students and myself about chemistry concepts found in the school science syllabus at the junior secondary level. Physical concepts such as boiling and the separation of mixtures were discussed. Simple chemical ideas such as the meaning of 'particle' in chemistry and the concept of a chemical reaction were explored.

Many of the students' problems in chemistry seemed to stem from:

- Limited understanding of the particulate nature of matter
- Limited understanding of bonding and chemical reactions
- Low ability to apply their well-learned definitions of concepts to actual chemical examples
- Little skill in drawing or discussing visual models of chemical reactions
- ✓ • Little experience in discussing and articulating ideas and problems about chemistry.

It was clear that the process of the interviews was of major interest to the students and several students commented that they had never discussed ideas in science before. They mentioned in general terms that language issues were of major concern to them.

✓ However, they were unable to articulate just what these language difficulties were. They said that it was more than just the meanings of words; comments like "English is just so different" were made several times. It seemed important to me to begin to look more systematically at Zulu and English and the learning of science.

Chapter 6 Teachers' styles of explanation

Context of this part of the research

The context of this part of the research was described in chapter 3. It is summarised again here. During 1988, the main research focus was on analyzing teachers' explanations of science in both Zulu and English. In this part of the research, I studied the differences between teachers' explanations of basic chemical ideas in Zulu and in English. The teachers were final year students at Indumiso College of Education, preparing to be secondary school science teachers. The work was done with final year Biology students rather than final year Physical Science students for two reasons; it was logistically easier in terms of the college program and the class size was larger — 22 Biology students but only eight Physical Science students in 1989. Five topics were chosen — diffusion, osmosis, proteins, carbohydrates and lipids. These topics were in the biochemical part of the syllabus and so closer to the earlier research work in 1986 on basic chemical concepts.

Some students gave their lesson explanations in Zulu and some in English. Each topic was taught separately by two students; one taught in English and one in Zulu. Each lesson was about 30 minutes long, so five hours of videotapes were obtained. The teaching was done to peers at Indumiso College. This activity was linked to an assignment in practical teaching skills in Biology and so was taken seriously by the students. Permission was obtained from the Department of Education and Training and the rector of Indumiso College of Education and the science staff were very cooperative and interested. As with the work in 1986, a research diary was kept.

The English tapes were transcribed. The Zulu tapes were transcribed and directly translated word for word (that is, without interpretation) by Zulu-speaking research assistants who were third year B Sc students.

A comparison of the overall quality of the images conveyed by the lessons in the two languages was then carried out. By 'quality' I do not mean a superior/ inferior evaluation but more an exploration of the qualitative differences between the lessons in the two languages. As was stressed in chapter 3 this can be viewed only as exploratory work to give guidelines for the future.

All the students who presented lessons prepared written responses in Zulu to aspects of their lessons which I had identified during the lessons. This enabled me to check up on points which I had noted as being problematic during the lessons.

The process of interpreting the literal translation was done as outlined in appendices 1-5. Comments were made beside sections of the transcripts. These were reflected on and, after many readings, reflection and discussion with teachers, Zulu lecturers and my student translators, some generalisations emerged.

Different styles of explanation

Brown & Hatton (1982, p. 7) classify explanations in three ways:

- Interpretive. 'What?' questions which involve clarifying the meanings of terms, or issues, e.g. 'What are proteins?'
- Descriptive. 'How?' questions which involve descriptions of processes or structures, e.g. 'How are proteins formed?'
- Reason-giving. 'Why?' questions which involve reasons, motives or causes, e.g. 'Why did structures like proteins come to be? Why are proteins so important to life?'

In the lessons there were interpretive and descriptive explanations but almost no statements at all which could be classified as reason-giving. While the lack of the explanations which attempt to frame science in a wider context is not the focus of this research, it is worth noting this lack in passing, even though it is not surprising.

Brief description of diffusion lessons

These are presented in point form, so that comparisons can be more readily made.

Zulu

A lengthy story style with filler statements and rhetorical questions

Difficulty in explaining proportion, e.g. in concentration

No discussion of energy

No discussion of temperature

Anthropomorphism

No distinction between 'dispersion' and 'diffusion'

Problematic use of the term 'scattering'

English

Answers expected of questions

Motion of molecules and direction of motion described

Bonds mentioned

Particle model portrayed (even if poorly)

Diffusion gradient described

Distinction made between 'dispersion' and 'diffusion'

Written answers

Description of a diffusion gradient with one example

Sense of a physical slope associated with diffusion gradient

No example given

High and low concentration in connection with diffusion

Concentration defined in terms of closeness of molecules.

For both answers:

Anthropomorphic sense — 'to feel in strength/ power to move', 'molecules make haste very much' and 'there is a situation of satisfaction'.

Brief description of osmosis lessons

Zulu

Some confusion about which molecules (solute or water) move during the process

Molecules described as 'leaking' or 'oozing'

No explanation of concentration gradient

The phrase 'power of osmosis' implies that the process itself determines the outcome.

Some description of the type of membrane, e.g. the size of the holes

English

A weak lesson with a very formal style

Distinguishes between the concentration of the solute and the concentration of the solution

Uses term 'selectively permeable membrane' but doesn't describe it at all adequately. This aspect of a different sort of membrane was actually better in the Zulu lesson where the term was not used.

Written

Description of a semi-permeable membrane

Uses an example to give a context for the explanation and this is quite good. But the anthropomorphic feel of 'the knowledge of the potato' is problematic.

Brief description of carbohydrates lessons

Zulu

Preoccupation with the ratio of hydrogen : oxygen

Descriptive classification

Little structural discussion — only that glucose exists in a chain and a ring

Confusion between a structure and a formula, though this was a general confusion

Weak description of isomers

English

Uses properties for classification

Isomers explained

Dehydration of condensation mentioned, though this was not clear

Written

The difference between the chain and ring forms of glucose.

Diagrams may be used.

Very descriptive - 'condition of chain' and 'condition of being round'

No mention of chemical bonds

No diagrams

Condensation reaction between two monosaccharide units

Examples given of disaccharides

Process described as the meeting of two monosaccharides and the moving out of water.

A structural equation given

For both answers:

The Zulu word 'ncibilika' is used for both 'melt' and 'dissolve'.

This is used in both answers.

Brief description of lipids lessons

Zulu

Saturated = united. Some sense of no space for hydrogen to be added

Unsaturated = dispersed = spaces for hydrogen

Some link with melting point noted. This is described as degree of hotness which does not indicate a change of state.

There is a mention of an ester linkage but no explanation — just mention of the coming examination!

The word chosen for 'dehydration' is the same as that for 'drought'.

Some discussion of the functions of fats in the body

English

Weak and stilted in presentation. Teacher appears to be closer to the Zulu/ English interface himself than his peers.

Mention of structural and chemical formulae

Some mention of bonds

Written

Why some fats are solids and some (oils) are liquid

Needed to use the terms 'double bond' and 'single bond' in English

Described double bond as 'where hydrogens are insufficient'; no description for single bond.

Oils described as 'the one the one causing / forming / making that to be there fats concentrated that those it's liquid'. Very difficult to see what the meaning of 'concentrated' is in this context.

The nature of ester linkage

Here a standard and adequate description of the reaction between glycerol and fatty acids was given.

The structural formulae were shown.

Brief description of proteins lessons

Zulu

Concept of basic units called building blocks established. However, it was not clear whether the building blocks were atoms or amino acids.

Analogies used — the skeleton and the alphabet. This was the only time in the Zulu lessons that explicit analogies were used.

A good attempt to describe the process of dehydration.

English

High density of specialist terms

Discusses properties of amino and carboxyl groups

Quite reasonable description of in what order atoms are joined to each other.

Written

Description of a chemical bond and how bonds break and form during a chemical reaction

Described below

How amino acids link to form proteins

Amino acids are called 'builders'. Proteins are called 'builder bodies'.

The 'builders' give the 'builder bodies' 'signs', by which is meant properties.

Mention of carboxyl and amino groups but no description.

Word count of Zulu and English lessons

The transcripts were obviously different in length, though all the lessons were about 30 minutes in length. The word count results are given in table 6.1. For several topics there are many more words in the Zulu transcripts than in the English transcripts. The reason for this is not clear. It may be that these word counts show the economy of English which has developed a succinct scientific and logical vocabulary which is suited to western science.

Table 6.1 Word count of Zulu and English lessons

	Word count	Word count
Topic	Zulu lessons (of the literal translation)	English lessons
Diffusion	1020 (Zulu words rather than literal translation)	1185
Osmosis	579	401
Carbohydrates	2015	532
Lipids	1685	811
Proteins	899	903

General conclusions about the explanations in the lessons

The analysis of the transcripts was not easy or clear-cut. It revealed several interesting aspects of teachers' style of explanation with respect to the likelihood of the formation of useful science concepts in their pupils. The generalisations posed below are tentative and a great deal more exploration is needed in this area.

- ✓ • **When teaching in Zulu about processes (such as diffusion and osmosis), the teachers used explanations which were interpretive and descriptive (what and how?) rather in terms of the underlying scientific principles (why?).**

By this is meant that the teachers described how one can recognize diffusion or osmosis, but said little about the thermodynamic energy relationships involved. The English lessons contained a greater attempt at forming understandings about energy relationships. Obviously, one of the main aims of science education is to assist learners to understand the principles behind the phenomena they observe.

For example, an explanation of osmosis needs to discuss that, in any closed system, there is a drive to establish a dynamic equilibrium. The movement of water across a semi-permeable membrane occurs because of that energy relationship.

Of course, often the thermodynamic explanation is complex and was not given in either the English or Zulu lesson on a topic. For example, in diffusion, the movement of a substance from a region of high concentration to one of low concentration occurs because the entropy of the system increases. It is unlikely any of the students, or many science teachers, would be able to explain this in simple terms. The result is that the overall explanation is always descriptive. Where the differences between the Zulu and the English tapes occurred was in the discussion of the mechanism by which particles moved in terms of their own individual energies. In the English tapes this was much clearer.

It is interesting to note that the Zulu descriptive explanations were often very anthropomorphic. It is not clear how problematic this might be.

- **When teaching in Zulu about substances (proteins, carbohydrates and lipids), the teachers used explanations which are functional rather than structural.**

For example, the explanation of what a protein is was in terms of what proteins do (body builders), rather than in terms of how protein molecules are built up from their component atoms. The English lessons contained many more passages with structural

explanations. In chemistry, structural understandings are essential and the difficulty that Zulu appears to present in this regard needs to be noted.

The central issues here are the concept of a chemical bond and an understanding of how bonds change during chemical reactions. An adequate explanation of chemical reactions such as ester linkages (in the formation of lipids) and peptide linkages (in the formation of proteins) must have some mention of which bonds are broken and which bonds are formed. This occurred, to some extent or another, in the English lessons but not in the Zulu lessons. Bonding is a complex concept; an understanding of the nature of particles is required as well as an understanding of what energy changes occur when bonds break and are formed. The difficulties that learners have with the particle nature of matter was discussed in chapter 4, page 47. Less work has been done on bonding. Peterson *et al.* (1986) used a pen and paper test to investigate students' misconceptions about covalent bonding and structure but this is in a context where English was well understood.

All the students who presented lessons prepared written responses in Zulu to aspects of their lessons which I had identified during the lessons. The style and choice of language used in these written responses confirmed the comments I have made above about the oral presentations. Below is an example of a description of a chemical bond. Only the literal English translation is given.

Chemical bond

A member / part where combining there builders two or many they formed builder one bigger or big indeed. This combination / joining builders combining / joining they distribute electrons. This combination / joining it occurs in chemicals, that is why this happening is called chemical bonding. This combination / joining of builders can separate because of power *energy* (in English) or enzymes.

Several points can be made about this example.

It is very difficult to read and interpret text like this. It is clear why I wish to stress the tentative nature of this research.

This is only one example. There is no assertion that a more helpful description of a chemical bond could not be given in Zulu. Certainly my Zulu-speaking research assistants and students have said that it is not helpful but they did not know how to improve it.

The reason why this is such an unhelpful description of a chemical bond is the absence of any discussion of electrostatic forces and the role they play in the making and breaking of bonds.

Again, it should be stressed at this point that the aim of this research is not to see how Zulu can be used for the teaching of science, but rather to see what difficulties learners, who are familiar with Zulu but only marginally so with English, have in using the constructions and modes of explanation used in English. It is reasonable to suppose that the greater the disparity between the usage of Zulu and the usage of English, the more difficulties learners will encounter.

In the next chapter some exploration will be made of pupils' discussions in Zulu and English. Then, in chapter 8, issues arising from the translation of individual words will be explored.

