The effect of th. .se of the RADMASTE Science Dictionaries on students' understanding of science concepts.

A research report in part fulfilment of the requirements of an MSc in Science Education at the Universi / of the Witwatersrand

Moyra Keane

Under the supervision of
Prof. M. Rutherford

Degree awarded with distinction on IO December I998

Signed: Student:........................

(Student no. 0392307)

Supervisor:.....................

Chair of School of
Science Education:..............

Johannesburg, 1998

Declaration

I declare that this research report is my own, unaided work. It is being submitted in part fulfilment of the requirements for the Degree of Master of Science at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

____

________________ day of ____________________ 1998

Abstract

This study reports the findings of a research project in a DET (Department of Education and Training)* school in Mamelodi, South Africa, in 1995. An investigation was carried out to ascertain whether students benefit from having access to science definitions in their vernacular, and to determine their preference in terms of the medium of instruction in the science classroom.

A Science Concept Guide, written at RADMASTE** Centre, was used as the main component of the intervention in a pretest - post-test study. This was followed by student questionnaires and interviews. The Concept Guide consisted of definitions and explanations of Physics and Chemistry concepts arranged according to themes. These explanations were translated into North Sotho.

Two groups of Std 10 students participated in the evaluation of the Concept Guide. One group used an English version of the Concept Guide and the other an English and North Sotho version. The *differences* between the pre-test and post-test scores of each group were compared. The results indicated that a significant improvement in scores had occurred in the English and North Sotho Group. Interview results showed that a number of students were in favour of having learning material of this sort available in their vernacular and claimed that they had found it helpful. In general, both groups expressed favourable comments about the Guide. Opinions about medium of instruction varied. Overall, findings indicate that further efforts in the development of vernacular material for the learning of science would prove beneficial.

Although the area of policy decision is outside the scope of this study, it hopes to contribute in some way to the knowledge about the preferred medium of learning in South Africa.

* DET. This department was responsible for Black pupils and was one of 4 Departments of Education in the Transvaal. The DET was phased out between 1994 and 1996.

** RADMASTE: Research and Development in Mathematics, Science and Technology Education.

Acknowledgements

I would like to acknowledge my gratitude for the assistance of the following people: my colleague Leslie Lekala who was co-author and translator of the Concept Guide and who helped me with interviewing students; Leslie Hlengani who went out of his way to assist me with the intervention in his classroom; the two schools in Mamelodi for participating in the study; Peter Fridjohn and Fienie Coetzee who gave me encouragement and advice when I was stuck; Professor John Bradley who edited the Concept Guide and provided guidance and encouragement; Professor Margaret Rutherford who provided lots of the enthusiasm and guidance during the course of the research and who has supervised the writing. Finally I would like to acknowledge RADMASTE centre for their support.

Dedication

For my parents
Pamela and Leslie Keane

Table of Contents

CHAPTER THREE - METHODS AND MATERIALS

CHAPTER FOUR - FIELDWORK

CHAPTER FIVE - RESULTS AND ANALYSIS

CHAPTER SIX - DISCUSSION AND CONCLUSION

APPENDICES

List of Abbreviations

ACPSE.....Advanced Certificate in Primary Science Education
ALH.......Acquisition Learning Hypothesis
ANC.......African National Congress
BICS......Basic Interpersonal Skills
CALP......Cognitive Academic Language Proficiency
DET.......Department of Education and Training
DNE.......Department of National Education
EFL.......English First Language
ESL.......English as a second language
GDE.......Gauteng Education Department
HSRC......Human Science Research Council
NEPI......National Education policy Initiative
OAU.......Organisation for African Unity
PSP.......Primary Science Project
R&D.......Research and Development
RADMASTE..Research and Development in Mathematics, Science and Technology Education
RIEP......Research Institute for Education Planning
S.A.......South Africa
SAAAD.....South African Association of Academic Development
SAIRR.....South African Institute of Race Relations
SEP.......Science Education Project
SRG.......Self Governing Regions
SSA.......Sub-Standard A
Std.......Standard
TBVC......Transkei, Bophuthatswana, Venda & Ciskei

List of Figures

List of Tables

CHAPTER 1

"and what is the use of a book," thought Alice,
"without pictures or conversations?"

Lewis Carroll

1.1 INTRODUCTION

The problems of science education in South Africa are well known and documented. (NEPI, (National Education Policy Initiative), (1992); Kahn, M. and Rollnick, M. (1993); Kallaway, P. (1991).) The HSRC, (Human Science Research Council), announced that South Africa came "bottom of the class" in the Third International Mathematics and Science Survey, (TIMSS), involving 41 countries. (Sunday Times, November 24, 1996). Concern about the lack of scientific literacy and technological skills has led to a great deal of discussion at all levels.
In order to ensure that school leavers will have jobs or be able to create jobs, more emphasis is needed on science and technology education. (South Africa's Green Paper on Science and Technology, 1996). Owing to the deliberate policy of the previous Nationalist Government, the education of Black students has been inferior to that of students from other groups. The overall pass rate at matriculation of 49% for Black students in 1995 compared to 97% for white students bears witness to the years of disparity between the different education departments. (SAIRR, South African Institute of Race Relations Survey, 1995/6).

The system of separate Education Departments for the different Race Groups was replaced in 1994 by a single Education Department. In this study "Black pupils" refers to those children taught in schools formerly in the DET, (Department of Education and Training), schools. Their mother tongue is not English although they write their examinations in English and their text books are in English. They are usually taught science mainly through English with some vernacular language instruction. Among themselves the pupils invariably speak their vernacular. Although some black pupils now attend former "White" schools or private schools and there is one education department, in practice there is still great disparity between schools. The following statistics highlight some of the problems in Black education.

Figure 1.1 (from RIEP, Research Institute for Education Planning) illustrates the failure within the system of Black students generally.

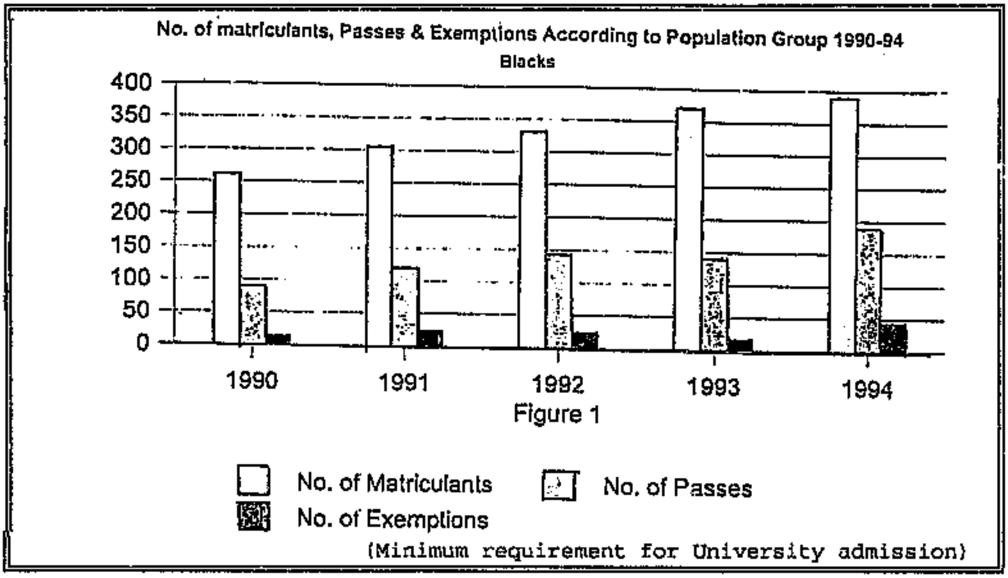


Figure 1.1

The actual picture is of course even worse when one considers the drop out rate of Black students before they reach matric. (It should be noted that available statistics are for the old system before the establishment of the GDE, (Gauteng Department of Education). There is, however, no indication that there has been a significant change in the last two years.)
See Figure 1.2

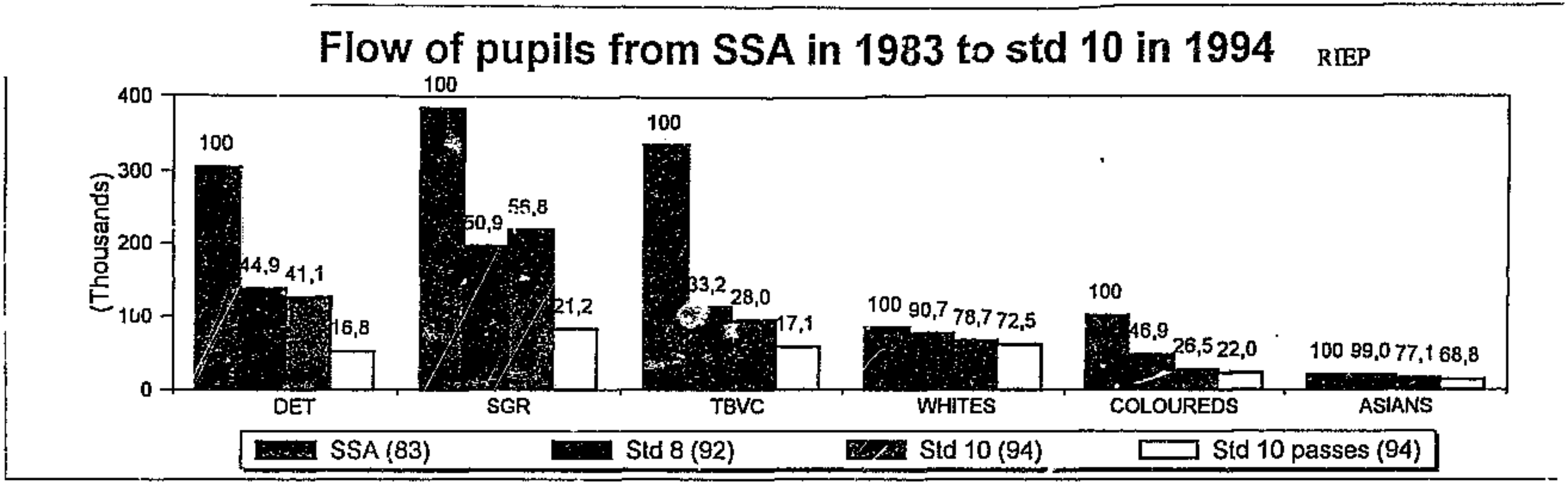


Figure 1.2

Key	
DET	Department of Education and Training
SSA	Sub-Standard A (now Grade 1)
SGR	Self-Governing Regions
TBVC	Transkei, Bophuthatswana, Venda and Ciskei
Std 10	Last year of high school