Chapter 7 Pupils' discourse about basic concepts in chemistry

Context of this part of the research

As noted in chapter 3, it was decided to audiotape dialogues between pairs of learners who are school pupils at Edendale Technical College. Two simple exercises on standard 6 chemistry were constructed. One was on particles where pupils could discuss the meaning of the word as it is used in chemistry and also do two exercises to gain some idea about the sizes of particles. The other was on classifying substances into elements, compounds and mixtures where pupils could discuss the meanings of the words and classify samples of various substances. They were also asked to classify by the state solid, liquid or gas. These exercises involve key conceptual areas in chemistry. The worksheets and materials are in appendix 7.

The school has a selective entry and has had relatively little disruption during the past few years. The science teachers at the school are mostly English-speaking. It is better equipped than most KwaZulu schools or Department of Education and Training schools in the area. Despite this, the teachers were quite sure that standard 6 (year 8) pupils would be unable to discuss basic chemical concepts. Only standard 7 (year 9) and 8 (year 10) pupils were involved, and then only the higher achieving pupils could cope with the material.

There were four standard 8 interviews and four standard 7 interviews — half on particles and half on elements, compounds and mixtures. The pupils seemed quite happy to assist with the exercise though they were not very confident about it. They were told they could discuss the work in either Zulu or English — whatever they wished — and all the tapes contained a mixture of both languages. As with the videotapes of teachers, transcription and direct translation of the Zulu to English was done. These transcripts are given in appendices 8 and 9.

Comments noted on the transcripts relate to

- The science ideas articulated by the pupils
- The linguistic structure of their discourse — language clues which may have resulted in or reinforced any unhelpful alternative conceptions noted
- The flow of dialogue — pupils' ability to pose questions to each other and resolve issues.

All these three aspects operate together which makes analysis tentative and complex.

None of the pupils finished the worksheet completely, nor did they tend to do the worksheet sequentially. When they differed on a point, few pupils had strategies for resolving differences. Often pupils used the strategy of changing the subject when the task became too difficult or not interesting enough. This is hardly surprising because, as many of them commented, this was the first time they had talked their way through a task. The pupils who coped reasonably well with the exercise clearly enjoyed it.

Classifying substances

Unfortunately, because of various logistic issues, all the dialogues on elements, compounds and mixtures were with pupils classified as being in the middle of their classes. These dialogues are discussed in appendix 8. These pupils who were meant to discuss elements, compounds and mixtures really had no basis for chemical classification at all. There was confusion between the dual classification system of solid/ liquid/ gas and elements/ compounds/ mixtures. The meaning of 'salt' was problematic (as it is for many learners). The written material they handed in contained several errors and there was no discernible pattern in the answers. As noted in chapter 8, in the discussion of the dictionary of scientific terms, there was one clear problematic definition of compounds in line with this dictionary entry.

Dialogues about particles

There were, however, some very interesting passages in the dialogues about particles which were produced by the pupils who achieved well in science and who were classified as being bright by their teachers. These dialogues are discussed in appendix 9. Some of these points are:

- They discussed the difference between matter and the properties of matter — the structural and functional divide noted earlier. They were some sections which showed an ability to infer the existence of matter from its properties.
- They discussed semantics such as the difference between matter in science and “What’s the matter?”.
- They were puzzled by the problem of visible matter being made up of invisible particles. There was some hint that there are two types of particles — visible and invisible. This would then account for air being invisible.

There was confusion between transparency and visibility of particles but the logic seems wrong, i.e., that transparency implies visibility. This was in a discussion about water. Also some hint that applied pressure implies visibility. The translation was difficult to understand on this point.

- There was discussion about whether particles in solids, liquids and gases were indeed different types of particles. For example, particles in solids might be more dense, not so discrete and hence visible. For example:

(Plain font — literal translation of Zulu;
Italics — transcription of English)

A. ... Ho, let us say they are similar the *particles* but there differs the *state of matter* if there be they are combined. Let's we take just air, it is gas; water are liquid, whilst *wood is solid*. Therefore because of that *wood*, it is hard, it is easy to see the particles.

B. No, I do understand.

The denseness of particles may also apply to liquids. Another reference is to mercury as "liquid, but more liquid because more dense".

- This is an example of a theory being built to help explain some aspect of a situation. In the tapes there is no suggestion that further testing or exploration of an assertion is needed.
- The microscope was mentioned as the instrument to use to see atoms. It is likely that pupils had not used microscopes. For example:

B. *Oh, the microscope.*

A. *I can say they measure the scale of one cell. Thus, by so doing able to calculate how many atoms are present for field of view.*

- Indeed, pupils had very little idea of scale or magnitude and no clue about the size of an atom.
- They were confused with the atomic/ molecular image of particle and the images of droplets of water or grains of sand being particles.
- There was one brief mention of colours in the rainbow being due to particles of light.

- There was one example of defining a substance as something that flowed, although the pupils were aware of their confusion between the terms, as were many of the pupils. For example:

B. What's then *atom, substance*?

A. *Substance* is something which is liquideous like water.
Dust is a substance.

B. These words they visit with each other, another it is another: *matter, substance, particles, atoms.*

- The classic error sequence atoms → molecules → compounds was described. Ionic substances (such as NaCl) did not feature at all.
- A couple of pairs mentioned 10^6 atoms in a mole. As pupils had little concept of magnitude this is not surprising; what is interesting is speculating how an incorrect number becomes popularly believed in a class. There was also a hint of a confusion between ml and mole.
- There was confusion about the distinction between 'explanation' and 'classification'. The word 'classification' had connotations of living or non-living for some pupils.
- One analogy was used — that of likening rusting with a wilting flower. But metaphorical language was rare.
- The points noted above are complex issues. The pupils took a great deal of time to articulate their ideas, especially when their discussion was largely in Zulu. There was a fair amount of switching between Zulu and English.
- There was a marked lack of critical discourse skills, even of a basic kind. Pupils really couldn't pose questions of each other in a sequential fashion. At best one question is used to probe another's assertion. Then, almost any reply is accepted.

- There is one interchange where the usage of 'particles of air' and 'particles in air' is clearly confusing; this also applies to 'of wood' / 'in wood'. Some further comments are made about this in chapter 8, page 110. Also, the prepositions 'by' and 'at' are often not explicitly included; the meaning is conveyed contextually.
- These were much more difficult tapes to try to understand than the teacher videotapes but do give some clear images of pupils struggling with unfamiliar words and constructions.

These tapes were collected in 1989. In 1990 the escalating violence in the Pietermaritzburg area precluded further research along these lines.

Comments from research diary

The research diary entries for this phase of the research at Edendale Technical College were quite different from those in 1986 and 1988 at Indumiso College of Education. I felt much less comfortable and less in tune with the teachers and pupils at Edendale Technical College that I did at Indumiso College of Education and the diary entries reflect that uncertainty that I felt about the way in which I was being received. The main reason for this was that I spent far less time at Edendale that I had at Indumiso before I began collecting research data. Edendale Technical College is somewhat further away from the University of Natal than Indumiso College of Education and I had visited it less frequently. While staff and pupils seemed quite happy to have me at Edendale, the sense of feeling close to the ethos of an institution was not there. I would have felt more comfortable in setting up these activities for pupils if I had spent more time in the school beforehand.

The other reason for spending less time at Edendale was the escalating violence in Pietermaritzburg. While I encountered no

problems personally, it was certainly a factor in determining the number of times I drove through the Edendale township.

This aspect of gaining a sense of the ambience of an educational institutional is one which is often neglected and yet is crucial to research which seeks to explore what understanding pupils make of events and knowledge. During 1990 it was just not possible for me to spend any length of time in a black school in an atmosphere where issues of science education would be a major focus. Much more work is needed about how pupils at the interface between Zulu and English use language to explore issues and ideas in science. In more settled times this will be very valuable to do.

In retrospect, I would have made the exercises for the pupils much more specific and less directed towards general exploration. However, these pupil dialogues are a useful beginning for further work in this area.

In the next chapter issues arising from the translation of individual words will be explored.

Chapter 8 Zulu/ English translations of individual words

Introduction

Cassels & Johnstone (1985) list English scientific words that English speakers find problematic. Their list contains 84 words which, in their research with 30 000 secondary pupils, less than 70% of secondary children can adequately understand. Other research (e.g. Watts & Gilbert 1983) supports this finding that scientifically associated words are often poorly understood by first language speakers of English. It is not surprising that second language speakers of English experience great difficulty.

The compilation of lists of problematic terms and constructions for languages which are dissimilar to English is not a new strategy. For example, Case (1968) worked in Northern Malawi in the 1960s and documented many interface difficulties between ciTumbuka and English. She noted not only problematic terms, but discussed issues of pronunciation and spelling, as well as grammatical aspects such as prepositions, articles and subjects. This useful piece of work is often cited. But the problem is still largely untouched. Similarly, CASME (1975) produced a compilation of examples of problems of vocabulary, syntax and transfer. More recently, in South Africa, Rutherford & Nkopodi (1990) and Rutherford (1993) have described similar problems.

In this chapter a little will be added to the knowledge about specific interface issues between Zulu and English. The need to bring this information into teacher education and curriculum development work will be discussed in chapters 9 and 10.

Translations of specific words — English/ Zulu dictionary of scientific terms

While the bulk of the research has been overall use of a language in the formations of key concepts, it is clear that difficulties arise

for learners when the word(s) used in English are quite different from those used in Zulu. It is reasonable to suppose that the greater the disparity between the usage of Zulu and the usage of English, the more difficulties learners will encounter.

An English/ Zulu dictionary of scientific terms with 760 entries was compiled from the two English/ Zulu dictionaries which exist (Dent & Nyembezi 1969, Doke *et al.* 1958). A literal translation was done of the Zulu translation of the English term. Research issues associated with this style of translation were discussed in chapter 3, page 27. The dictionary is in appendix 10.

The English/ Zulu section of the dictionaries were scanned looking for scientific terms. We were aware of trying to limit the scope of the exercise, especially as this is exploratory research. At about 760 entries we stopped. There is a large area which has been inadequately covered and that is English words which are more frequently found in common use but are also used scientifically. Examples are 'combination', 'extract' and 'divide'. This is a large area which is under-represented in this first attempt at a dictionary. Researchers may wish to address this in future. As several of these words are in the list referred to above by Cassels & Johnstone (1985), this is an added reason to note this aspect. It is of interest to note in passing that all 84 words listed by Cassels & Johnstone are listed in the English/ Zulu dictionaries which were consulted.

There was some variation between the two dictionaries, but not a great deal. My subjective judgment was that these differences had little conceptual significance. There was no particular criteria used for selecting one set of wording or another. It was largely the decision of the translators as to which seemed to them to be closest to their understanding of the term. This is a fairly good research process to use in this situation. More detailed research in this area could well use an extended panel, both for the choice of words and for selection/ refinement of definitions.

One further research issue in this aspect of the research is that Zulu/ English dictionaries do not have the same status as English dictionaries. There are only the two dictionaries cited above; both are somewhat dated in comparison with English dictionaries. They are the product of small groups of people and do not necessarily represent a broader community definition and usage of all terms. In addition, there is a Zulu dictionary (Doke & Vilikazi 1972) which the translators used as a reference source.

The pupils at Edendale Technical College did not distinguish between compound and mixtures (chapter 7 and appendix 8). The words 'combination' and 'combine' (ukuhlanganiswa and hlanganisa) were used for both terms. The dictionary noun for mixture which is related to hlanganisa is 'inhlanganisela'. It is interesting to note that the Zulu word 'lumbana' which Dent and Nyembezi (1969) list as the word meaning 'chemically combine' was not used by any of the pupils or by my two research assistants or by six other teachers I questioned. It is not listed by Doke *et al.* (1988). This is just an illustration of how a dictionary for Zulu/ English needs progressive development.

As with all this research, this part on the meanings underlying specific Zulu words must be seen as tentative but does give glimpses and indicators for those involved in science education in South Africa.

Often there is a Zulu word which is essentially just the English word and, of course, many scientific words are just not present in these standard dictionaries. However, often the understanding of the word which has evolved in the culture is revealed by the Zulu definition.

The majority of the words in the list convey an image which is entirely congruent with the way the terms are used in western science. Indeed the metaphorical imagery of some of the entries is rich and useful. For example:

Table 8.1 Metaphorical imagery in the literal translation of some Zulu scientific terms

English	Zulu	Literal translation of Zulu
ellipse	okusasiyingi okumise okweqanda	that which is circular form like an egg
octopus	isilokazane esizombezombe kasishiyagalombili	a little zoan that is zigzag eight times
zoophyte	isilwane sasolwandle esithi asifane nesithombo somuthi	zoan of sea which says to resemble plant of tree

In Table 8.2, 70 entries from the full English/ Zulu dictionary in appendix 10 are presented together with comments.