The chances of a Black pupil matriculating in maths and science are small. The subject choices for Black and White pupils are shown in Figures 1.3 and 1.4. (RIEP)

Choice of some Subjects of Black students

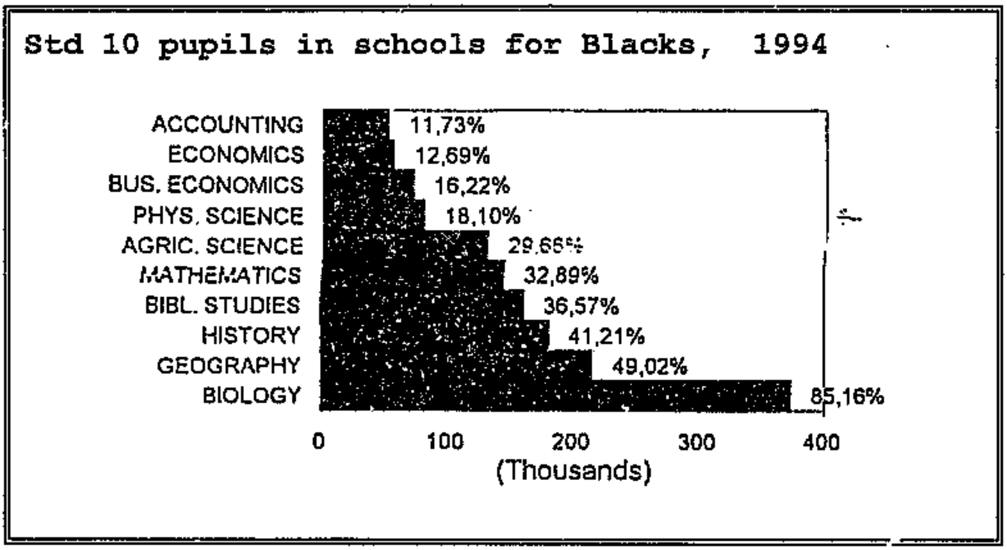


Figure 1.3

Choice of some Subjects of White students

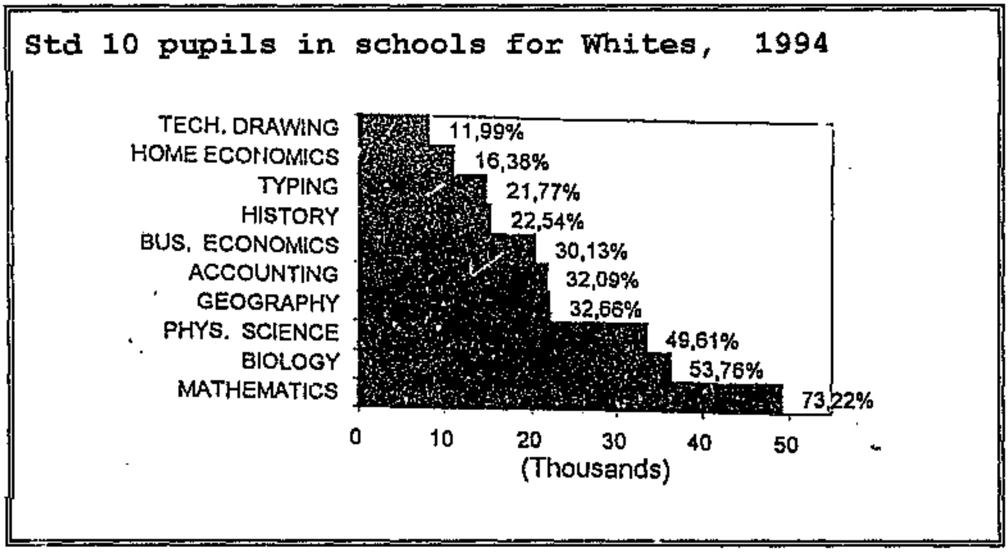


Figure 1.4

From these figures it can be seen that in 1994, 18,10% of Black students chose Physical Science as a subject compared to 49,61% of White students. These figures highlight the seriousness of the problem of Black students' science education. Less than 41% of Black DET students ever reach Std 10. Of this percentage only about 18% take Physical Science and of these only 25 % pass. This is summarized graphically in Figure 1.5.

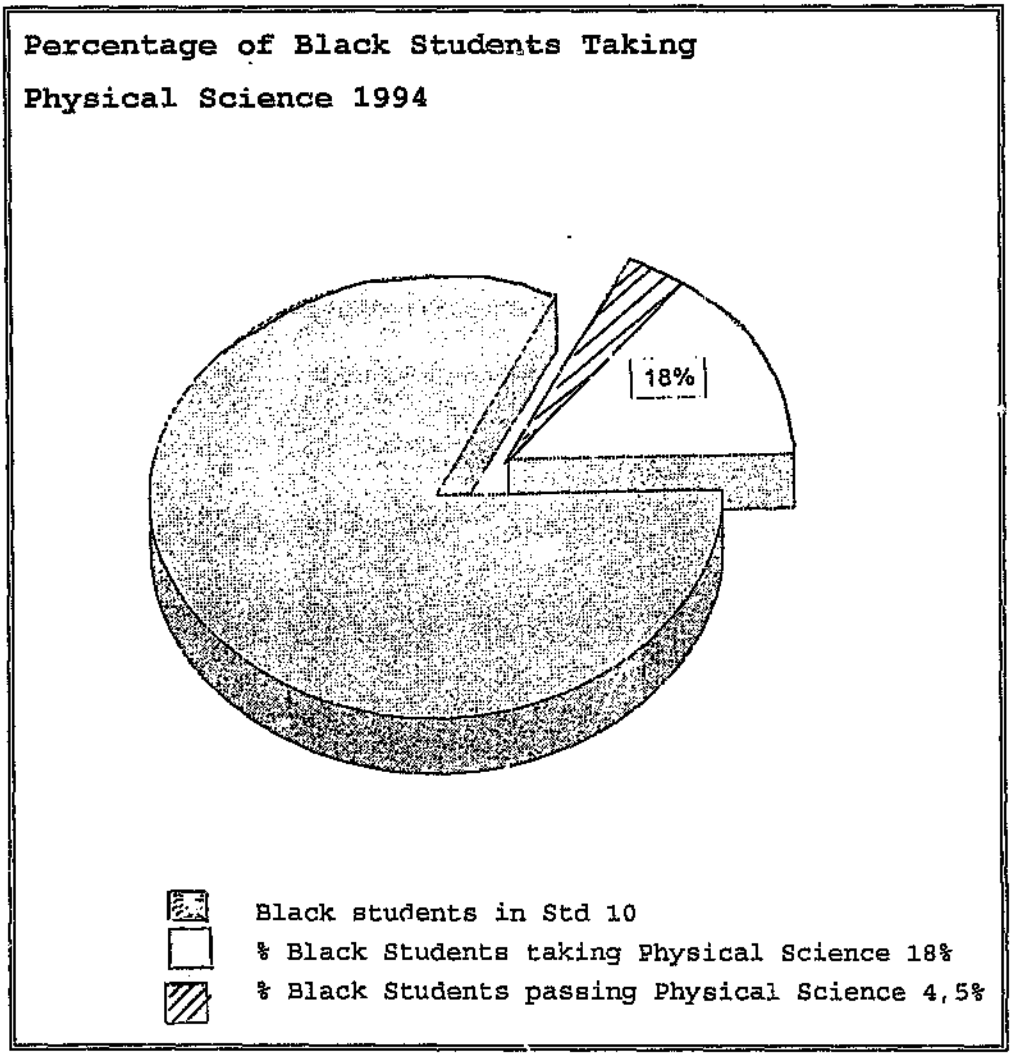

Percentage of Black Students Taking
Physical Science 1994
18%
Black students in Std 10
% Black Students taking Physical Science 18%
% Black Students passing Physical Science 4,5%

Figure 1.5

From figure 1.5 we can see that Physical Science is a relatively unpopular subject for Black students. There is also a shortage of teachers of Physical Science in DET schools: Figure 1.6, and a number of teachers who are underqualified* and inexperienced, Figure 1.7.

Estimated DET secondary teacher shortages in mathematics and sciences, 1992 (Kahn,1993).

Subject	Junior	Senior
Mathematics	600	700
General Science	700	n.a.
Biology	n.a.	1300
Physical Science	n.a.	500

Figure 1.6

DET Teacher Experience and Qualifications in Mathematics and Science, 1992 (Edusource, No 4, 1993).

Subject	< 5 years experience	Qualified	Under-qualified	Total
Mathematics	1689 (47%)	1007 (28%)	2587 (72%)	3954
Physical Science	676 (70%)	461 (48%)	505 (52%)	966
General Science	813 (46%)	349 (20%)	1420 (80%)	1769

Figure 1.7

* Fully qualified: matric + 3 year professional qualification.
Underqualified: less than matric + three year qualification.
Unqualified: no teaching qualification.

The problems in science education are reflected in the shortage of technologically qualified people in the workforce. In 1980 the estimated R & D scientists and engineers in Africa constituted 0,4% compared to 40,3% for Europe and North America and 55% for U.S.S.R and Asia. It is evident that every effort that is directed at investigating and rectifying the situation in science education for Black students is desperately needed.

The ANC (African Nationalist Congress) policy document, (1994) sets out plans for curricula changes and an increased availability of science and technology for all students. Many projects have been initiated to address this issue,(e.g. Handspring Trust; Primary Science Project; Science Education Project; RADMASTE). Has enough attention been given to the *reasons* for this desperate situation in science education?

It is extremely important that at this critical point the issue of language is given due attention. Herbert, (1992) states that: "One thing which can be said.. about the language situation in S.A. is that there is a pressing need for basic research at virtually every level of analysis." As there are over 700 million English Second Language speakers in the world, the scope for research in the area of teaching science to English Second Language (ESL) students is enormous. In South Africa, the 1991 census indicates that only 10% of the population have English as a home language, although about 45% can speak English. The section on Language Provision of the Gauteng School Education Bill, (1995), makes the following statements:

> "Every learner shall have the right to instruction in the language of his or her choice where this is reasonably practicable." Section 41(b)
>
> "Science language policy should be designed to facilitate the maximum participation of learners in the language process." Section 17 (2,c)
>
> "Special measures should be taken to promote the status and use of all languages which have previously been neglected or discriminated against by education authorities in the

province." (2,g)

A number of research papers (e.g. Bamgbose, 1984; Nkopodi 1989; Rutherford & Nkopodi 1990; Sutton 1992) suggest that there is a link between achievement in science and language proficiency. This points to a need for developing language use in the science classroom. One area where there is obvious scope for innovation is development of materials. In the same ANC document, (1994), materials' development was noted as one of three areas needing most urgent attention. It seems that in the current urgency of the educational situation efforts towards remediation should take priority over more esoteric research. That is to say that there is a need for practical intervention in classrooms to address issues that have been neglected for decades. Research should guide the mechanism of this intervention. Rollnick and Rutherford, (1993) noted the tendency of research to focus on identification of misconceptions rather than their remediation.

Based on this observation, this research report offers a possible solution to some of the language problems in the multilingual science classroom. It is based on the "testing" of a science lexicon that was written specifically for South African students and educationalists (including writers).

Problems in learning and teaching science

Not only does science have a particular content but it can be said to use its own specific language. It is generally acknowledged that the language of science poses problems for both first and second language students: Lemke, (1982) states that students have problems with "the ponderous style of textbook science".

Scientific language is notoriously inaccessible and incomprehensible. These difficulties are especially evident in the definition of concepts. There seems to be very little assistance available to students and teachers in the area of clear, correct and simple concept definitions. The problems here cannot be underestimated. Curtis and Millar's, (1988) research concludes that "Language plays a crucial role in the child's ability to construct meaning." This may appear as a truism but it is an aspect of science teaching that is often overlooked. The problem is exacerbated by the pupils' lack of awareness of their own ignorance of terms, Nhlapo, (1993).

Gonzales, (1981) recommends that "The focus of instruction should be on *deliberately* teaching the student the vocabulary necessary to handle the unit." This not only benefits the students' understanding of science but, as Johnstone and Cassels, (1978) point out: "science should provide excellent opportunities for the enrichment of pupils' language". Wright, (1982) maintains that it is the duty of every subject teacher to ensure that specialist vocabularies are properly explained.

In an attempt to address this issue, the RADMASTE Centre has been compiling a Concept Guide / Science Dictionary of Physics, Chemistry and Mathematics terms in accessible English for the writers of scientific material, lecturers, teachers and students. Key concepts have been identified and arranged into related sections. These have been explained in increasing detail and complexity but with a view to keeping the language simple and therefore accessible to both English first-language and second-language speakers.

The writers have tried to avoid formal definitions as much as possible as it is widely acknowledged that these often lead to rote learning. In the paper mentioned previously, Nhlapo, (1993) found that a large number of ESL pupils did not know the meanings of **non-technical** terms. He suggests that these pupils would therefore have difficulties in understanding the words used to explain the technical terms. Explanations have therefore been made as simple as possible but this also leads to much longer descriptions than a conventional dictionary definition.

The guide has been translated into North Sotho and back-translated by an independent science expert. The translation is intended to serve as an aid to both teachers and students who may find it easier to access the concepts through their vernacular language or who may be interested in developing the scientific register of their vernacular.

1.2 AIMS

The aims of the study are to:

1. Determine whether students, who speak English as a second language, show a greater understanding of specific science concepts after having had access to the English version of the RADMASTE Science Concept Guide or the English plus North Sotho Guide.

2. Receive feedback from teachers and students about the use of the Guide and to canvas opinions about the use of language in science teaching.

The Null hypothesis

Aim No.1 above may be formulated in the null hypothesis: H_0 : There is no difference in the increase/decrease in the scores of the English & North Sotho Group and the English Group on the pre- and post-tests.

1.3 RATIONALE and BACKGROUND

It is fairly obvious, given the enormous problems in science education in South Africa, the difficulties of second language instruction and the diversity of opinion on language policy, that steps will need to be taken to deal with the issues of language use in the South African classroom.

Vocabulary is a particular problem in science teaching and text book writing. Cassels and Johnstone, (1979) and Sutton, (1980) both point to the difficulties of multi-valent words in science. My experience in the classroom confirms this: often, in the case of words with more than one meaning, the student is unaware that the word has a different meaning from its everyday meaning when used in a science context. Common examples include: *weight; power; velocity; salt; mole; composition*. Words like these are problematic for EFL speakers as well as ESL speakers. The writers of the RADMASTE material have attempted to address this problem by providing various meanings of the words in some detail. Students are often inexperienced in reading large tracts of discourse which contain no narrative and have little relevance to their experience of life. Students also have little opportunity of using such language themselves but when they do, their writing reveals their lack of understanding and becomes a parody in imitation of scientific style.

In a pilot study workshop with ACPSE students (who are teachers studying for an Advanced Certificate in Primary Science Education), the students were asked to translate some science definitions into North Sotho and then one of their colleagues wrote down the back-translation of the definition. The following back-translation was obtained from a description of Newton's Third Law:

> "From the force which is attracted to each other force from the body is formed by something else that they force the force from the first line with the same mass from different directions. Those masses are called action-reaction pair of forces."

(The original: " The first object exerts a force on the second object; the second object exerts a force on the first object of

equal magnitude but opposite direction. This pair is called an action-reaction pair of forces.")

The above translation is an indication of just how incomprehensible such definitions are (even to a science teacher)! This was certainly not an isolated incident.
Further examples are given in Appendix 1.

In developing the material used in this study, RADMASTE has attempted to avoid the formal scientific style with the predominance of passive voice and many subordinate clauses.

It was hoped that with the feedback from the interviews in initial workshops that some of the more pressing problems in relation to North Sotho would become apparent. In attempting to deal with some of the obvious problems, e.g. lack of relevant vocabulary, a strategy of transliteration was adopted or existing words were used in a more clearly defined way. It was hoped that this strategy would contribute to the knowledge about the existing language situation. If carefully considered steps are taken timeously, possible reactionary or emotionally based actions may be pre-empted.

1.4 LIMITATIONS OF STUDY.

This report was aimed at assessing the effectiveness of the Concept Guide with a view to revising it and possibly translating it into other official languages.

In view of the small sample, the results cannot hope to present a comprehensive overview of student or teacher opinion on the issue of language of instruction in science in Gauteng, (let alone in South Africa or other Anglophone African countries). It can, however, give some indication of the interest that is there in developing vernacular languages for educational purposes.

It is intended that this research report serve as a guide for further study; to increase awareness of the language issues in science education in Gauteng and to help assess the need for the development of relevant material in vernacular languages. This project deals with a very limited sample of students and only two of the 13 official languages of South Africa.

1.5 ETHICS

North Sotho speaking students may be seen to have benefited more from the trial than the other students, but no students were disadvantaged. Students who were in the English group were given the North Sotho version of the dictionary after the trial if they requested it.

Students were also told about the research project in some detail and about the compilation of the Concept Guide. All students expressed willingness to participate in the study.

CHAPTER 2

LITERATURE REVIEW

"Alice felt dreadfully puzzled. The Hatter's remark seemed to have no meaning in it, and yet it was certainly English."

Lewis Carroll

2.1 INTRODUCTION

When considering the question of students' understanding of scientific concepts in English and North Sotho several factors need to be taken into account. There is the intrinsic problem associated with scientific language; cultural and gender differences; theories of second language acquisition; metacognition and medium of instruction. Scientific language and culture is a specialized area of knowledge that needs to be presented to students as does a specific science curriculum. Previous research in these areas may help to inform the research process when assessing the results of the research findings.

2.2 PROBLEMS OF SCIENTIFIC LANGUAGE

At the root of the problem of learning scientific language is the general lack of awareness on the part of the teachers and text book writers of the difficulties involved. Not only do students have the problem of learning new words, but these words often embody very sophisticated concepts that are not easily acquired, (White, 1988). They are not the simple translations of vocabulary as may occur in the learning of a second language.

To add to the difficulty many of these words are current in everyday language (or are used in other subject areas) but have entirely different meanings in science, e.g. cell, nucleus, work, force. Ryan, (1985) tabulates lists of common words that proved problematic for first language learners. These included matter, mass, charge, basic. Mokuku, (1993) found considerable confusion in students' understanding of ecological terms. Students who use a standard dictionary are likely to make mistakes when it comes to scientific terms. One example from Mokuku's study was the word *composition*. Some students explained: "I can say it's like an essay." Even in scientific journals there is a lack of consistency in the meaning of terms. In our chemistry textbooks *element* is defined as a substance made up of one type of atom only. The ACI Materials Journal (1996), however, lists the following *elements:*

Table 2.1 Use of the word "Elements"

Chemical composition of cements

Element	Type 10, percent	HSF*, percent
SiO_2	21.28	21.38
Al_2O_3	4.42	4.10
Fe_2O_3	3.50	3.47
CaO	60.87	61.59
MgO	3.49	3.81
Na_2O	0.04	0.25
K_2O	0.51	0.51
SO_3	2.98	2.90
C_3S	42.8	47.4
C_2S	22.3	19.3
C_3A	5.8	5.0
C_4AF	10.6	10.5

* Blended commercial cement containing 7.5 ± 0.5 percent silica fume.

Unless the issue of vocabulary is deliberately addressed, many words will continue to cause confusion.

Vocabulary is not the only problem and as Strevens, (1980) points out Technical, Technological and Scientific English, (TTSE) has grammatical patterns different from other varieties of English. Often the passive voice is used and statements are frequently qualified for the sake of precision. A random sample from G. F. Liptrot's Modern Inorganic Chemistry, (intended for 1st year undergraduates), illustrates the point:

> "The enthalpy of the chemical system will be lowered if the process of making bonds to give product molecules is more exothermic than the process of breaking bonds in the reactants is endothermic, provided of course that the energy so released is allowed to flow out of the system into the surroundings (by the law of the conservation of energy there is no overall change in energy, since the energy lost by the chemical system exactly matches that gained by the surroundings)." (P.103).

This sentence yields a Fog Index factor of 39. (A Fog Index of more than 12 is considered too difficult for most readers! - See Appendix 2.)