Table 8.2 Selected entries from the full English/ Zulu dictionary in appendix 10

English term	Zulu definition	Literal translation	Comments
adhesion	ukubambelela; ukunamathela; inqokothela	attachment; sticking on; accumulation	Very similar to cohesion. Difficult to distinguish between the two terms
alkali	i-alikhali; okutholakala ezingeni eliphezu kuka-7 kwi-pH kunamandla okubulala ubuasidi	alkali; that which is found in level above 7 of pH with power to destroy acidity	A functional rather than structural definition
ammonia	umuthi ongumoya oxutshwe ngamanzi onephunga elihlabayo; NH ₃	poison that is air mixed with water with smell that is piercing	A functional rather than structural definition
ampere	isibalo okubalwa ngaso amandla e- elektrisiti	measurement that count by it the power of electricity	'Power of electricity' rather than 'current'
amphibian	isilwane esiphila emanzini nasemhlabeni esifana nengxangxa	an animal that live in water and earth that resembles a frog	A functional rather than structural definition
bacillus	imbewu yokufa	seed of death	Negative definition. Many bacteria are essential to health.
battery	ilahle eligcina ielektriksi yokukhanyisa	coal that stores electricity for lighting	Quite a nice image but it is not one which gives any hint of chemical energy which can be converted to electrical energy.
blood	igazi; iphulotheni eyinhlanganisela yokuningi	blood; a protein that is a mixture of many	Blood contains much more than protein. Also see 'haemoglobin'.

bond	ubudlelwano benxumano ngama-athomu	the relationship of binding by atoms	However, bonds were not mentioned in the Zulu lessons. Perhaps the term is not in general usage.
camphor	uzamlandela	they followed	Nice but very cryptic sense of a volatile substance
chemical	isithako sahlobo luni esivezwa ongoti kwezezithako	mixture of any type shown by expert in chemistry	The use of the word 'mixture' is very general in Zulu
chemistry	isayense ephathelene nezithako zemvelo	science about mixtures of nature	Mixtures again. Also what is meant by 'nature' here?
cohesion	ukunamathelana; ukuqongathelana	the attachment; the combining	Cf 'adhesion'
compound	inhlanganisela yazithako zemvelo ezimbili	the intermixing of mixtures of nature which are two	The definition used by pupils at Edendale Technical College
density	ukuminyana; isikalo sesisindo nomthamo	the concentrate; the measure of mass and volume	No indication of ratio at all
diffusion	ukuhlakazeka; ukuhamba kwamamolekhulu ezinto esuka lapho emaningi khona aye laphoemancane khona	the dispersion; the movement of molecules of things from where many to where are smaller	No distinction between 'diffusion' and 'dispersion'. Does 'smaller' refer to concentration or particle size? Not clear.
digestion	ukugayeka kokudla emgudwini womzimba kwenziwa izigayi-kudla	the grinding of food in canal of body done by grinder-food	Very mechanical definition with no sense of chemical action.
element	into engumsuka wezinye izinto neyisithako semvelo	a thing that is a source of other things is a mixture of nature	'Mixture of nature' again
empirical	ngafundanga ngendlela yesayense kodwa ngokubona nangokulinga	not learnt in way of science but by seeing and experiment	Does this imply that science does not involve 'seeing and experiment'?

energy	amandla okwenza umsebenzi	power to do work	No distinction between 'power' and 'energy'
equilibrium	ukungashukumi okuvezwa ukucindezelwa nhlangothi zombili ngesisindo esilinganayo	no movement due to pressure sides both by mass equal	Again a physical definition. No sense of chemical potential at all.
evaporation	ukuphenduka kokusamanzi kube wumoya; umhwamuko	the changing of watery into air; vapour	Image of: Liquid = water; gas = air
experiment	umsebenzi wokulinga	the work to attempt	No image of design for an experiment
feather	uphaphe	wing	Same word for 'feather' and 'wing'
fibrous	-nemithambo	veined	Fibres are quite different to veins in structure, even though both have long, thin strands.
focus	indawo okuqondiswe kuyo	place directed to it	Sense of a particular point but not of the reason for it.
force	impoqo yokududula noma yokudonsa	forcing act of pushing or pulling	Force seems well defined, in contrast with energy, power and work.
fraction	iqhezu; ingxenyana; ucezwana	small piece; small portion	Not sure whether this can be extended to include the precise mathematical sense
function	umsebenzi obhekene nomuntu noma nento ethile	duty facing a person or a thing certain	The word 'duty' gives an anthropomorphic sense to the term.
fungus	ukhunta; ugwayi kanhloyile	rotteness; cigarette of a hawk bird	Interesting cultural description
galvanic	i-elektrisi elenziwa ngemithi	electricity made by mixtures	Problem of 'mixtures'

gram	isilinganiso sesisindo	scalar of mass	Same definition as for 'kilogram'
haemoglobin	iphulotheni eveza umbala obomvu ezinhlayiyeni zegazi	protein giving colour red in the particles of blood	Again, a functional rather than structural definition. Also, haemoglobin is not a protein; it is an organometallic compound.
helium	uhlobo lomoya ongugesilolungabonakali	type of air that is gas not seen	Gases all linked with air. As 'air' is not visible, this definition is not helpful.
hymenoptera	izilokazane ezinamaphiko amane	insects with four wings	Same as 'lepidoptera'
inorganic	-ngenakho ukuphila	without life	Inorganic means without carbon (mostly), not life.
integral	into edingeka ukuphelelisa ngaphakathi	something needed to complete the inside	Again, a physical definition. Would be difficult to link this with the mathematical meaning of 'integral'.
kilogram	isilinganiso sesisindo	scalar of mass	Same as for 'gram'
kilometre	isilinganiso sebanga	scalar of distance	General definition
lepidoptera	izilokazane ezinamaphiko amane	insects with four wings	Same as 'hymenoptera'
liquid	uketshezi; yinto esamanzi	watery; that which is watery	Liquid = water
logarithm	ililogarithimu; unembe oveza izikhathi okumelwe ukuba unembe othiwa isiseko, aphindwe ukuze kubonakale inani elithile	number showing times represented that number called foundation, be multiply so that appear amount certain	Difficult to describe a logarithm to a base.

macromolecule	okukhulu kokudla okwakhiwe kokuncane	the large of food built on the small	Macromolecules not only relate to food. There are many different types of polymer.
magnesium	insimbi okuyiyona iveza ingisawoti	steel that gives salt-like	'Steel' often used for metal.
mass	isisindo	weight	Same word used for 'mass' and 'weight'.
mathematics	iseyense ephathelene nezibalo	science pertaining to counting	Mathematics involves much more than counting.
matter	into ephathelene nokukhona nokuphilayo kube kunendawo	thing pertaining to existing being living with a place	The word 'living' is problematic here.
melt	ncibikilisa	dissolve	Same word for 'melt' and 'dissolve'. Exacerbates a common difficulty in distinction.
mercury	ummpunyumpunyu onozibuthe	the spongy content with magnet	'Spongy' because it is liquid. The reference to a magnet is not clear.
metallic	okusansimbi	steel-like	'Steel' often used for metal.
metaphysics	isayense yenzululwane ephatha ubukhona	science of dizziness that consider the existence	Rather nice metaphor of the head-spinning nature of thinking about existence!
momentum	umfutho; ubukhulu bejubane ekukhuleni kwesisindo	power; the biggest of speed at increasing mass	No sense of the product of speed and mass
nerve	umuzwa	a feeling	As sensation rather than a physical structure

osmosis	ukuchinineka kwamamolekhulu edlula olwelwesini esuka enqwabeni eya kwingcosana	diffusion of molecules passing a membrane from abundance to deficiency	The nature of the membrane is lacking, i.e., only that small molecules can pass through.
oxide	ukuthomba; ukugqwala	rusting; discoloured	Rust is the only oxide considered.
ozone	umoya ogcwele i-oksijini okuthi umuntu angashaywa yiwo aqine umzimba	air full of oxygen which when a person is struck by it numbs the body	'Full of oxygen' rather than a description of their being 3 atoms per molecule. Some hint of a difference in physiological action.
physics	isayense yezinto zemvelo	science of things of nature	What does 'nature' mean? What about synthetic substances?
proportion	ukulinganisana; okulinganisene	equality; proportion	Gives the impression that there is no real distinction between 'equal to' and 'proportional to'. This is borne out in the Zulu lessons.
purification	indlela yokucwebisa sakuhlanzisa into ezintweni eziningi ize igcine isiyiyona njengamaphulotheni	method of clearing like purifying things from things many till it ends being itself like proteins	'Proteins' again used rather generically
quantity	ubuningi	large amount	Small quantities exist.
radium	isithako semvelo esiyinsimbi ekwazi ukukhipha imisebe ephethe okugijimayo ngelikhulu ijubane	mixture of nature that is steel able to elicit rays containing that which running at high speed	Issue again of 'steel' being used for metal. 'Running at high speed' implies purposeful action on the part of the X-rays.
rainbow	uthingo lwenkosazane; imibala eyisikhombisa ebonakala emva kwemvula, ibe idalwa ukuphetshezwa kwemisebe yelanga ngamathonsi emvula	bow of queen; rays seven appearing after the rain, being caused by reflection of rays of light by droplets rain	'Reflection' rather than 'refraction'

rarefaction	ukuhlambuluka komoya lapho amagagasi awo ehlukana	the clearing of air when its waves separate	Seems to be written with sound waves in mind and gives the sense of the opposite to compression. But the waves do not separate. The particles in air move as the wave passes through.
salt	usawoti; ingxube yezakhi ze-sodium ne-chlorine	salt; mixture of elements of sodium and chlorine	'Mixture' rather than 'reaction between'
solid	okusalugqinsi; okusatshe	that which is hard; stony; rocky	Very physical metaphor. What about cloth, bread, paper?
torque	amandla okuphenduphenduka kwezinsimbi eziyingxenye yenjini	power of turning-by of steels which are part of engine	A torque is a turning moment. Found in all manner of machines, not just engines.
ultra-sound	umsindo ongabekezekeleki ngenxa yobukhulu	noise not tolerated because of loudness	Confusion between loudness and frequency
volt	isilinganiso samandla elektrisiti	measurement of power of electricity	'Power' rather than 'energy per charge'
weigh	linganisa esikalweni	measure in scalar	Weight is a force, not a scalar, though probably the idea of a scale is all that is meant here.
weight	isisindo; ifosi umhlaba odonsa ngayo izinto uziletha kuwo	mass; pull by which earth attracts things to itself that are in it	No distinction between 'mass' and 'weight'.

In all these examples the definitions given are somewhat lacking in precision and indeed are somewhat counter-productive to the learner. The functional/ structural divide mentioned in chapter 6 is clear in several definitions. One should not read too much into these definitions but they certainly illustrate the difficulty Zulu learners have in grappling with the meanings of English terms.

While there is really no suggestion at all that Zulu should be used as a medium of instruction in South Africa, and hence there is no attempt to create new Zulu words for scientific terms, it is worthwhile noting that in some cultures there is an active process to create new dictionaries of new words that will be used for teaching science.

Ohio (1990 p. 125) discusses how Maori curriculum material is progressively being collected; Barton (1990 p. 169) discusses several issues with respect to ethnomathematics within a Maori setting and gives some examples of topics to investigate. This type of research is essential for building a meaningful bilingual/ bicultural curriculum and needs to be given the highest priority. Where translations are to be used, one does have to be careful about the appropriateness of the translation; for example, I have some problems with the translation of 'to digest' being 'to dissolve' (Waiti 1990 p. 190).

Problems with logical connectives

It became clear to me from reading the transcripts that certain logical constructions in English are not matched in Zulu. At several places, the direct translation did not match easily with the logical intent. It is well known that scientific language relies heavily on the use of logical connectives. Gardner (1977) produced a list of 220 logical connectives which are commonly used in school science text books. He tested 16 530 secondary school pupils and identified the logical connectives which pupils found most difficult to use. In this research the two translators translated the 220 logical connectives from English to Zulu. They gave a qualitative indication

of the difficulty they had in carrying out the translation for each item. This difficulty is a composite of:

- the difficulties the translators had themselves with certain logical connectives. They worked through the tests together which McNaught *et al.* (1980) produced for work in Zimbabwe. (These tests were based on those used by Gardner (1977); indeed, I was an item writer for Gardner's Logical Connectives in Science project in 1975.) They had more difficulty with the logical connectives in an everyday context than they had with them in a scientific context, perhaps because much of their contact with formal English has been in scientific contexts. We spent a great deal of time teasing out nuances of meaning, e.g. between the different meanings given to the same connective.
- the level of difficulty in making a direct translation. In some cases, the meaning of the connective comes contextually rather than grammatically.

The indicators given in appendix 11 are provisional. They are just the estimates of the two student translators. No testing was done with teachers or pupils. The logical connectives which Gardner (1977) found to be difficult ones were also difficult for the translators. There were some additional difficult logical connectives. Further research in this area could be profitable.

Teachers and those who produce curriculum materials (not a mutually exclusive coupling) need to be aware of the extra difficulty Zulu-speaking learners have in the use of logical connectives.