It is unfortunate that introductory science textbooks persist in using a type of language that obscures rather than clarifies concepts for students. It is interesting to note the increasing popularity of series of books like "Einstein for Beginners" published by Writers and Readers Publishing; the IDG Books like "Windows for Dummies"; and "Computers for Beginners" by Errol Selkerk. I include this extract from Windows for Dummies by Andy Rathbone, (p.25), to contrast its use of metaphor, direct speech and Fog Index of 4 with the above extract:

> "Fun CD-ROM Drive Stuff. Most people think compact discs contain music. Nope. Compact discs contain numbers. That's

all the information they can handle. The CD factory translates music into numbers, and the CD players translates those numbers back into music."

Is it necessary for scientific concepts to be presented to novice students in a language that is sometimes more difficult than the concepts themselves? Mokuku, (1993) refers to the "lack of reality" in scientific language. In order to serve the precision and logical argument required by scientific enquiry, language has been deliberately adapted: as explained by William Whewell (quoted in Sutton, (1982)

"When our knowledge becomes perfectly exact and purely intellectual; we shall exclude all vagueness and fancy, imperfection and superfluity, in which each term shall convey a meaning steadily fixed and rigorously limited. Such is the language of science."

It is, of course, debatable whether language can ever be purely intellectual; vagueness and ambiguity are evident in many scientific terms (e.g. radiation, current flow); and "fancy" is fortunately present in such terms as the description of sub-atomic particles as "charm", "beautiful" and "coloured"! The aim to arrive at "fixed and rigorous" meanings has the (*perhaps* unintentional) effect of confusing the science student and making scientific writing inaccessible to the majority of readers. According to Sutton, (1982) the attempt to achieve maximum economy and efficiency of communication has been emphasized at the expense of using scientific language to make sense of experience. M. Laing, (1990) in his review of science textbooks stresses that "A book should have a soul, and not be called: '9 New Syllabus' "! Janet White, (1988) points out that students are usually given "less instruction and guidance in writing for expository purposes than they are in writing of narrative fiction." The problem obviously applies also to the reading of texts as I stated earlier Science text book writers are becoming, to some extent, more aware of the confounding effect of complex language. Compare the first passage explaining inertia from two text books:

> "The extent to which a body resists change in its state of rest or motion is called the inertia of a body. Thus if an object is in motion, and a large force is required to change that state of motion, we say that the object's inertia is large." (P.52) Brink and Jones Physical Science 9, (1977).

> "A sack of mealies has more inertia than a tennis ball. Not only is a sack of mealies difficult to throw, it is difficult to catch!" (P.5) Successful Science (Physical Science) 10, (1989).

Sutton, (1992) asserts that:

> "Practical activities can become so prominent that they leave little space for learners to reflect on ideas, or for teachers to organize the means for them to do so."

He goes on to say that teachers are given little guidance "...on how to plan thinking, talking and writing activities" in science. (P.3)

This issue becomes even more pertinent when applied to ESL students. Perhaps, as most scientists are not experienced language teachers, not enough attention is given to ensuring that students have the opportunities to define terms for themselves and to have many experiences of the new concepts. Gilbert and Osborne, (1980) state that the "original idea is left stranded" in the child's mind and the new meaning has no connection with experience. Where teachers are unaware of students' language difficulties or do not have time to probe students' understanding of terms, confusion is compounded. One example from my own teaching of ESL science students arose with the concept **pure**. Students argued that honey was "pure", as was rain water. Water that was found *naturally* (in clean rivers) must be pure.

Science educators often claim that they encourage students to draw on their own experience and not simply learn by rote. In the example above we see that this can also lead to misconceptions.

The works of both Case, (1968) in Northern Malawi and of Strevens, (1980) in the U.K. highlight many of the language problems experienced by ESL learners. These may be summarized as follows:

(i) Problems of direct translation where words giving distinction between "all" and "both", for example, do not exist in the vernaculars.

(ii) Pronunciation. English has about 30 vowel sounds whereas many African languages have only 5. It is not surprising that students come up with statements like: "We tasted the acid with litmus"!

(iii) Lack of scientific words. Teachers in our pilot study expressed difficulty in translating words like "energy". In North Sotho "maatla" may mean energy, power or force.

(iv) Lack of specific concepts (not just words), e.g. infinity; gravity.

(v) Lack of prepositions and articles.
Case, (1968) cites the confusion arising from "We dried the crystals **on** the sun" rather than drying them **in** the sun! Or "CO_2 is **the** gas that does not support combustion", rather than **a** gas.

(vi) Idiomatic and metaphorical expressions.
"The batteries are flat". (finished /squashed)?

(vii) Lack of precision in the language. Not distinguishing between "too" and "much" or "if" and "when".

(viii) Non-decimal counting system.

Bulman, (1986) mentions additional language problems:

(ix) the use of the passive voice makes science texts difficult to understand.

(x) conjunctions that provide logical connections between clauses (e.g. "however", "provided") do not exist in most African languages.

Strevens, (1980) also points out that a scientist needs to be familiar with at least eighty prefixes and suffixes (mostly of Latin or Greek origin) as well as about 100 roots (e.g. bio, therm, etc.) In addition to this new words are continuously being coined.

Perhaps educationalists over-estimate the ESL learner's proficiency in scientific language. Cummins, (1980) distinguishes between basic interpersonal skills (BICS) - which might be well developed for many ESL students - and cognitive / academic proficiency (CALP). Educational progress is largely dependent on CALP. The sophistication of grammatical construction that allows for precision in scientific or mathematical statements is explained in the work of Sigabi,M. (1993). The same word that can be used as a verb or a noun can cause confusion especially when common usage is careless. He sites the example:

A. The SUM OF THE SQUARE of two numbers...

B. The SQUARE OF THE SUM of two numbers...

It is common for teachers to talk about doing "sums" when they might well mean subtraction or multiplication problems!

Another problem, identified by Wandersee, (1985) in relation to biology terms is also evident with South African ESL science students. This is the existence in English of numerous homonyms. A common example here is *ion* and *iron*.

One route in helping ESL students with the study of science in South Africa may well be the development of science materials in other official languages. Although at present the task of developing a scientific register in North Sotho is daunting, other languages have been successfully developed fairly recently in Israel, Malaysia, Tanzania and in South Africa with Afrikaans.

The practice outlined by Isa and Maskill, (1982) in translating into Malay has been adopted by the translators of the RADMASTE Science Concept Guide, i.e. words are transliterated or directly adopted from English. Kwesi Prah, (1993) advocates that "concepts and terminology in science should be constructed within indigenous languages". This project is an attempt to make inroads into this area. The development of the vernacular also helps students to express their own feelings, thoughts and observations.

Sutton, (1981) points out that although English is the means of communication between examiners, text books, teachers and students, the function of language for making sense of experience, is equally important. For this purpose the student may prefer to use the vernacular.

A random look at definitions given in science text books indicates that definitions are often far from "precise" and pupils are often memorizing wrong definitions, (Popov, 1994). Popov quotes examples from Grade 3 and 4 textbooks used in Mozambique:

"Temperature is the state of heat or cold in which the air finds itself."
"Transformation from solid to liquid state due to a rise in temperature is called fusion."

Other examples that I came across in South African text books used in the DET are:

Dissolve: "Something is dissolved when a solid is mixed with a liquid and the solid disappears."
Surface: "Surface is a flat side of something."

These examples serve to highlight the problems that arise when abstract concepts are expressed in an oversimplified way. They also show that explanations given in English (the preferred language of science texts) are not always as clear as may commonly be believed.

Lynch *et al.* (1985) found in their study with Hindi speaking students in India and English speaking students in Australia that where words had been specifically coined in Hindi, (to make connections between words apparent) e.g. atom = annu; and molecule = pramanu, Hindi students showed greater recognition of such terms than English students.

Defining science concepts in an accurate yet simple way is often problematic. Ignoring the problems of scientific language altogether results in a breakdown of communication between teacher and student, or between the text book and the student. Educators and writers need to persevere in making the language of science comprehensible. Bulman, (1986) points out that many science classrooms do not have even simple science dictionaries. It is in keeping with recommendations arising from the ANC meeting in Harare in 1990 that languages need to be developed to meet the needs of the majority of the people, Herbert, (1992). This is particularly relevant for the language of science.

2.3 MEDIUM OF INSTRUCTION IN AFRICAN COUNTRIES

There are traditionally three schools of thought about the medium of instruction in educat· ı in Africa:

Those who advocate use of:
1. Mother-tongue instruction for all years of schooling
2. English as medium of instruction (at least from year 3)
3. Mixed language practice (showing flexibility at all levels)

1. Mother-Tongue Instruction

Schmied, (1991) summarizes the opinions of this group: "English has been accused of being elitist, of being culture bound, of being a remnant of colonialism and a cause of cultural alienation, and of cutting Africans off from their own traditions."

The Second Congress of Negro Writers and Artists in Rome resolved as early as 1959:

(a) that independent African countries should not adopt European languages as national languages;
(b) that a pan-African language be chosen and fostered;
(c) that a team of linguists be selected to modernize that language.

2. Pro-English group: "Adaptionists".

There appears to be considerable support for the use of English in education, particularly after the first three years. English has the advantage of being an internat: ›nal language and the predominant language of science and technology and the Internet. It is also the language that will be used by most S.A. students who go on to tertiary education.

The OAU has English and French as official languages (although there have been suggestions to change these to four African languages).

3. A mixed language strategy in teaching.

This appears to be, in fact, the current practice in many of the schools in South Africa and elsewhere. The practice of language use in education is not necessarily the same as the official language policy of a country. A brief look at some of the official language policies in Africa gives some perspective on the diversity of language use.

Language Policies in some African Countries:

The following gives some idea of the variety of languages in use in Africa and although a European language serves as the official language in many countries, literacy in this language is often very low. Countries which use one or more indigenous languages as the main means of national communication are said to employ an endoglossic policy whereas those countries using primarily a foreign language are said to be exoglossic.

1. Countries that have adopted an active endoglossy policy: Heine, (1992):

(Use of an indigenous language as primary means of communication.)

Country	Language
Tanzania	Kiswahili
Somalia	Somali
Sudan	Arabic
Ethiopia	Amharic
	Guinea Fula; Manding; Susu Kisi; Kpelle; Loma; Basari & Koniagi

Countries that have adopted a non-active endoglossy policy:

Country	Language
Botswana	Setswana
Burundi	Kirundi
Lesotho++	Sesotho
Malawi	Chichewa; Nyanja
Ruanda	Kinyarwanda
Swaziland++	Siswati

++ English as semi-official language

2. The following countries have adopted an exoglossic policy using a non-indigenous African language as the official language: Kenya; Mali; Senegal; Uganda.

3. The following nations have an exoglossic policy, adopting a foreign language as the national, official language.
(A vernacular may, however, be used during the first years of education.)

Country	Language
Mozambique	Portuguese
Angola	Portuguese
Congo	French
Nigeria	English
Ghana	English
Sierra Leone	English
Gambia	English
Zimbabwe	English
Zambia	English
Uganda	English
Kenya*	

Tanzania*
West Cameroon*
South Africa*
Namibia* (* English as co-official language)

Although English is firmly established as an international language and is the official language of a number of African countries, it has remained a minority language in Africa with a very small proportion of the population being able to use it with ease.

Countries in Africa having English as an Official Language

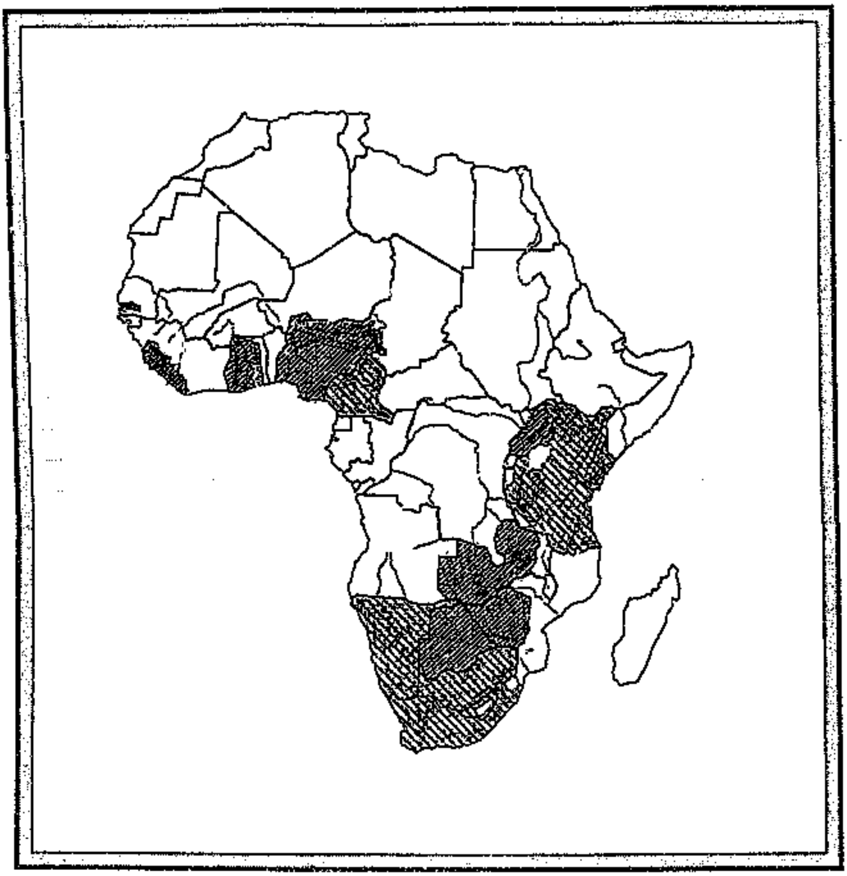


Figure 2.1

2.4 LANGUAGE AND CULTURE

It is unlikely that the learning of a second language will take place without influencing the learner's cultural values. This would also apply to the language and culture of science. Maley, (1989), claims that: "language and culture cannot be separated out. ...culture must be taught along with language." (P. 26).

There are various aspects that may be considered as part of a student's culture. These include language, religion, socio-economic level and rural or urban background. Nkopodi, (1989) found in his study with North Sotho speaking high school students that those from an urban area performed better in the recognition of physics concepts than those from a rural area. Also, those from a higher socio-economic background scored higher than those from a lower socio-economic background.

Language use in education cannot be considered in isolation from culture. Rather like a cost-benefit analysis, many factors need to be considered when investigating the impact of mother-tongue instruction on students' learning. Terry Volbregt, (1992) recommends "that universities do not limit their engagement with language policies to educational issues". Clearly cultural, political and economic concerns cannot be ignored. Although this study aims to assess students' understanding of certain science concepts, conclusions need to be viewed in the context of the whole child. Although this aspect is beyond the scope of this study, research on the interaction of language and culture is relevant to the situation. This was well illustrated by Volbrecht at the SAAAD conference, (1992) where he quoted J. Tollefson, (1991):

"Each time a society requires some people to learn another language in order to carry out human activities necessary for survival, an act of injustice has occurred that places those people at a disadvantage...In much of the world, second language learning is not a solution to exclusivity, privilege, and domination, but rather a mechanism for them."

"Education", Fafunwa, (1975) claims "is the servant of society" and as such, the wider implication of English as opposed to mother-tongue instruction should be considered.

Focussing on the relationship of culture to science education many direct problems are evident. Some researchers claim that actual science concepts that exist as part of our science curriculum are absent in some cultures. (Seddon and Waweru, 1987). They claim that it would therefore be impossible to teach or test these concepts using the vernacular language. Whorf (1978) goes so far as to say that one's view of reality is entirely formed by one's language. He maintains that the commonality of a particular system of language is outside our conscious control and that communication is dependent on an underlying shared framework of the linguistic process: grammar shapes our ideas. He sites the radical difference between Hopi and Western European culture as being rooted in language structure. Our experience of space, time and matter is conditioned by language. (We speak, for example, of " ten days" without thinking of the imaginary nature of the use of such plurals.) In Hopi, such a construction - and hence such a concept - is impossible. A day can only exist one at a time. It is also so foreign to our mental paradigms to conceive of the Hopi freedom from verb tenses: for them everything is in consciousness now. There is no linear-spatial representation of time. Time varies for each observer. Instead of the Western "form-matter" dichotomy there is an underlying concept of "eventing". Thus in place of our notion of matter acting on matter to effect a consequence, "eventing' is prepared for through the power of thought and motivation.

It is, of course, not necessarily the case that the absence of a word implies the absence of the concept. For example, although some languages (like Kpelle) have words for only three colours: red, white and black; and the Dani, in South East Asia, have only two words for colours: 'bright' and 'dark', the speakers of these languages can recognize the whole spectrum of colours, Weiten, (1995). Conversely, the existence of a *word* does not assure an understanding of a concept. One could argue that many science concepts taught through the medium of English are absent from the common experience of EFL (and ESL) students. So although people may use a fairly common word like "weight" or "velocity", this does not mean that they understand the exact concept referred to. These concepts need to be taught along with the vocabulary. Other examples may include: the conservation of matter, constant acceleration of falling bodies and a frictionless system. In fact, common English usage often encourages misconceptions: we talk about things "burning up" (so that there is nothing left)!

It is also obvious that paradigms that exist in one culture may readily be understood by another and the associated vocabulary is usually adopted into the foreign language. A common example is the South African word "apartheid" or Russia's "glasnost".

The importance of a familiar context does however have a bearing on understanding of concepts. Jordaan and Nangu, (1995) in their report of the influence of text on Std 6 pupils' understanding of elements and compounds found that pupils performed better in questions where an everyday context was used as opposed to a scientific context.

It is, however, not only the cultural differences relating to language and concepts that affect science education for ESL students. The existence of social and family hierarchies in traditional African culture discourages the questioning of propositions. This makes it difficult for these students to adopt techniques of scientific investigation, Mokuku, (1993.) It also makes it difficult for teachers to employ constructivist techniques in the classroom and to discuss and negotiate meaning with students.

Many cultural aspects should be viewed in relation to a rapidly changing world in which the cultural norms mentioned above are changing. Maley, (1989) quotes a West African conference delegate who demanded: "Why should you assume that what you think we are is what we want to be?!" Maley cautions that studies should pay more attention on what cultures *are becoming*. In the same paper he also points out that in trying to define and understand differences we often overlook the many aspects that people have in common.

In considering culture we usually think of it in relation to groups of people. There are of course also cross-national cultural groupings such as the culture of sports , science or music. By considering groups of people as belonging to a scientific culture we encompass different nationalities. Hawkins and Pea, (1987), point out that: "Science learning is a process of socialization into a professional community..." (P.294). And like other cultures, the culture of science is constantly evolving.

Science curricula are also changing with the advance of technology. That is to say, that even in an English speaking western culture the world we live in and the skills we need are very different from those required by our grandparents or even our parents. Culture is therefore not static nor easy to define. What is perhaps needed in this area is a sensitivity and awareness on the part of teachers and text book writers. Learning about different or new cultures while learning new skills could be seen as a very positive aspect of science education.

2.5 LANGUAGE AND GENDER

Barba, (1993) maintains in her study of culturally syntonic variables in the bilingual/bicultural classroom, that "learning science involves a Eurocentric / androcentric way of knowing and learning." That science education favours boys may be borne out in the results of Nkopodi's study in Lebowa where he found that more physics concepts were recognized by boys than girls. Nhlapho's study, (1993), with students' recognition of ecology terms showed no significant differences between the performances of girls and boys. Much of the research findings in this area are contradictory and would appear to be related to other factors such as single-sexed or co-educational schools, Ndunda and Munby, (1991). If there are gender differences in performance in science at schools the causes may not be easy to isolate. The relevance to this study is not in terms of any intervention, nor is it the focus question. Results are analyzed with this factor as a variable and observations were made in terms of classroom practice and response to interview questions.

2.6 THEORIES OF SECOND LANGUAGE ACQUISITION

Many linguists agree with Livingston's assertion in <u>The Development of the Human Brain</u>, (1992) that:

> "... a language is learned by using the previous language as a tool and for the rest of one's life one learns new languages on the basis of languages one already knows."

Swain, (1979) states:

> "..the development of skills in a second language is a function of the level of the child's first language competence..."

This would seem to imply that the cognitive development that has already taken place and the language skills that have been internalized should aid the acquisition of a second language. Some of the research supports this claim which is named by Swain and Cummins, (1979) as the "threshold hypothesis" in their studies of immersion and submersion programmes in Canada. (This hypothesis states that a critical level of competence is required in a second language for pupils to benefit from an immersion program.) If this prerequisite is met then these pupils perform significantly better than those in a submersion program. Their level of competence in both languages is superior as is their cognitive development. Although the basic claim in the above quotations has an intuitive appeal the question still remains: Why then do adults often have such difficulty in acquiring a second language?

Before a particular theory proclaiming the mechanism of second language acquisition is proposed, there is usually an investigation into the method employed in learning and from this a learning theory or model is constructed. (This in turn, of course, influences future teaching strategies.)