Rutherford and Nkopodi (1990) have studied North Sotho speakers and have noted similar problems with logico-grammatical connectors.

It is interesting to note in passing the results of some research done in Zimbabwe (McNaught *et al.* 1980) about the use of logical connectives in English. For items on a test where the contexts were everyday ones, English-speaking learners at form 2 level (standard 6/ year 8) did significantly better than their peers whose first language was an African one. There were no significant differences at higher levels of school. However, on a test using science contexts, form 3 African language speakers performed significantly better than the form 3 English speakers. This may be due to the fact that the African pupils were much more highly selected than the English pupils. In general, the African language speakers improved in their ability to handle logical connectives as they moved higher up the school, while the English speakers actually got worse as they received more education! This is noted to indicate the need to consider many factors in interpreting language problems in education. Isolated linguistic research is not likely to produce fruitful results.

Problems with the locative construction

It was noticeable in places that the locative construction in Zulu creates some difficulties for Zulu speakers. The same construction is usually used for words such as 'on, in, to, at' etc in Zulu. In normal conversation this is not a problem as the context provides the needed definition. However, in science this is not always the case. For example, distinctions such as 'in the flask'/ 'on the flask' are not always clear. One clear example occurred in the conversations between pupils reported in chapter 7 where the usage of 'particles of air' and 'particles in air' was clearly confusing as was that between 'of wood' and 'in wood'.

It should be noted that variations in meaning in locative constructions are well known, both with respect to body parts and environmental locations (Heine 1991). In some cultures 'below' a person means on the ground, in others it means under one's bottom; 'in front' can mean in front of the trunk of one's body, or in front of one's face. 'Over there' can mean different things in terms of distance in different cultures. Anthropological linguists are only

now becoming aware of the nuances for the simplest grammatical structures.

The locative construction is mentioned because there is a need to focus on a range of grammatical differences between Zulu and English

Summary

In chapters 6 and 7, differences between Zulu and English with respect to styles of explanation were discussed. This chapter has illustrated that, for Zulu learners, specific words in English may have different meanings or nuances of meaning from the common usage in scientific English.

In chapter 9 and 10 some ways of bringing the discussion about language into the mainstream of teacher development and curriculum development are discussed.

Chapter 9 Action — Scisa

Introduction

Chapters 9 and 10 do not directly follow on from the linguistic analysis presented in the preceding chapters. It would be nice if the identification and articulation of an educational issue could lead to a tailored solution. Educational change does not occur in this way. As explained in chapter 3, a critical perspective on educational change sees that political and social theories and contexts must interact with learning theories in order for there to be pragmatic outcomes. Indeed a constructivist perspective, where the learner is situated within her/his unique context implicitly demands a broader analysis; this can create difficulties.

In chapter 9 the early stages of an action research initiative about impacting on the process of science curriculum development in South Africa is presented. In chapter 10, a more focused project about language issues in black primary schools is presented.

Dilemma of a constructivist approach to teacher education and curriculum development

The dilemma of a constructivist approach to teacher education can be explained as follows. In a constructivist perspective, the learner constructs meaning through a process which begins with the learner defining the nature of the problem for her/himself. In an education system which is largely dominated by fixed syllabuses and content-laden external examinations, the job of teaching is one of transferring packets of predetermined knowledge to pupils. In such a system, teachers do not see individual construction of meaning as having a high priority. So we, as teacher educators, give teachers a new set of educational problems by persuading them that they must consider and use the ideas of alternative frameworks, etc. Appropriate constructivist teacher education should rather be designed in a way in which teachers help themselves. For example Solomon (1985) discusses

the involvement of teachers in research in their own schools; they can then use the process of interpretation of their own research data as a mechanism for defining the learning problems they wish to investigate. This is a valuable strategy for in-service teacher education.

Like teacher education, constructivist curriculum development cannot be prescriptive. In theory, one should only provide resources for teachers to use in constructing useful learning environments in their classrooms. The importance of pupil dialogue, especially framing and asking questions, must be acknowledged in any curriculum development work. However, without adequate teacher support, resources will not be used. A series of science text books written by myself around the idea of creating situations for pupils to explore, questions to ask, etc. can be used to illustrate this point (McNaught *et al.* 1984a, McNaught *et al.* 1984b, Deoda *et al.* 1983). For example, there are seven activities in the chapter 'Particles of matter' in McNaught *et al.* (1984a) — boiling water, opening a bottle of ether, bromine diffusing through air, making ammonium chloride smoke, potassium permanganate diffusing through water, squeezing air and squeezing water, and the smoke cell. Each activity has a set of questions for pupils to discuss and explore. I have seen many lessons in a variety of schools where the answers to all these questions were just dictated by the teacher, often all in the one lesson!

In the UK, the staff of the Children's Learning in Science Project (CLISP) at the University of Leeds have been, for many years, mostly practising teachers on secondment. In this way practising teachers are used in the production of resources for the teaching schemes CLISP has published on particles, energy and plant nutrition. Strategies such as pupils producing posters to clarify their own ideas have been extensively used by CLISP teachers in classrooms. In this model shown in figure 9.1, teacher development and curriculum development are inextricably intertwined.

Here in South Africa, the teacher support zonal groups of the Science Education Project (Gray 1985, Keogh 1987) provide an example of adapting this curriculum philosophy to our situation.

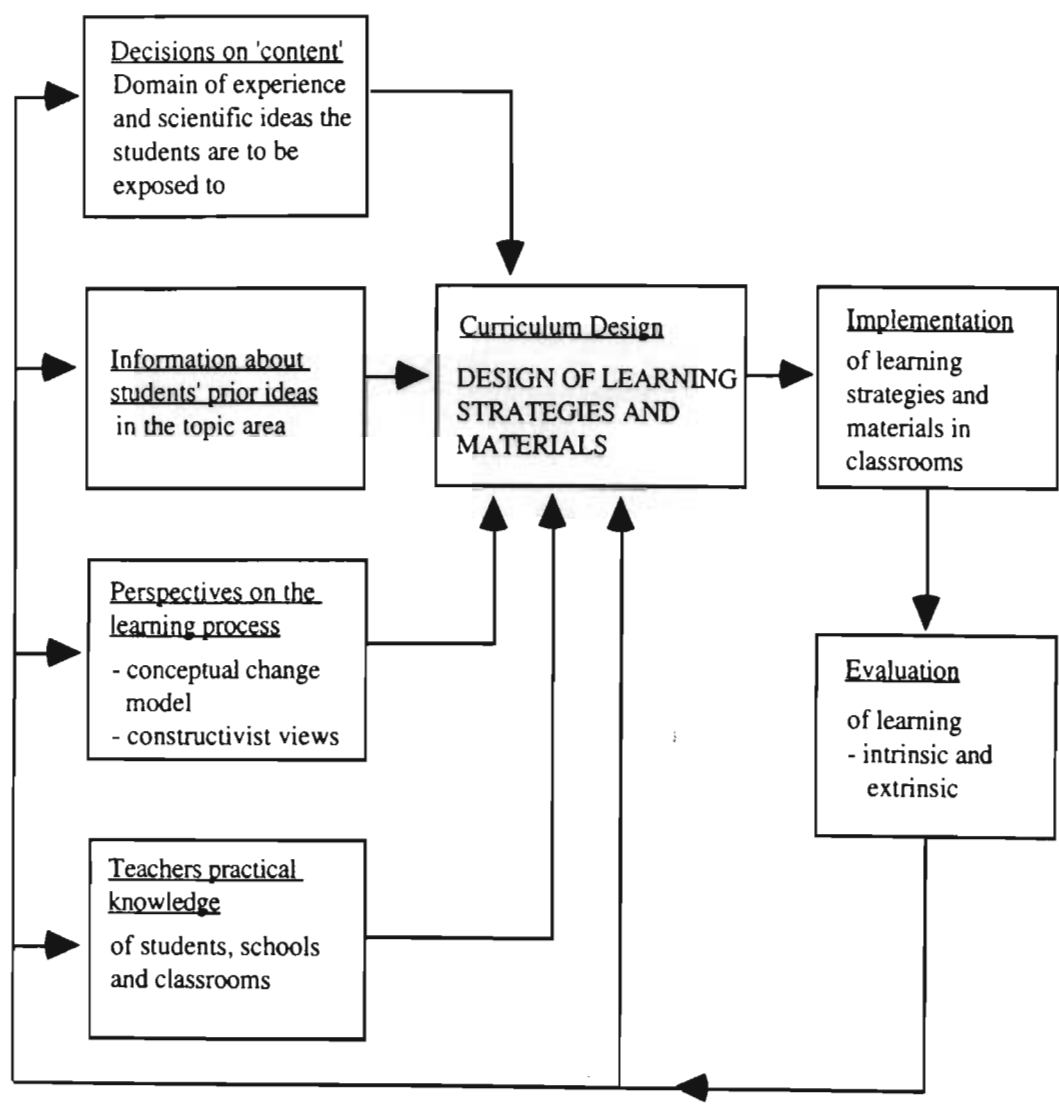


Figure 9.1. CLISP model of teacher development and curriculum development (from Driver & Oldham 1986 p. 113)

An examination of prevailing approaches to curriculum change

Before examining possible alternative curriculum approaches any further, it is important to explore the nature of current curriculum practices in South Africa. Many curriculum development activities adopt positivist approaches to curriculum development. These have usually involved external, rational and objective research processes (called curriculum development), followed by dissemination / adoption strategies to communicate the new curriculum to teachers or to implant it in schools (called curriculum implementation).

‘Develop and implement’ approaches to change have, unfortunately, proved to be surprisingly weak (Papagiannis *et al.* 1982, Popkewitz 1984). Their repeated failure has most often been ascribed to communication weaknesses, insufficient or poor evaluation and a lack of teacher participation (Eisner 1985). Curriculum projects have thus centred their efforts on trying to improve evaluation research and communication strategies for curriculum dissemination.

This may well have been a waste of effort as many of the key failings of prevailing approaches to curriculum development can be traced to flaws in the underlying assumptions of a deterministic model of change. Figure 9.2 outlines the classic RDDA model. We need to examine carefully the assumption that the management of change through external and rational processes of curriculum development is either possible or desirable.

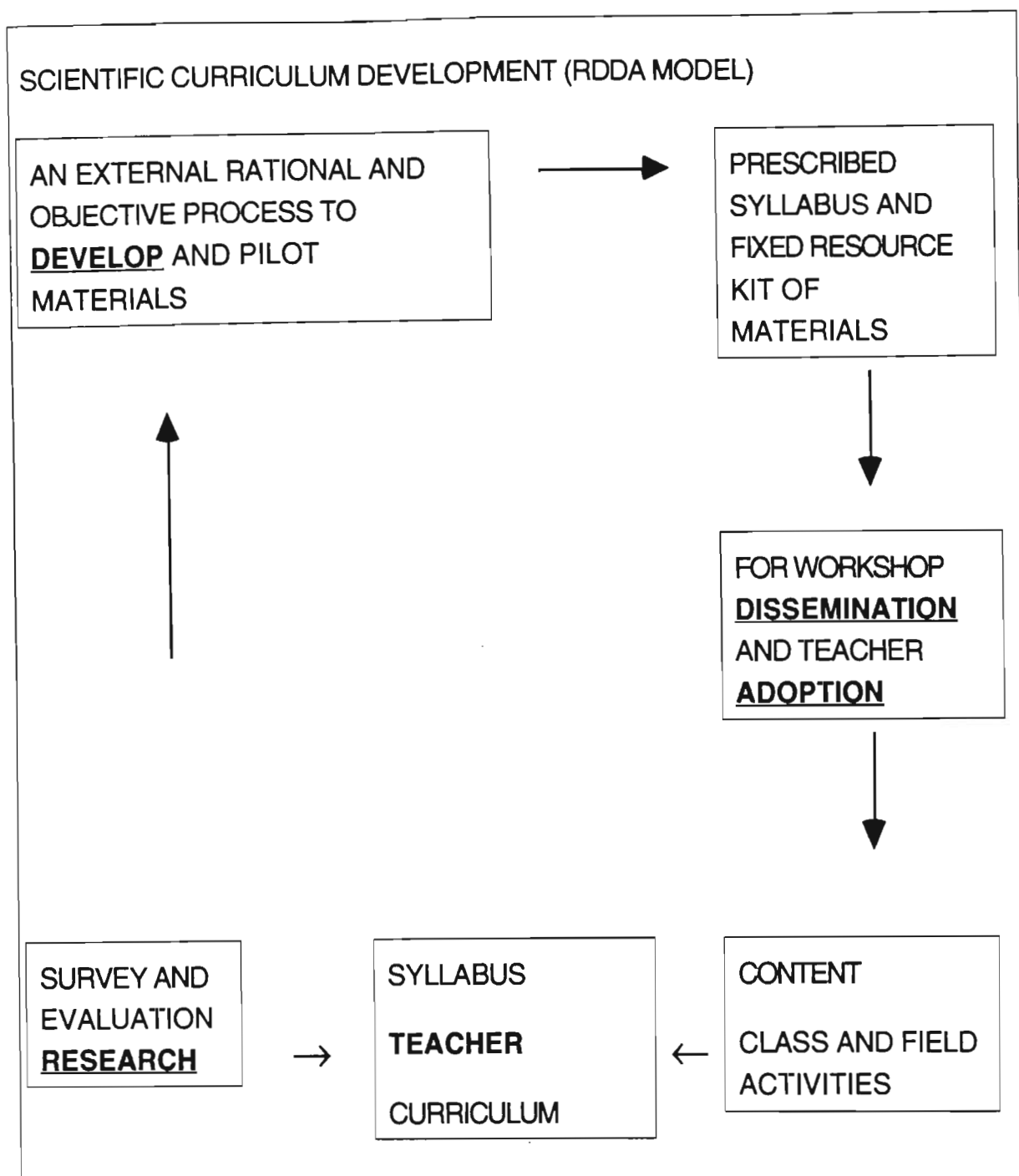


Figure 9.2. A deterministic model for curriculum development (RDDA) (adapted from O'Donoghue & McNaught 1990 p. 29)

The RDDA model does not fulfil several of the criteria which educational projects in South Africa have used in order to describe their identity. On a sociopolitical level, the hierarchical power structure implicit in a top-down approach ignores the need for people to be involved in determining the parameters of their own

existence. Education is such an important part of our society that any democratic renewal must involve consultation with all stakeholders.

From the viewpoint of constructivist learning theory, the RDDA model is not acceptable. If the learner is to be placed at the centre of the education process, there needs to be elements of sensitivity, flexibility and adaptability in curriculum development that are just not found in curriculum development which is removed from action in the classroom. So, whether one reads psychological constructivist literature (e.g. Driver & Erickson 1983, Gilbert & Watts 1983) or the literature of liberation and democracy (e.g. Freire 1985), it becomes clear that we need alternative models for curriculum development.

Developing alternative models for curriculum change — A critical approach to science curriculum issues

For sustained and meaningful change, people have to reconstruct the way they see the world. This means that groups of people need to become agents of change by reflecting on everyday activities and by acting to resolve the tensions and ambiguities that confront them in their daily lives (Freire & Shor 1987).

It is important to note that this outlook does not exclude the need for well communicated messages or structured workshops and the provision of resource materials. These do, however, need to arise out of and complement local initiatives. They also need to be undertaken in a way that does not disempower people or inhibit the dialogue and reflection that is necessary for people to reconstruct their own perceptions.

A radical change in outlook is required. This includes an overturning of both a centre-to-periphery outlook and the desire to manage or manipulate education. We should approach curriculum development in a way that enables people to take the initiative and to act to become confident thinkers and doers. In this perspective, teachers are partners in the process of change (Taylor & O'Donoghue 1990).

What I wish to suggest now is that if we genuinely espouse a constructivist view of learning science, we naturally align ourselves with critical philosophical perspectives about the nature of science and the functioning of human societies. We cannot uncritically adopt traditional western science curriculum patterns into our schools. We need to examine the issues which most need addressing and then work at producing the sort of science curriculum activities which are most appropriate. Science education can only be successful to the extent that the participants (pupils and teachers) in schools identify with the course content, can use the knowledge practically and see the link between school science and the wider society at large.

A critical approach requires the examining and questioning of the overall structure of the education system. However, the art of curriculum renewal and development involves being realistic about what can be achieved. Hawes (1979) cautions that denying the resources (both in terms of funding and expertise) that many centralised government bodies have is foolish. There are also many examples in many countries of valuable centrally located curriculum projects. This section is not trying to argue for an absolutist perspective where only locally based, participatory curriculum projects are of value. What is being argued is that the focus of curriculum development should be with the participants (pupils and teachers) in schools.

For some time science Inset (in-service education of teachers) projects in South Africa have been aware of the constraints of a deterministic model of curriculum development and, indeed, have realized that the current situation locked them into perpetuating the unsatisfactory status quo. In this situation democratic aims for teacher development become reduced to mere rhetoric. There was a genuine desire to democratically facilitate teacher development and curriculum development; the process of dialogue and reflection about how to do this in science education in South Africa led to Scisa.

What is Scisa?

The Science Curriculum Initiative in South Africa (Scisa) represents a group of individuals whose concern about the current status of science education in South Africa have motivated them to set about finding a solution. Scisa aims to tackle one of the fundamental needs of science education in our schools, namely the need for all pupils to be introduced to science in primary and lower secondary schools in an exciting, environmentally relevant and conceptually sound way. To this end, we need new science syllabuses for standards 3 to 7 and new complementary strategies for science teacher education and professional development.

It is crucial that the production of more relevant syllabuses be linked to the professional development of teachers. The current process of syllabus revision does not permit this and effective curriculum development in South Africa must recognize the need to produce other working models for curriculum change.

It is also crucial that all stake-holders in education enter the debate about the nature of science education in our schools. One particularly important group which has been largely excluded from syllabus construction in the past is employers. Commerce and industry are clearly concerned about the shortage of people entering the job market with scientific and mathematical skills. The philosophy of curriculum development which is described in this chapter is one where all those concerned with science education in this country need to contribute their views and expertise to a network of ideas and resources. This is ambitious, but possible.

Aims of Scisa

1. To develop General Science curricula which are appropriate to the needs of a non-racial society for the whole of South Africa
2. To broaden the base of curriculum decision-making in South Africa

3. To link the professional development of science teachers to the process of curriculum development
4. To liaise with curriculum accrediting bodies.

Anticipated products arising from Scisa

1. A new strategy for decision-making about curriculum issues
2. Ongoing workshops as part of teacher support services
3. Strengthened teacher networks for professional development of science teachers. These networks will be both formal and informal.
4. A series of stimulus papers and newsletters about science curriculum issues
5. New General Science syllabus documents
6. Exemplar curriculum modules.

Developing strategies for Scisa

The formation of Scisa

Scisa was established as a formal project after a meeting of the Science Forum in Natal in July 1988. Science Forum represents science education projects and departments of education in KwaZulu/ Natal. From the beginning, contact with a wide range of science education bodies was seen as having high priority. A small coordinating committee was formed which had members who had both science education project and university experience (myself, Dianne Raubenheimer and Margaret Keogh).

Production and dissemination of a central stimulus paper

A process of informal networking led to the first Scisa meeting which was a workshop at Michaelhouse school in the Natal midlands on 11-12 January 1989. A group of 22 science educators from throughout South Africa met. The purpose of the workshop was to draft a document highlighting concerns about the current General Science syllabuses. In doing so the group considered philosophical issues about the nature of science, modern learning theories and curriculum design; explored issues surrounding the choice of science content and teaching methodologies; and articulated the curriculum relevance of environmental and technological concerns. Three basic principles were formulated. These were:

- (1) Scientific ideas are provisional and relative.
- (2) Pupils construct scientific knowledge themselves.
- (3) Environmental (including technological) concerns are central to curriculum development. (McNaught *et al.* 1989 p. 3)

These considerations were applied to issues of syllabus design, and the selection of appropriate content and methodologies. The dichotomies shown in Table 9.1 illustrate the nature of the paradigm shift that was discussed at this Michaelhouse workshop.

The stimulus paper (McNaught *et al.* 1989) arising from the workshop at Michaelhouse was drafted at the workshop. All the participants had read and considered a selection of papers on science curriculum issues before the workshop; this preliminary reading and reflection enabled the workshop process to be one of active debate right from the beginning.

Table 9.1 Tensions in the curriculum debate (from McNaught *et al.* 1989 p. 3)

PHILOSOPHY OF SCIENCE	
<u>Current convention</u>	<u>New ideas</u>
Science is about facts	Scientific theories are provisional and relative
Objective, apolitical and value free	Socially constructed
The way of describing reality	One way of understanding our environment
SOCIETY	
<u>Current convention</u>	<u>New ideas</u>
Academics set the curriculum	Community involvement
Certification	Quality of education
Competition	Cooperation
Schools isolated from the community	Workplace input into education
CHILDREN'S LEARNING	
<u>Current convention</u>	<u>New ideas</u>
Child as the receiver of knowledge	Child constructs meaning with teacher support
Children are empty vessels	Children bring their own conceptions
Uniform approach	Variety essential
CONTENT	
<u>Current convention</u>	<u>New ideas</u>
Facts dominate the syllabus	Skills and processes must dominate
Syllabuses are long	Syllabuses must be shorter
Fragmented	Integrated
Academic approach	Environmental approach

It is of interest to note that the methodology used at this workshop incorporated a technology which was designed to support a participatory approach. Groups at the workshop wrote their ideas directly onto personal computers; these ideas were then circulated for comment to other groups. By the end of the two day workshop several rounds of editing had occurred. The matching of a philosophy of dialogue and participation with a technology infrastructure which enables this process was a significant advance.

The stimulus paper reviews the current situation in which our existing syllabuses are 'out of balance' with the needs of children preparing for the twenty-first century in South Africa. The document formulates several questions and issues which need to be addressed in the process of effective curriculum revision.

One aspect of the debate which deserves discussion here is the breadth of what is meant by an environmental emphasis. This is shown in figure 9.3. The recognition that sociopolitical issues need to be considered in understanding what is meant by environmental stress has implications for the whole of science education. This holistic perspective on the nature of science and, hence, on what is appropriate for curriculum development in science education, is an important aspect of the dialogue that Scisa seeks to promote.

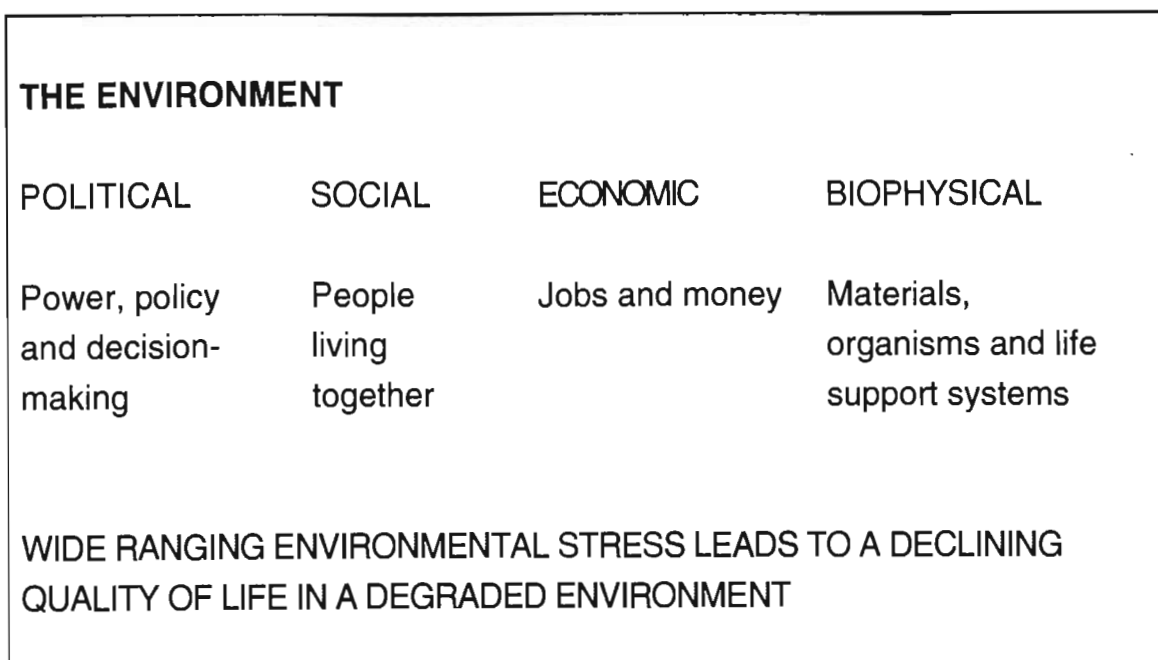


Figure 9.3. The environment and environmental issues (adapted from O'Donoghue & McNaught 1990 p. 24)

A general awareness of the need for syllabus renewal has prevailed for many years, but the emphasis to date has been on the upper secondary level. This document was the first to crystallize issues at the primary and lower secondary level. However, the articulation of issues in the Scisa stimulus document is not sufficient in itself. A process of networking and teacher participation is needed in order to translate these concerns into effective action. This process will enrich existing science teaching in schools as well as providing a workable strategy for designing the science curricula in our schools.

Translating the stimulus paper into action

From the beginning of 1989 till the middle of 1991 about 70 curriculum planning activities (workshops and conference presentations) were run under the auspices of Scisa or the science education projects associated with supporting teacher development and the examination of curriculum issues at primary and lower secondary level (appendix 12).