One of the problems of linking method to acquisition is the large number of other variables that impinge on the process. The contradictory results obtained in the research into immersion and submersion programs is an obvious example. Swain, (1979) acknowledges that the home-school language switch may not be the causal variable in the success of the English students in the French immersion program in Canada. These children usually come from middle to upper-middle class homes; are in no danger of losing their first language and their teacher is fluent in English. Submersion students studied in this research typically came from lower-working class homes; were in danger of losing their mother tongue and their teachers could not speak their language. Swain concludes that "additive bilingualism" has positive results whereas "subtractive bilingualism" has negative results.

In South Africa Black students generally are faced with a situation different from either of those mentioned above. Students are taught for three years in their mother-tongue and then switch officially to being taught in English by teachers who often have a poor command of the language. In practice most teachers resort to a mixed language strategy of teaching. In the past two years some Black students have been exposed to an immersion situation as they enter Model C schools. Historically, Black students' language proficiency in English has been of little interest to the Education Departments. The Bantu Education Act of 1953 ensured that Black students were educated for menial work only. The imposition of Afrikaans as a medium of instruction in 1976 and the tragic consequences are well known.(DBSA, (1994), DNE, (1994)). As language has been a central political issue in South Africa it is appropriate that it is given due attention.

In what way may theories of language acquisition inform educational practices and policies in South Africa?

Three of the major theories of first language acquisition are:
1) **Behaviourist** as proposed by Skinner,
2) **Language Acquisition Device** (L.A.D.) from Chomsky,
3) **Cognitive** based on Piaget.

In his discussion of second language, Littlewood, (1984) categorizes two models which are very similar to those mentioned above:

1) **Skill-learning model** and
2) **Creative Construction model.**

The Behaviourist and Skill models are more or less equivalent as they propose that learning takes place through conscious training. Littlewood offers the further categorization of "Conscious" and "Sub-conscious" acquisition. The **Language Acquisition Device** and **Cognitive** models above could be viewed as "sub-conscious" acquisition models.

Considering first the conscious model:

1.) Skill Learning: instruction and drill leads to an internalization of the language. Behaviourism claims that language is learned through operant conditioning. The empirical evidence does not support this theory as applied to humans since it is derived from experiments with rats. The literal and all-encompassing generalizations to the human being can be little more than allegorical. It can be seen that a certain amount of conditioned response takes place in adopting phonetic structures and simple word associations. Contiguity, repetition and reinforcement are the basis of this model. Much of our second language teaching has been based on this hypothesis. There is no innate knowledge of language: acquisition is attained through conditioning. Evidence for this theory is cited by Littlewood, (1985): ".. the learner's mother-tongue knowledge influences the sequences" of second language learning; and "learners imitate and memorize specific utterances without analysing their internal structure". Although this implies that previous conditioning affects learning, Littlewood points out that "interference" errors account for only 3% of mistakes made by 2nd language learners.

This calls into question the whole hypothesis of the influence of the first language and lends support to the second theory:

2.) Creative Construction Model: This is similar to the cognitive model of Piaget. Learners construct their knowledge according to an inbuilt syllabus. In trying to learn a new language the learners tend to follow natural sequences in internalizing the system. These sequences are often independent of the learner's mother-tongue. Some research supports this contention that the *learning* sequence does not always follow the *teaching* sequence. Students also often make the same type of error irrespective of the course they have been following. This model incorporates the concepts of acculturation and simple code.

Acculturation is that factor that motivates learning for functional or social needs. These two functions are described by Littlewood as 'instrumental' and 'integrative'. These psychological factors are also emphasised by Krashen and Scarella, (1978) in his Acquisition Learning hypothesis (ALH), as is the concept of simple code.
Simple code incorporates the idea that a second language is learned through a 'reduced system' or 'simple code' as seen in the speech of young children. This theory is thus also applicable to first language learning. Vocabulary and complexity of construction develop according to need.

This Creative Construction model can be considered to be sub-conscious as learning develops spontaneously according to an internal system. Chomsky, (1975) proposes that there is a Universal Grammar (UG) and that human beings have an innate ability to acquire language. His Language Acquisition Device (L.A.D.) theory is similar to the "simple code theory" mentioned above. Chomsky drew attention to the speed at which language is acquired by very young children. This ability outstrips that of cognitive development and is universal in its manifestation. He therefore proposes that there is an innate, self-motivating, inherited mechanism which is triggered by exposure to language - the L.A.D. This L.A.D. enables the child to formulate rules and construct an internal grammar. Some evidence of this is seen in the child's misuse of syntax that does not arise from imitation but from an over-generalization of rules which leads to completely original mistakes. Wilkinson, (1982) comments that all this may be accounted for by the human's natural inquisitiveness, tendency to imitate and casual observation.
Chomsky believed that the innate capacity for language learning dies out as the child develops. Some research suggests that this might not be the case: given similar circumstances of meaningful communication opportunities, free from performance anxieties, adults too can acquire a second language as spontaneously as they did the first. (Krashen and Terrell, 1984).

Krashen, et al. (1978), make a distinction between the two main schools of thought: the one believes in language learning and the other in language acquisition. This first school is based on the idea of *empiricism*. The skill-learning model and behaviourist model belong to this school.

The second school of thought is *nativism* (or *mentalism*). Mentalism presupposes an inborn capacity which develops through a natural maturation. Humans are viewed as fundamentally different from animals. Kr ledge is believed to be inherent and requires a trigger to allo. t to be manifest. Chomsky's L.A.D.; the Creative Construction el; Cognitive model and Krashen's A.L.H. fall more naturally within this framework. There is however an area of overlap and a theory may incorporate aspects of both schools. It can thus be seen that the major differences are not in the distinction between first and second language acquisition but between the two basic schools of thought.

Krashen's A.L.H., although stating that language is acquired subconsciously, does allow for its refinement and editing through formal learning. Initially Krashen formulated this: "acquisition gives fluency; learning gives accuracy."

Rather surprisingly research disproved to a large extent the pedagogy of this aphorism. 95% of accuracy in adult learners seemed to be due to acquisition, (in children this rose to 100%)!

Krashen explains that the learning process is very simple: people learn any language at any stage when they understand messages, i.e. when they receive comprehensible input. This is a complete reversal of the commonly held teaching belief. Krashen is saying: "we acquire when we unders nd". Ability is a result not a cause of acquisition. Krashen cites similarities between his research into 2nd language acquisition and 1st language acquisition. Talking emerges on its own after a time lapse (silent period) and follows a predictable process. All the rules that the learner needs to know are there in the input and do not need to be learned artificially. Rule learning has been shown to be counter productive. Krashen, (1978.)

As suggested initially there are probably other factors that inhibit the learning of a second language, especially if it is, as claimed by Krashen, such a simple process. In answer to this Krashen adds to his theory the **affective thinker hypothesis.** Motivation, self-esteem and anxiety play a vital role in language acquisition. Anxiety provides a filter which blocks the L.A.D. in the brain. It is only in this way that second language learning differs from that of first language learning. Krashen subscribes to the LAD theory but does not believe that it becomes inoperative later in life.

The implication is that the environment in which teaching takes place and the actual teaching methods may either enhance or inhibit learning. Perhaps we are so used to living with high levels of anxiety that its detrimental affect on the learning process has been underestimated. Krashen acknowledges that in certain tasks some level of anxiety provides motivation but definitely not in language acquisition. This does seem to be the one outstandingly relevant factor in distinguishing first and second language acquisition. No one seems to be concerned that they (or their children) will not succeed in learning to speak their first language. Anxiety is generally absent. The A.H.L. thus seems to be the most convincing theory and it applies to both first and second language learning. If one subscribes to Chomsky's L.A.D., one is left with the puzzle of second language acquisition. If one subscribes to the behaviourist models they fail to explain the lack of success in applying the behaviourist teaching methods to second language learning.

What are the implications of this for the learning of technical language in science? Experience seems to bear out the theory that learning is most likely to take place when meaningful input from the environment is received in an atmosphere free from the anxiety about failure.

2.7 METACOGNITION AND LANGUAGE

From his case studies of the stages of human development, Piaget, (1954) maintained that thought precedes language, but once acquired, language helps to inform the thinking process. The sensory-motor stage gives rise to language. Thinking may consist of other types of symbolic representations such as internalized actions. Eventually the young child is motivated not only by the desire for satisfaction of physical needs but by the desire to communicate. Language is seen therefore as a result not a cause of this process. It is structured by the development of logic and is also linked to affective development. As language is assimilated into the cognitive process it can then be used as a tool to free thinking from the perceptual field. As language becomes more sophisticated it, in turn, undergoes a change in function and contributes to the refinement of thought. It is at this stage that thought begins to be language dependent and there is an unconscious constraint as concepts become determined and restricted by the mould of a particular syntactical structure and the habitual use of a conceptual framework.

This is an important consideration when examining language policy in education. Collison's, (1974) research in Ghana showed that school children function at a higher conceptual level in their vernacular than in English. Fishman, (1984) too, advocates late immersion to avoid detrimental effects on cognitive and cultural identity.

Whorf, (1956) maintained that one's language determines the way one thinks: linguistic relativity. People view the world differently because impressions are filtered and explained through language. If this is the case, it has a great deal of significance for language use in science education. One may also then assume that the more languages a student knows, the more advantaged he or she may be in concept formation.

Vygotsky, (1962) claims that language develops from a pre-linguistic stage which is distinct from the pre-intellectual stage preceding thought. The two processes do, however, affect each other and are constantly interacting. Words find meaning in thought and thought is expressed though words. The awareness of this point of interaction is metacognition. Through language we regulate thought.

In an attempt to discover links between thought processes and speech, Vygotsky and Piaget investigated the phenomenon of egocentric or inner speech. Vygotsky distinguished between speech for oneself and speech for others and posits that different functions give rise to different structures. According to Whorf, however, these peculiarities in structure are possibly superficial and any abbreviation or prediction in inner speech does not fundamentally alter one's employment of prevalent grammatical structures. Vygotsky maintains that verbal thought is not simply thought + words. The child's egocentric speech is a precursor to inner speech. At about 7 years the child's egocentric speech dies out and inner speech is a monologue. It is practised in the presence of others under the illusion that they understand.