Many of these workshops began with a discussion of the basic Scisa principles outlined above and some of the ideas contained in the stimulus paper. These ideas were applied to a specific task and a tangible product resulted. This was usually in the form of a poster about the design of a particular teaching module, often in flow diagram form. These flow diagrams indicated the relationship between parts of the topic and the interrelationships with other topics. Teachers contributed a large number of valuable curriculum ideas and these ideas can be readily shared and developed by groups of teachers together. Reports have been produced about each workshop and a source of curriculum ideas is thus rapidly accumulating. What is perhaps even more important, at this stage, is the fact that many more teachers came to believe that they had the right to be involved in curriculum planning, and appropriate ideas and skills to contribute to the curriculum process.

The activities listed in appendix 12 provided the material for reflective evaluation within the action research spiral. Meeting times to share experiences and plan forthcoming activities were considered essential in this development stage of Scisa.

An expanding network

Share-net is an organization that developed at the same time, but separately to Scisa. It developed through the experiences of the staff of the Wildlife Society and the Natal Parks Board who have been supporting teachers for many years by developing resource materials in environmental education. Their first approach was to provide teachers with fully developed and tested materials, but these have either overwhelmed them or disempowered them in other ways. Collections of materials have also, on occasions, become valued possessions while being seldom used. For the past few years an alternative approach has been researched. This involves offering teachers and curriculum projects advice and whatever support they think they need for their own environmental education endeavours.

Many of the curriculum ideas which have emerged from Scisa workshops and Share-net projects have been used to generate useful resource materials. Various authors and artists are helping to create resource materials through a participatory process with teachers and a range of materials is now available (e.g. Hart 1990, Keogh 1991, Taylor 1990, Mhlongo & Vilikazi 1990, O'Donoghue *et al.* 1989, Umgeni Valley Project 1989, Urban Foundation 1990). Many of these materials have been reworked and reissued as reflective action proceeds.

By mid 1990 the central issue for both Share-net and Scisa was that a large number of small projects and several publications existed. The need for a more formal network became increasingly clear so that people could be in touch with one another's work. Also, there is a need for focussing and avoiding duplication so that maximum support could be given to any worthwhile initiative.

It is clear that the philosophy developed by Share-net for the production of resource materials is the same as that being used by Scisa for syllabus construction. Indeed, the process of determining what science should be taught in our schools is intimately linked to how that science should be presented and what resources are most appropriate. The meeting of two streams of experience in this way has been an affirmation to those who work in both initiatives.

There has been a strong network of science educators in the Natal region for many years (linked together through the Science Forum). Scisa developed as an initiative from the science education projects which have been working for a considerable time in Natal. The work of Scisa has always been supported by and, indeed, is often inseparable from that of the Urban Foundation Primary Science Project and the Science Education Project. It is important to note that the work of Scisa and associated projects has developed in a simultaneous and complementary style. This is not surprising given the extensive and conscious emphasis given to dialogue aimed at critical reflection by the science education network in the Natal region. The expanding network of curriculum development actors in Natal by the end of 1990 is shown in figure 9.4.

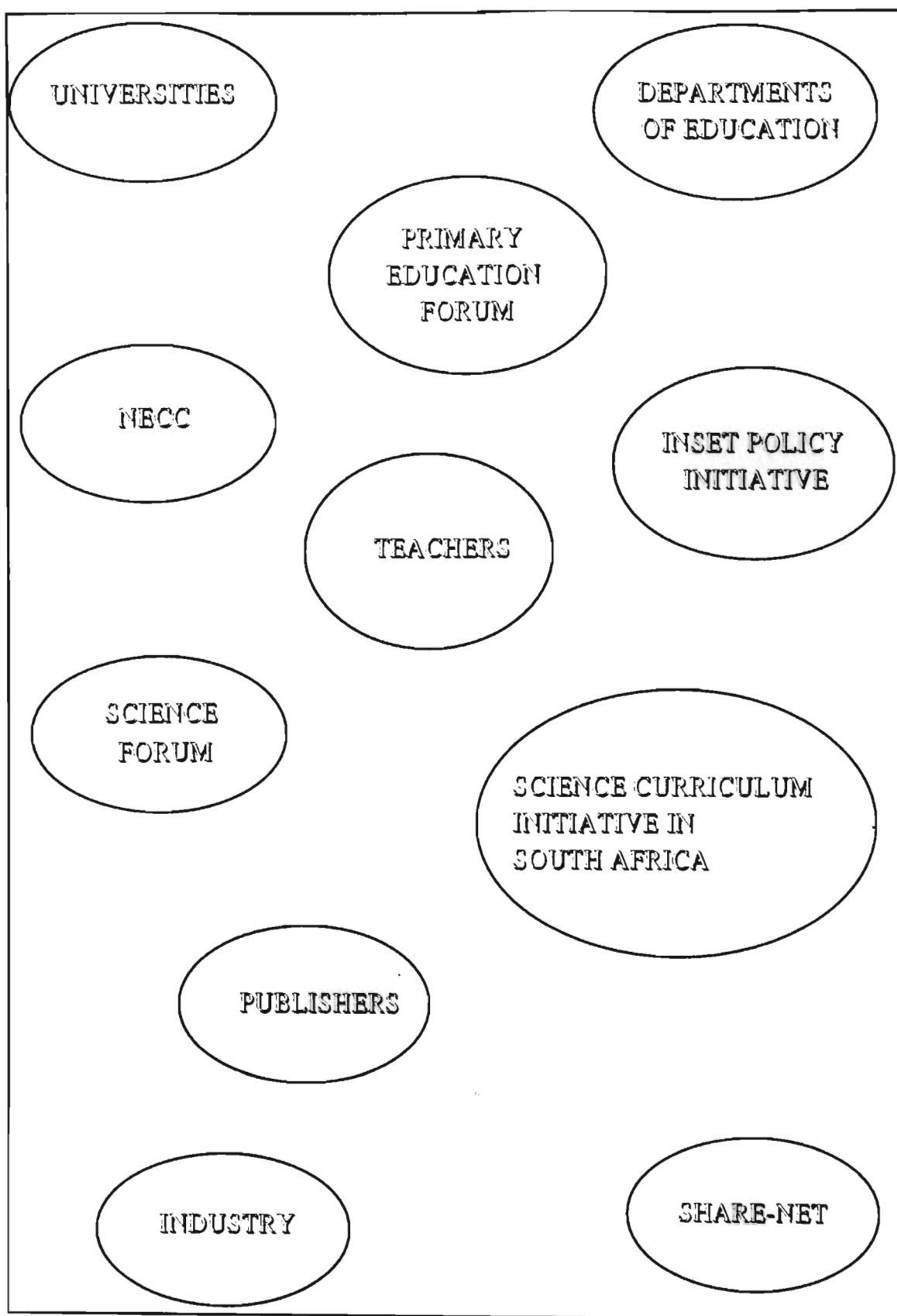


Figure 9.4 The expanding network of curriculum development actors in Natal

Two examples of how this expanding network of curriculum actors is impacting on education may clarify the concept. Through the network of actors dealing with primary school education a process reflecting on the overall primary school curriculum began. This group, the Primary Education Forum (Pef) is looking primarily at language across the curriculum, and focussing on language strategies for primary science teachers. This project will be discussed in chapter 10.

The Inset Policy Initiative (Ipi) is a national initiative which developed to stimulate debate about the general principles on which Inset projects in South Africa are based. In a sense Ipi hopes to strengthen Inset work by providing possible models for future educational scenarios in South Africa (e.g. Raubenheimer 1990). An early mailing list of Ipi contained 54 entries. Most of these entries were for the Natal region, though some were national projects. There were 18 nonformal projects funded by the private sector, 7 teacher associations, 5 science subject associations, 4 universities, 10 formal in-service centres, mostly associated with government departments of education, 3 curriculum initiatives, and 7 research and policy groups (including groups of the ANC National Education Consultative Committee — NECC). This illustrates the number of Inset initiatives operating in South Africa and the need for communication channels to be developed between them. The need to develop communication channels between non-government organisations (NGOs) in development in general and education in particular is illustrated by the number of networking publications which have appeared in recent times, e.g. Prodler (1993a&b), Levy (1992).

These curriculum networks have been strengthened enormously by the breaking down of barriers between initiatives. A concept of curriculum development based on effective participation between all stake-holders in the process is not congruent with the building of educational empires. Teachers and classroom action can benefit by networks; in contrast, it is largely academics who benefit from the building of central empires. Coles (1984) describes the gulf between teachers' theories and researchers' theories and classifies

particular theories as ‘stepping stones’ (p. 107) across the divide. It has been the experience of Scisa that action research in networks can help this gap to be bridged and bring valuable theoretical insights into practical implementation. The cooperative networking of all science projects is essential if dynamic, adaptable science syllabuses and supporting resources are to become a reality in South Africa. This is illustrated in figure 9.5.

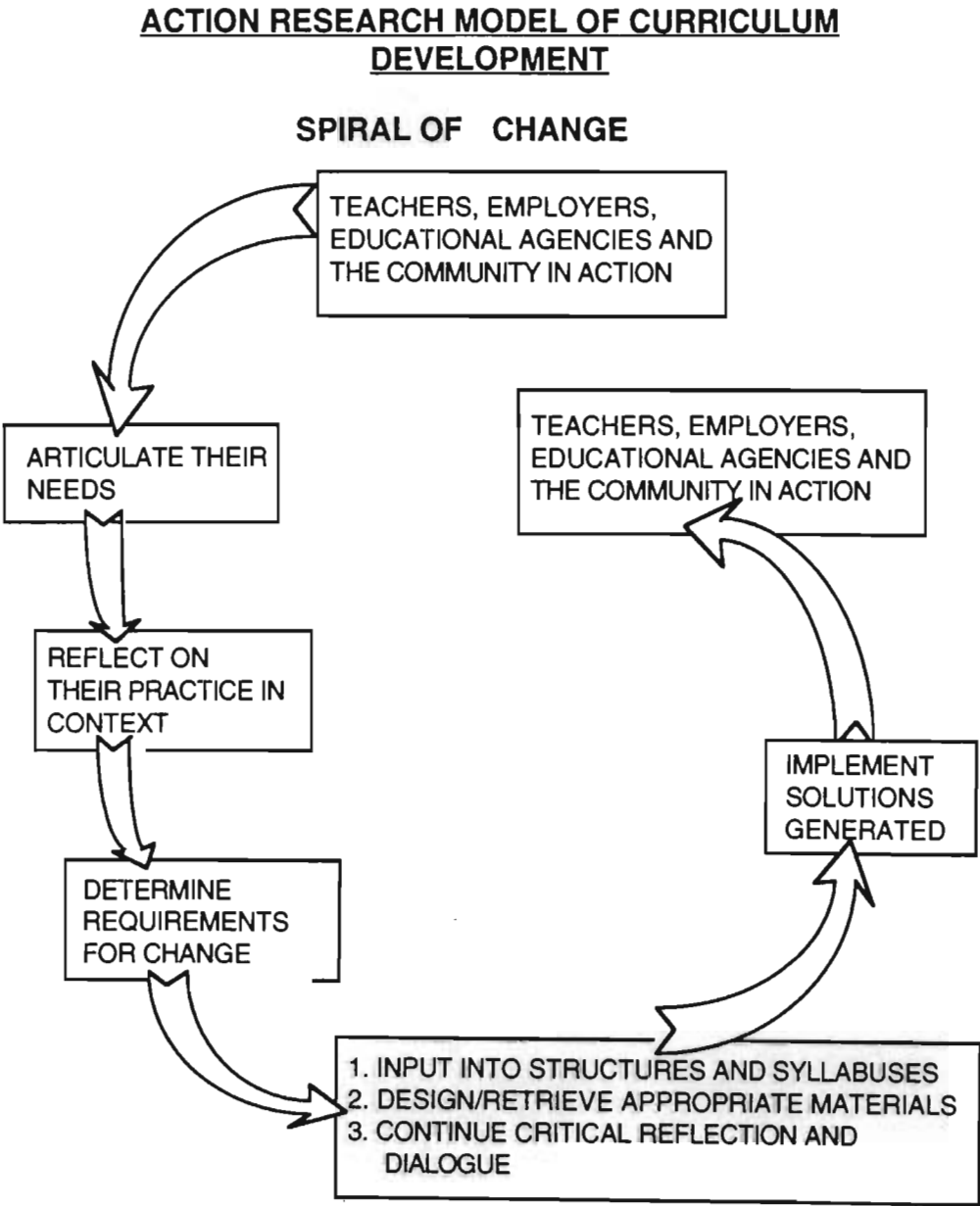


Figure 9.5 A people-centred partnership of curriculum change by reflection and action (after McNaught *et al.* 1992 p. 296)

Scisa in 1991

By the beginning of 1991, Scisa had become identified as a project which had brought greater coherence to the network of science curriculum action which is continually developing in South Africa. This particular 'grass-roots' network is based largely in Natal, though workshops are run in other regions and ideas are shared with other science education initiatives in the country.