Piaget proposed that egocentric speech was a manifestation of a child's autism and faded away with gradual socialization. Inner speech was a different phenomenon. A distinction is made here of the divergent functions of s'eech and some of the theorists expand on this and study language from the point of view of function. This may have some relevance for science in the classroom. A student may have some facility in one area of language use but not in another. Halliday, (1976) identifies numerous functions of speech and categorizes them accordingly into:

instrumental	(getting things done)
regulatory	(regulating the behaviour of others)
interactional	(defining the group - social)
personal	(developing an identity)

heuristic	(exploring the environment)
imaginative	(stories)
representational	(expressing propositions)
ritual	(defining social class)

This representational organization does not challenge acquisition theory but emphasises the purpose, motivation and pervasive use of language in human action. The following categories have particular relevance to learning science: instrumental; heuristic and representational. It appears unlikely that all languages facilitate the operation of each of these categories equally. The existing theory would seem to indicate that where one wants to develop thinking skills one needs to also to develop language. However, the way language develops is not thoroughly understood. Most of the theories refer to language as a whole and not to one specific use of language. These are considerations to be borne in mind when analysing research results.

2.8 MOTHER-TONGUE vs ENGLISH MEDIUM OF INSTRUCTION

A great deal of research supports the use of mother-tongue instruction. E.g. Fafunwa, (1975); Livingston, (1992); Stoll, (1994); Barba, (1993). In considering its use as the medium of instruction for science in South Africa, broader educational, sociological and political issues need also to be taken into account because no single issue relating to the child exists in isolation. John Rogers, (1982) quotes from D.C. Soni's Ideas in Action which gives a powerful warning of ignoring the meta-cognitive processes and cultural implications of making children learn in a foreign language:

> "This is indirectly to discourage people, to tell them that their speech habits are incapable of literacy, education,

and development. ... their own spoken language (which is part of their personality) is incapable of becoming the medium of education."

There is, however, contradictory evidence which suggests that bilingualism enhances cognitive development. Cummins, (1977) reports that bilingual children display greater diversity and flexibility in thinking. Fafunwa, (1975) of Nigeria is adamant that European education in English "educates the child out of his environment" making him unfit to relate to his family and his community. It can be seen therefore that different researchers have come to different conclusions.

Effect on literacy:

An important aspect of acquiring competence in English is often claimed to be dependent on fluency in mother-tongue. Swain, (1978) in 'Home-School Language Switching' concludes that:

"the development of skills in a second language is a function of the level of the child's first language competence.."

Livingston, (1992) makes a similar claim:

"...a language is learned by using the previous language as a tool and for the rest of one's life one learns languages on the basis of languages one already knows."

Effect on achievement in science

Some researchers claim that science instruction in a second language is detrimental to the child's development of understanding. This statement may appear to be a truism, but there is evidence that suggests that this is not necessarily so. Ho, (1982). Also, considering the problems of alternatives one needs to assess the optimum language strategy in a given situation.

This may not therefore mean abandoning second language instruction for science learning. It is this problem that this report seeks to help to clarify.

Barba,(1993) concludes in his research with Hispanic/Latin children that where "students experience a science education that .... is culturally asyntonic, the result may be that learning is decreased". Curtis and Millar, (1988) sugge... .at differences in achievement in science for pupils of different language background, can be attributed more to language fluency in the medium of instruction than to science ability.

Stoll, (1994), who reports on science education in developing countries, asserts that it "is of crucial importance that learners should be able to discuss in their mother's tongue "' features and examples familiar to them which could contribu... attaining a full understanding of these new concepts."

It may be argued that this could cause confusion and that learners still have to revert to the language of instruction for tests and exams. Research by Seddon and Waweru in Kenya, (1987), showed that for Kenyan science students at secondary level there was little problem of the transferability of concepts between English, Swahili and Kikuyu.

<u>Comparison between mother-tongue instruction and instruction in English:</u>

Ho, (1982) found in his investigations with Chinese senior students that there was no difference in the performance of students who were taught in Chinese and those who were taught in English. It should be noted, however, that these were older students with high levels of fluency in English. (The sample used was also very small). Bamgbose, (1984), through the Six Year Primary Project, (SYPP) in Nigeria showed (albeit in an investigation into primary education) that more effective learning took place when Yoruba was used as a medium of instruction compared with English.

It is evident that research findings are not all in agreement and that the situation is complex. This suggests that what is perhaps more appropriate is not a simple quantitative study but one including qualitative data in the form of feedback from participants.

The choice of an official language may be based on commercial or government expediency and may be less concerned with educational considerations or its impact on the people. In fact, less than 20% of Africans use their countries' official language. This illustrates the lack of relevance of official language policy to the majority of the population. Use of the vernacular in Tanzania, has had a marked effect on literacy *per se* apart from academic achievement. Kiswahili is the only national language and literacy has reached 77,6%. On the other hand, Zanzibar declared, in 1966, that Kiswahili would be the sole medium of instruction in schools, but as standards declined, English has been reinstated.

This demonstrates the complexity of the problem and clearly all relevant factors need to be taken into account in a particular situation.

<u>Arguments against mother-tongue as sole medium of instruction:</u>

Research done by Rutherford and Nkopodi, (1990) in South Africa with North Sotho speakers showed that recognition of science concept definitions was enhanced when students were tested in English. As has been pointed out, at present, vernacular languages do not have the necessary scientific vocabulary nor do they have the same number of logical connectives, prepositions and articles. The situation is further complicated by the existence of many vernacular languages. English, in spite of its political history, enjoys a certain prestige and is seen as a vehicle for further education. Results of initial attempts to

translate science concepts into a vernacular are not very encouraging.
McNaught, (1991) lists some of the literal translations into English from Zulu obtained from her research in Natal in 1991:

ozone: air which is good with oxygen a lot.
From our pilot workshop we received these back-translations from science teachers:

force: can be equal the way momentum is changed.

power: is the product of different that will be there with electricity inside the conductor.

Considering that teachers do often translate for their students it is seen as essential that they have a reference guide to aid them. Rollnick and Rutherford (1993), rightly point out that it is part of the science teacher's job to teach the language of science and they show the effectiveness of a mixed language strategy.

Rollnick and Rutherford's project in Swaziland involving the use of a conceptual change model and a mixed language strategy showed that using a combination of vernacular and English was the most effective in alleviating misconceptions. This latter research is particularly relevant to the teaching of science to ESL students in South Africa as this is the method that is often spontaneously employed by teachers and it perhaps draws on the positive aspects of both views. It is this aspect that this study hopes to investigate further.

Another way of integrating the two views about medium of instruction would be to move towards depolarization. That is, just as a vernacular may have to change and develop to embrace science and technology, English may have to be developed here to a specific form of South African English. Strevens (1976), makes it clear that there are many forms of English. The insistence of some arbitrary standard may be detrimental to the linguistic development of the country.

It may also be noted that a great deal of research rests on the testing of word recognition, whereas, as Steven Pinker (1994), debates, we think in many media and not necessarily in one language. We think, and therefore learn, in visual images, big maps, auditory images, graphics etc. These aspects may need to be considered in future investigations into science language learning.

2.9 CONCLUSIONS

That scientific language poses a problem is clear. That culture has an effect on one's understanding of language and concepts is also clear. The development of the Concept Guide was initiated to address these issues.

That use of a foreign language may affect one's understanding of one's culture is also evident; it may even affect one's cognitive development. There are many conflicting arguments therefore, for and against the use and development of mother-tongue as a medium of instruction. What may be said with some certainty is that this is a sensitive and important issue in science education in South Africa. The questionnaires and interviews reported in this study attempt to gain some insight into how North Sotho students think and feel about this language issue. The relevance of gender to these issues is less certain. However the study also attempts to identify any gender differences that may be present.

CHAPTER 3

RESEARCH DESIGN

' "... the patriotic archbishop of Canterbury, found it advisable - " '

"Found what?" said the Duck.

"Found it," the Mouse replied rather crossly: "of course you know what 'it' means."

Lewis Carroll

3.1 Introduction

Leslie Lekala and I completed the writing of the Concept Guide which was then translated into North Sotho by Leslie and Nkopodi Nkopodi. The intention was to eventually have it translated into five of the official languages of South Africa. However, before doing this, it seemed sensible to try to assess the effectiveness of both the guide and its translation and also to find out if there was a demand for such material in the classroom.

3.2 SITE, POPULATION and SUBJECTS

A DET high school in Mamelodi was recommended by the DET Science inspector. The recommendation was based on practical reasons of good attendance, North Sotho speaking students and the enthusiasm of the science teacher to participate in the project. It was also fairly representative of a typical co-educational, urban school with a large number of Sotho-speaking pupils.

Population: Std 10 ESL science pupils.

Sample: One Std 10 class from Mamelodi.

This was an intact, mixed-ability class of about 35 pupils. After introductions and an explanation of the project, I asked which students had North Sotho as mother tongue so that we could hand out the Guides. Rather surprisingly, I thought, only a few students came forward. It took many reassurances that they would **all** have a copy of the Guide in English before others came forward to accept the North Sotho version. Even so, some North Sotho students refused to admit to being North Sotho speaking.

In this way the groups chose themselves. I do not think that this presented a problem but it may in fact have been fortuitous in that this is what would happen if the Guides were available in schools. This also eliminated factors of unmotivated or resentful students being in one group rather than another.

The English and North Sotho Group consisted of eight males and eight females and the English Group consisted of nine males and six females. Two students from each group were not present for the post-test.

3.3 Research Questions

1. Do North Sotho speaking high school students show a greater understanding of specific physics and chemistry concepts after having had access to the English version of the RADMASTE Science Concept Guide or after using the English plus North Sotho Guide?

2. What opinions do students have about the use of vernacular and / or English in the science classroom?

3. What are the participants' experiences and criticisms of the RADMASTE Science Concept Guide?

4. Does data obtained show any differentiation according to gender?

The Research Hypothesis:

H_0 : There is no difference in the increases/decreases in the scores of the English & North Sotho Group and the English Group on the pre- and post-tests.