By this stage in the project a great deal of debate was taking place around the issue of which 'domains' Scisa operates within. Taylor *et al.* (1989) describe the three domains which are central to curriculum as the academic, the bureaucratic and the school. These are obviously influenced by the formal political domain. Emerging curriculum models for South Africa need also to consider the domain of alternative education domain. This concept of mapping domains of concern is a valuable way to explore the balance of a network. For example, the ideas that have been articulated through Scisa have been presented to the official General Science syllabus committee, to the Independent Examining Board (described by The Alternative Education Projects Team 1989), and to the NECC research project, Nepi (National Education Policy Investigation — linked to the ANC). The decision to attempt to engage with as many domains as possible seems important if a representative science curriculum network is to emerge. This means that constantly Scisa needs to address and debate questions of balance and power relations.

This was particularly clear in the establishment of a broadly representative Scisa Advisory Committee. Any curriculum initiative at this time must be sensitive to the imminent political changes in this country. Establishing a basis of legitimacy is essential if the products of this project are to be accepted in a new South Africa. As we are working in a time of transition, a broadly based Advisory Committee is essential and this has been achieved using the criteria noted in chapter 3, page 32.

It was also clear that if Scisa is to make a significant contribution to science curriculum renewal in South Africa, staffing issues needed to be addressed. Funding was secured for a full-time coordinator for three years. The post was filled early in 1992.

This chapter then sets out the context of Scisa's early development. The project then entered a new phase in which the following activities were envisaged.

1. The continuation of workshops with teachers to generate curriculum ideas and materials. The products of these working groups could be
 - * core curriculum details
 - * exemplar modules
 - * some optional material
2. Networking nationally with educational decision makers within teacher organizations, educational institutions and departments of education to inform and set up debate. Particularly, there is a keenly felt need to begin more work within colleges of education.
3. The production of a newsletter as a forum for science curriculum innovation. This newsletter can disseminate the ideas and materials produced by the teacher working groups. Modifications can occur as the result of feedback.
4. Liaison with a broad spectrum of organizations with a specific interest in education. This will include community organizations as well as commerce and industry. This is essential if relevant syllabuses are to be produced.

Chapter 10 Action — Primary Education Forum and publishing

Introduction

If compilations of language data such as presented in chapters 6 to 8 are to be of some use we need to develop models for change within teacher education and within curriculum development where the sorts of language difficulties which have been described in this thesis are examined and acted on. In one sense, it is not the details outlined above from this piece of research which are of the greatest importance. It is the awareness of language difficulties and the formation of a commitment to focus in this area that is essential.

A key element in this process is that of collaborative action. Individual projects are unlikely to have impact on a major problem. Two examples are given here of the kind of work which can utilise language research data; these are the Primary Education Forum and dialogue with formal publishing firms.

1. The Primary Education Forum — a model of examining language in science in-service teacher education

For some years there has been a great deal of cooperative interchange between the various science education projects which operate in the Natal/ KwaZulu region. This has increasingly crystallized into fairly formal networks, each network having a particular emphasis. One example of a network in Natal/ KwaZulu in which language issues are of central concern is the Primary Education Forum (Pef). I initiated the formation of Pef and organised and chaired the Pef meetings. The work resulting from Pef is, of course, due to all members of the forum. The members of Pef began meeting in order to look primarily at language across the curriculum, with a focus on language strategies for primary science teachers. Members of Pef came from the Urban Foundation Primary Science Programme (PSP), the English Language Educational Trust, READ, the Wildlife Society, the Natal Parks Board and the University

of Natal. Four meetings took place in 1990/91 and involved detailed examination of theoretical ideas, ideas for workshop strategies with teachers, and planning curriculum materials. In their projects, participants were already preparing alternative approaches and materials geared to addressing the serious language problems at the standard 3 level where the medium of instruction changes from mother tongue to English. These meetings enabled them to share and reflect on these experiences and strengthened the cooperative work being done by various projects.

The threshold at standard three

The Threshold Project is a research project conducted in the second half of the 1980s into the complex problems facing black children when the medium of instruction changes from the home language to English. Language testing, cognitive developmental research, materials development, and observation of classroom practices were carried out. The comprehensiveness of this research has resulted in a valuable resource for all concerned with black primary education (Chick 1990). The research (Macdonald 1990a&b) is based on an illuminative perspective (chapter 3, page 12). This is probably appropriate with an external research team. One of the issues with the contextual aspect of illuminative research is to decide at what level one analyzes context, especially of historico/cultural aspects. Language is a political matter. There is quite a lot of discussion about cultural relativism vs pragmatism in the Main Report of the Threshold Project and a pragmatic stance is adopted. The theoretical framework is that of communicative language based on Vygotsky's theories. Within this framework, culture must be included within the learning experience and perspective. 'In advanced higher mental functions, there is a progressive decontextualization of mediational means (DMM). This progressive decontextualization is an explanatory principle of socio-cultural transition' (Macdonald 1990a p. 71). Basically, this is about the socially mediated development of metacognitive strategies which are personal to each learner: they are essential for learning in general and, in this context, literacy in particular.

It is clear from the research that children at standard 3 don't manage to learn under the constraints operating on them. Also it is difficult to change the situation (Macdonald 1990a p. 25). Poor reading skills are noted (p. 76) and no examples of self-initiated expository writing in English as a second language were found (p. 77). The problem of the vicious circle between mastery and coverage was noted. This is exacerbated when teachers have poor management skills, especially with respect to time (p. 126).

There are gaps in competence between the demands of content subjects and between a concept of idealized English competence. There is also a gap between idealized English competence and actual English competence (p. 138).

Specific structural problems in children's English are discussed. (pp. 131-6) Many lessons appear to be successful because children can make sense of nonsense through deduction (p. 142). However, one must be careful about condemning non-standard English which is genuinely communicating ideas and images. One must be careful to not impose a deficit model on second language speakers of English. The difference between 'disadvantage' and 'deficit' is not explored fully enough in the Macdonald reports.

A 'gradual transition' model for the introduction of English is advocated (p. 55). Certainly, 'straight for English' requires mother tongue literacy and is problematic. If one adopts a gradual transition model, then the choice of subject for transition order will be determined by: children's experiential base, how the subject can be related to children's lives, and the terminology demands of the subject (p. 169). The *Breakthrough to Literacy* and *Bridge* materials used by the Molteno Project (described in Jansen 1988) are recommended (Macdonald 1987) as being suitable for lower primary classes. The findings of the Science Report (Macdonald 1990b) support the gradual transition model.

Greater integration between departments of education is advocated and guidelines are given for the preparation of curriculum materials which incorporate process skills and language skills into the subject content.

Teacher issues

At the first meeting of Pef the insecurity that teachers feel about handling language issues was discussed. Often teachers have some difficulties in using English themselves and also they often have a very limited range of strategies to assist pupils in learning in English. However, one cannot just give teachers a set of prescribed rules as language strategies. We need a great deal of research on what are the qualities/ characteristics/ strategies of effective teachers. For example, the Wildlife Society employs environmental education officers who are not trained teachers. Their success lies in their people skills, interpretative skills, content knowledge and the availability of natural examples. Often the work with pupils at the environmental education centre at Umgeni Valley goes better when the teachers are absent!

Many teachers have an approach to teaching that is intuitively valuable. They naturally pose questions, ask children to explore ideas and their environment. Is there any way to give teachers who do not have this intuitive approach, a new direction to their teaching? We often presuppose that teachers have a desire to change but many teachers are quite comfortable with a rote learning approach and feel they get better results that way.

There are two ingredients which must be part of any Inset initiative which is attempting to assist teachers in becoming critical about their teaching.

- Face-to-face interactive experiences. Not even the best printed material or educational TV can provide the opportunity for dialogue which is essential.

- Exposure to case studies of innovative teaching. For example, READ produces a newsletter for rural schools. This is full of photos and examples of work being done in project schools. There are also descriptions of the ideas and skills which can be gained at READ courses.

The next step in this process is the active involvement of teachers in the production and reflection on materials. The testing of READ materials in Soweto and in rural schools, and the workshops on worksheets which PSP run are examples. It is important to note that the teachers in these cases are supported teachers; the further development of an infrastructure whereby such work is facilitated is essential. Hawes (1979) describes an institute for primary education in the Cameroon as an appropriate model.

Many teachers are taught the model of chant and repeat. Teachers need to want to change this longstanding classroom practice before other methods can become attractive. Another factor is the tension between fluency (e.g. in reading and speaking) and accuracy (e.g. in grammar lessons) — this needs to be recognized and worked with. This research has highlighted that syntax is not just the concern of the English teacher. In science, understanding the structure of the discourse is essential to learning science. Cleland & Evans (1984a&b) have produced a text which English and science are well integrated. Interestingly, the book is titled *Learning English through General Science*, not vice versa.

The members of Pef are largely concerned with in-service teacher development. The group explored ways to promote interest groups in colleges of education so that beginning teachers are also sensitized to language issues. Because of the problematic situation in black colleges of education, no real action beyond the level of discussion of needs occurred by the end of 1991. From discussion with Zulu-speaking teachers, it is clear that the implications of the differences between English and Zulu are not considered in teacher education courses at black colleges or universities. Also, they are not considered in teacher education institutions where teachers who do not speak Zulu are training, despite the fact that an

increasing number of these teachers are likely to teach Zulu children.

Specific language strategies for classroom use

Pef members compiled some specific language strategies which classroom teachers can use. These were compiled from their pooled experience and were of value in planning and reviewing workshops conducted by Pef members.

- Labels on a chart can be used with questions. These are aimed at finding out what pupils know (constructivist ideas) rather than just focussing on the activity of sticking the labels on.
- Linking adjectives to functions. Once one has nouns, the discussion of functions leads to descriptive adjectives, e.g. beak (noun) → seed-eating (function) → curved (adjective)
- The use of card sorting. Cards can have index names in English and Zulu, and descriptors such as habitat, food, etc. Various categories can be obtained through a brainstorming session.
- The use of sentence strips. Building up sentence strips on pieces of paper stuck to the chalk board through question/answer class sequences.
- The ordering of sentence strips into paragraphs. Sentence strips → ordering of sentences → paragraph. The paragraph contains the concept of sequence and the need for logical connectives.
- Reaction frames. A paragraph can be extended with a reaction frame which contains a set of observations. Phrases like "Another thing I saw...." can be used.
- Stories with gaps, e.g. "What will happen next?"

- Direct story telling — what, where, when simple questions. The use of stories is important because of the connectives involved, as well the processes of articulating events and ideas.
- Levels of questioning — why, how questions which require higher order skills. As teachers become conscious of the level of questions they are using, they can find the most appropriate level for individual pupils.
- Activity cards with questions.
- Research skills from books. This can begin with matching pictures to cards which have information.
- Recording skills and note-taking skills. This is almost never done in black primary schools; study skills are an important class of process skills.
- If Zulu (or other mother tongue) is used, then there is a need for immediate translating and recycling of questions. Skills are needed here; teachers are often not aware themselves of the fine detail of the linguistic interface between Zulu and English.
- The use of an insertion of one Zulu word as a language bridge. The Natal Parks Board has produced some material using this strategy.
- Sorting and classifying activities where the strategy is free articulation with Zulu and English rotating. This is the 'private' stage. Finally, there is a public stage where the products are translated into English, either in spoken or written form. The teacher acts as a mediator in this process, progressively assisting pupils to see the links between Zulu and English. This is a more holistic approach to the learning of language and can be contrasted with a more formally designed stepwise model where levels of difficulty are carefully monitored.

- The publishing of a newspaper such as is done by READ. This can inform teachers of language strategies and include examples from local schools.
- The transition from natural language/ social dialogue to the formal language of science with logical sequence and precise meanings for words needs to be made explicit.

This list of strategies grew over time, was shared and refined. It is a simple example of how a dynamic and appropriate resource can arise from reflective action.

The role of projects

Projects produce ideas which feed into a growing resource pool. Their products are often ideas and strategies rather than curriculum products. Both are needed. There is a tension between an emphasis on dialogue and an emphasis on packs of products. Projects now need to explore these tensions more consciously.

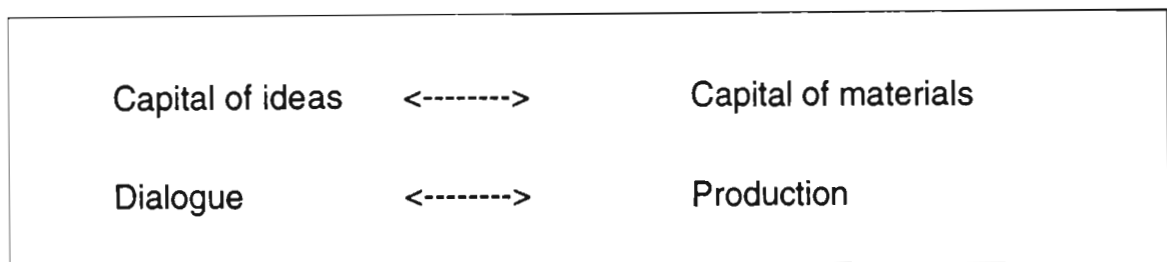


Figure 10.1 Tensions within projects about their focus of action

While projects are trying to coordinate work through Projects Forum and Science Forum, there are other smaller initiatives in the field. Teachers can really only give their allegiance to one project at a time. They will naturally select the project which they think gives them the most. Cooperative work in the field between projects may not be seen that way by teachers; they may see themselves selecting between competitors.

The role of key teachers in projects creates dilemmas in that often good teachers are taken from classrooms in order to work in projects.

The support of principals is also important. This is needed so that teachers who go to workshops can demonstrate their ideas to other teachers at their schools. Time needs to be allocated for this.

The following guidelines for workshops were formulated by Pef members.

- Workshops need to be genuinely experiential, e.g. by the use of drama.
- Metacognitive processes need to be included by asking teachers to discuss strategies. Teachers need to talk about the process of teaching.
- The pace should not be too fast. Some points need to be explored again and again.
- Concept mapping should be covered.
- Generalizing comes from a series of activities. Teachers will only try out new strategies which they have used comfortably and adapted for themselves in several ways. Otherwise, they will use a new idea as another dogmatic prescription.
- There is a need to explore the concept of 'risk-taking'. One often has to accept the poor English but vibrant sense of writing in order to build up confidence. This is not a 'wrong' thing for teachers to do. Expectations about pupils' level of English must be realistic.
- Workshops around stories are very valuable Garvin (1987) discusses this strategy.

- Building up a series of questions around a picture or a story can assist concept formation. One way of looking at this is by considering concept formation to have 5 aspects:
 identification,
 qualification,
 classification,
 relation, and
 manipulation.

Questions can be phrased to support development of all these aspects.

Models for curriculum renewal

The second meeting of Pef centred around models for curriculum renewal. In 1990, the junior primary pattern for white pupils was three years of environmental science followed by three years of primary science. For black pupils it was two years of environmental science followed by two years of primary science. There was a great deal of uncertainty about the structure of new syllabuses and it was felt useful to explore the alternatives.

At this time Patrick Van Rensburg had returned to South Africa from the Foundation for Education with Production (FEP) in Botswana. The FEP model (e.g. Seidman 1987, Seidman & Stuart 1990, Seidman 1990) incorporates skills training (e.g. beekeeping, bricklaying, crafts) into formal education. It was felt that there was a lack of an environmental focus in many of these materials (e.g. sustainable agriculture). The FEP materials have a clear philosophical basis of structural materialism; one would not want to replace the dogmatism of Christian National Education with another rigid approach.

Of course, no curriculum project is ever a resounding success. The following materials and approaches have been widely used in southern Africa and are considered valuable. All were produced with an awareness of language issues and have a strong commitment to visual literacy. Yet all have had implementation problems. Issues in the Ministry of Education limited the impact of

Zim Sci in Zimbabwe. The *Science Focus* series (Deoda *et al.* 1983, McNaught *et al.* 1984a&b) is based on constructivist principles but requires too much preparation and commitment from teachers. The original *Action Ecology* materials also require a great deal from teachers; in addition, detailed interpretation of the syllabus was needed (O'Donoghue & McNaught 1991).

The interface between written language and visual material is complex. The term 'visual literacy' is used to describe the level of familiarity, comfort and comprehension of illustrations, photographs, charts, etc. which are embedded in text. Teachers' limited understanding of this interface between text and visual material was mentioned in chapter 5, page 70. McBean (1980) explains that most rural populations in Africa have had very little exposure to printed materials of any sort. He produced a very practical guide for the production of visual educational material in the context of a developing country.

There is a tension between planning for alternative approaches which seem more appropriate for enhancing learning, and realising how disadvantaged some schools are. Many schools (especially in rural areas) do not even have a copy of any syllabus, let alone resource materials. All members of Pef have experienced these problems first-hand. The construction of new, improved versions seems rather academic in the face of enormous communication and dissemination issues. The tension between the need for teachers to use language strategies much more than they do now and the need for teachers to have more confidence in their work is central. The discussions both within formal Pef meetings and the strengthened communications between members outside meeting times led to the following model for action.

There is no panacea but the best compromise involves a combination of:

projects producing :

1. suitable resources,
2. collaborative, interactive workshops, and
3. ongoing dialogue and research

using teaching strategies which focus on:

4. relevant experience,
5. discussion of the meanings of vocabulary, and
6. use of appropriate diagrams.

Figure 10.2 Model for action for primary teacher language development

The famous word 'relevant' mustn't be reduced to the level of jargon. Both the physical and cultural life of the child must be considered. Pef members used the topic of air at standard 3 as an example to explore this concept of relevance.

- The use of a bicycle pump could transform a unit on air.
- Wind is not just a feature of the weather. Children need to think about wind on a small scale such as blowing on the backs of their hands or blowing papers across a table.
- Stories (such as the contest of strength between the wind and the sun) are another way in which science can be related to the life world of children.

The use of other experiential strategies such as practical work and drama were discussed. Simple parachutes (as simple as catching air in a plastic bag) and paper gliders may well be good starting points.

Extracts from Catherall (1981) and Berluti (1989) were examined. Certainly there are lots of sources for ideas. How can we make these ideas available and accessible to teachers? The text in

Catherall is quite complex. There are a lot of words; instructions for activities are not well separated from questions to think about. Berluti is probably easier to follow but is very linear in design and dry in presentation. There is a lot of evidence that teachers do not follow a linear sequence of instructions, especially when they are very wordy. It is not practical to present a diagram for every step in a lesson and indeed this would also be tedious. We need innovative approaches to the presentation of instructions for activities. One suggestion is that a diagram of the finished product (e.g. paper glider) or equipment (e.g. spirit burner heating a test tube with a solution) be surrounded by a sequence of numbered instructions. This may enable teachers to see each step as part of a whole.



Figure 10.3 Diagrammatic presentation of instructions for activities

Simple English is not just a matter of using simple syllabuses. It involves the integration of language with educational processes; this involves considering process skills, study skills as well as content. The approach taken by the Cambridge Primary Language Course could well be adapted for use in South Africa (Cuff 1984).

Pef existed to develop strategies for teachers to cope with the existing systems in schools. The link with Scisa where the focus is on developing alternative models for curriculum development is clear. New curriculum models can only be successfully implemented where teachers have been actively working with innovation and thinking about children's learning. If future science syllabuses are to be more sensitive to language issues a great deal of work with teachers needs to be done before the new syllabuses are implemented.

Pef is a more informal network than Scisa. There was no mechanism for an advisory committee, or the conscious dialogue about action research that was an integral part of Scisa. There are two reasons for this. Firstly, several Pef members were also active in Scisa. Those who weren't (the English Language Educational Trust, READ and some University of Natal staff) were also aware of the Scisa network and had read the documents produced by Scisa. Secondly, Pef was formed because of a need for a practical working group. We met to discuss ideas and formulate guidelines. The combination of a more formal, more ambitious (?) network (Scisa) with a local pragmatic one (Pef) suited the needs of the context.

2. Dialogue with formal publishing firms

There is another strategy that needs to be employed when considering how to improve the educational resources which teachers have at their disposal. This is the formal textbook publishing arena. The deficiencies of many South African text books are well known (e.g. Langan 1990). Many teachers, especially in rural areas, do not have access to the support of educational projects, either in English or in science. Textbooks are all they have. Dialogue needs to be set up with publishers about the issues outlined in this thesis. This was done with one publisher, Centaur Publications, as part of the implementation phase of this research. Besides general discussions about the nature of language difficulties with both the publishing staff and various authors, some more focused work took place in three projects:

Mathematics for the three years of junior primary — ssa, ssb and standard 1 (Parry & Shandu, 1991a&b, 1992)

Children are still being taught in their home language at this stage but it is not realistic to translate English texts into Zulu, Xhosa etc. It is clear from this paper that the concepts will not translate well. The teacher has an enormously difficult task. S/he must verbally translate the instructions to the children, using the key words in English as they arise. This will only be possible with texts which

use simple English and have a lot of visual material. The syllabuses are not appropriate but one can improve the quality of text material. In this project I acted as editor on a previously written manuscript, reorganising the examples, working with the diagrams and substantially adding to the sections of guidelines for teachers.

Environmental studies for standards 1 and 2

Texts around these syllabuses, which focus on the environments in which children live, will be translated into African languages and should provide valuable background development before children begin science in standard 3. Zula and Tsonga editions are in print (Clacherty *et al.*, 1993 a&b) and Xhosa, Venda and Northern Sotho are in press. In this project, the work centred around discussions with the author who wrote in English about how best to prepare the text so that translations could be as sympathetic as possible.

Biology at standards 8, 9 & 10

Most black pupils at senior high school study biology. Obviously the language of instruction is English at this level but pupils' level of English is often weak and the density of complex biological terms is high. Great care needs to be taken to ensure that pupils have some method — practical work, models and diagrams — to assist them in building up appropriate personal concepts. Discussion exercises also need to be formally incorporated into the text. In this project, I discussed these principles with the authors and then edited the final manuscript. Unfortunately, the new biology syllabuses which were to have been implemented in 1992, were not introduced because of the transitional state of the nation. To date, these books have not been published (e.g. Hunter & Oberem 1991).

Importance of an action research model

This kind of work is reported in a Ph D thesis quite intentionally. Within an action research model, there is a commitment to implementation and reflection on practical outcomes. Scisa, Pef and the work with Centaur Publications are examples of how research can be integrated into more tangible educational outcomes. It is not a tidy model, but more realistic in a dynamic educational context.

Chapter 11 Summary and reflective comments

The research described in this thesis is exploratory and tentative. It is embedded in a framework of critical theory and action research as described in Figure 3.2. page 32. The **hypotheses** given in chapter 2 are:

1. The central hypothesis for this research is that Zulu learners have difficulty forming concepts in science partly because of the process of translating from their Zulu cultural and linguistic experience to verbal formulation of concepts in English. ✓
2. An hypothesis about strategies for overcoming this difficulty is that learners can bridge the differences between Zulu and English if:
 - a. they consciously explore what these differences are,
 - b. articulation and discussion are seen as central to the learning process.
 - c. teachers are involved actively in the curriculum development process.

The research into teachers' styles of explanation (chapter 6) and the translation of specific words (chapter 7) do provide some indicators of a linguistic distance between Zulu and English which can create difficulties for learners who are at the interface between Zulu and English. There is thus some evidence to support hypothesis 1.

Neither teachers nor pupils seem to consciously explore the differences between Zulu and English at present. The work of the Primary Education Forum was partly based on seeing how this can be done (chapter 10). Whether hypothesis 2a is reasonable is still yet to be validated, though some teacher development work described in chapter 10 seems encouraging.

The work done with pupils working in pairs on tasks (chapter 7) does indicate that pupils with a better conceptual grasp of science do appear to have better skills in articulation and discussion (hypothesis 2b). Again this is only a tentative impression.

Hypothesis 2c is partly addressed by the work of the Science Curriculum Initiative in South Africa. The curriculum frameworks and materials produced thus far have been done so with language issues in mind.

The **expected outcomes** for this multidisciplinary, exploratory research were given as:

1. make a contribution to the study of the relationship between language and learning in a bilingual situation such as we find in KwaZulu
2. gain an understanding of learners' difficulties when operating at the interface between Zulu and English
3. develop guidelines for material production
4. provide indicators for teacher development programmes.

These outcomes have been achieved:

1. — especially by the work described in chapters 6 to 8
2. — especially by the work described in chapters 4 to 8
3. — especially by the work described in chapter 10
4. — especially by the work described in chapters 9 and 10

To summarise briefly, there is a tremendous need for deep research into the origins and consequences of learners' alternative conceptions of science in developing countries. This research must examine the cultural and linguistic aspects of learning science in particular. The implications for curriculum development seem to lie in the area of making articulation and discussion much more central in science lessons. The involvement of teachers in the development of these new materials will provide an effective system for professional growth.

Work in this area is not tidy or easy. Research which does not fit into neat packages is needed. A mixture of tightly focused explorations into specific linguistic issues is needed but this needs to be within a framework where the results can be fed into the overall process of educational development in the country.

I think the overall directions of this research have been reasonable for an exploratory study. Also, the need for and some strategies for establishing working links between linguistic/ cultural issues and educational change have been clearly demonstrated. To this framework I would hope that future researchers explore specific questions in greater depth and feed their findings into the growing number of networks in South Africa, so that good research becomes accessible to all those involved in educational change and development in South Africa.