3.4 Construction of the Concept Guide

The Guide has three sections: Physics; Chemistry and Mathematics for science. The idea was to create a reference book for students, teachers and material writers in these three fields. The Guide differs from a dictionary in that the definitions are less cryptic and are given in increasing stages of complexity. A standard 7 pupil may, for example, read only the first one or two phrasings of a concept definition given whereas a senior student may read all of them. It also differs from both a dictionary and an encyclopaedia in that the authors tried to identify abstract concepts that are important for a growth in

understanding of each of the subject areas. That is to say, the definition of common nouns such as beaker or clamp were omitted. In an attempt to form an overall basis of understanding the terms were grouped into themes as they might arise when drawing a concept map. Finally, every attempt was made to avoid formal definitions that may be rote learned.
In compiling the Guide the following steps were taken:

1. Identify a theme.
2. Select concept words belonging to the theme.
3. Compile existing definitions (from various sources) for the terms in English.
4. Reword the definitions into more accessible language taking care to retain accuracy.
5. Editing by subject expert.
6. Translate the definitions into North Sotho.
7. Back-translate to English.
8. Revise where necessary.

Within a section various themes were identified. For example, the section on **Mechanics** included the themes **Force; Speed, Velocity and Acceleration; Momentum; Work, Energy and Power**. The concepts belonging to the theme of Force are: force; contact and non-contact; equilibrium; changes; direction; shape; rotation, speed; velocity; acceleration. The order in which the concepts appear is determined by their relationship to the main concept. An example of a web of concepts is shown in the figure below:

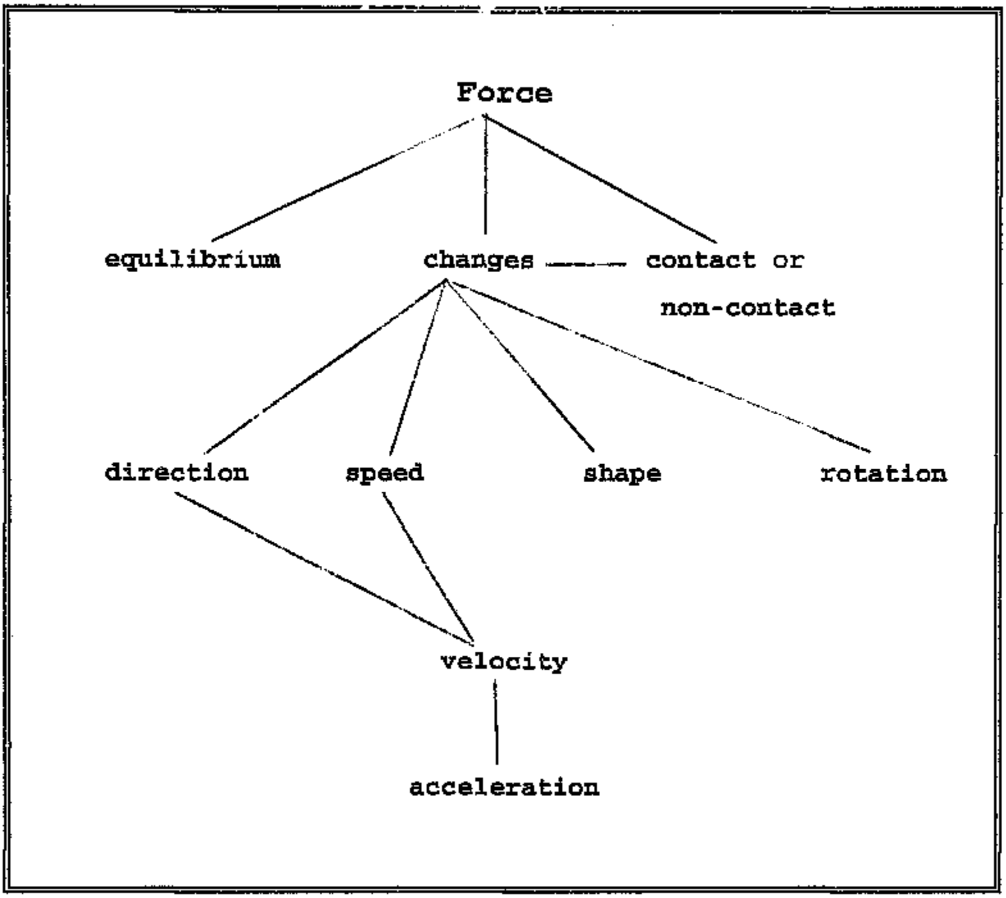


Figure 3.1 A web diagram of force

Other concepts related to this web were brought in. **Mass** and **weight** are followed by acceleration, (gravitational acceleration), gravity, momentum, (which is related to the velocity of the object), rate of change of momentum, conservation laws. Where there is an overlap of concepts a cross-reference system is used.

About the translation

The translator tried to portray the meaning of a concept rather than stick to a literal or word by word translation. A number of problems were encountered when translating. The main ones being:

(i) Lack of scientific words in North Sotho.
For example, there are no words for: metal; matter; orientation; conductor; liquid.

(ii) A single word in North Sotho may have many meanings.

(iii) Lack of vocabulary to differentiate more subtle meanings, e.g. sphere, circle.

(iv) Where there are no equivalent words in North Sotho, approximations lead to significant inaccuracies: e.g.
"resultant" in back-translation becomes "result"
"directly proportional" becomes "equal"
"renewable" becomes "used"
"equilibrant" becomes "equal", "equilibrium" or "equating".

Two approaches were used in dealing with these problems. First, to address the lack of words in North Sotho, especially when dealing with microscopic particles, the English words were transliterated, giving them a North Sotho pronunciation, e.g. electron was written *eleketerone*. This is not seen as the coining of a new word as such pronunciation is already fairly common among North Sotho speakers. This approach was only possible in situations where the meaning of a concept could still be retained. In other instances, however, this was not possible without compromising the meaning. Particularly when dealing with more abstract concepts such as *magnetic field* or *flux*, words having a North Sotho sound could not be created. Such words were left in English.

The following table gives examples of words that have been given a North Sotho spelling and pronunciation:

Table 3.1 (a) North Sotho translation of terms

English	North Sotho
electron	eleketerone
proton	protone
neutron	nuterone
ion	ayene
particle	phatikele
nucleus	nutlease
ionize	ayonaise
angle	enkele
lens	lense
charge	tshatse

Table 3.1 (b)

English	North Sotho
atomic number	palomoka ya athomo
mass number	palomoka ya boima
velocity	lebelothiwii
acceleration	makhura
heat	phiiso
heating	phisetso
attractive force	maatla-kgogedi
resultant force	maatla-kakaretso

Revision of the Guide

After completing the first few sections of the Guide, it was workshopped with a group of North Sotho speaking science teachers who were enrolled in the ACPSE (Advanced Certificate in Primary Science Education - Wits University) course. Teachers were given a North Sotho section and asked to translate the definitions back into English. The English versions resulting from this were for the most part incomprehensible! This has already been mentioned in Chapter 1 and some of the translations are given in Appendix 1. This led to a revision of many of the descriptions and also to some extent a revision of the style of writing.

Some minor revisions were also done after the pilot study. This included the addition of pictures and diagrams which the pilot students felt would be both useful and make the Guide more appealing.

3.5 Method

Quantitative assessment

Many research projects have been undertaken to assess the effectiveness of teaching materials. Assessing the effectiveness of such a "dictionary" as an aid to improved understanding of science is more problematic. It is, of course, not intended to be used as a sole means of teaching a topic. Its usefulness is also probably more apparent over a considerable period of time as its use will normally be incidental to other material. Because of the limits of time and finance, the testing of the RADMASTE Concept Guide was restricted to two weeks in one school.

Nevertheless, it is hoped that with special efforts to promote the dictionaries' use on a daily basis over the two weeks, while doing revision of two topics, noticeable results could be obtained. The shortcomings inherent in the situation will apply equally to both groups tested, (one English & North Sotho and the other English only), so that it is hoped that any differences between the two groups may indicate some connection to the languages used in the different versions of the Guide given to students.

In order to optimize the use of the dictionary during lessons rather than concentrate on text books or other teaching materials, I decided on an intervention strategy that involved the revision of one physics and one chemistry section of the DET matric syllabus that students had already learned. There was in this situation more scope for students to use the dictionary in class to clarify terms they had forgotten or were not sure about. In using two sections that students had already completed, it was possible to administer a pre-test to assess their understanding of the concepts.

The research design was therefore a **pretest - post-test.**

$O_1 \longrightarrow X \longrightarrow O_2$	(RADMASTE English)
$O_3 \longrightarrow Y \longrightarrow O_4$	(RADMASTE English & vernacular)

In this design there was no control group. The aim was to compare the **English** and **English and North Sotho Guides**. This could be considered a more ethical approach than leaving one group as a control group. It also allows for other factors such as the Hawthorne effect to apply to both groups equally.

<u>Qualitative assessment</u>

The aim here was twofold. Firstly, to obtain feedback from users of the Concept Guide in terms of criticisms and suggestions. In other words a "market research" strategy was envisaged. There seemed little point in continuing with multiple translations if the overall feedback from users was negative! Secondly, to find out in the broader context of language policy whether students perceived a need for the development of their vernacular in science education. As this issue seemed historically very sensitive, the interviews were made as informal as possible and were preceded by a questionnaire. It was hoped that the combination of these two methods would facilitate honesty and openness. Some students may prefer the anonymity of a written response. They may also be shy or lack confidence in speaking to adults. Others may feel more open with interpersonal communication. Although it was intended to interview students individually, this proved to be difficult. Students were extremely reticent, so group discussions were used.

3.6 Research Instruments

Three instruments have been used in this study: a pre-test and post-test; a questionnaire and interviews.

Cassels and Johnstone, (1984) have criticised the validity of multiple choice tests in chemistry claiming that minor changes in the phrasing of questions can greatly affect students' performance. They found, for example, that students had problems with questions posed in the negative form. They postulate that such questions involve more stages in thinking. Yarroch, (1991), maintains that students have a tendency to simply try to guess the correct answer and also do not check their responses.
Mokuku, (1993) argues that "a test item which is inaccessible to students because of unfamiliar language ... " has questionable construct validity.

These criticisms may ignore some of the stated aims of science education. If language and thought depend on each other for development then we should aim to develop both and cannot just continually simplify language. If we also accept that science education is not just the recall of facts but involves thinking skills then construct validity must include the ability to deal with sequential steps in thinking, language, checking and critical reading. Some students may have had difficulty understanding the questions but the language used was that required for scientific competence at that level.

Pre- and Post-tests.

Two equivalent tests were used. The tests were deliberately based on the type of questions asked in the matric examination. These were, after all, the tests that would assess the students' understanding of science at the end of the year. Whatever the shortcomings of these tests are, they are generally accepted as providing some measure of a student's understanding of science. The type of questions also had the advantage of being ones that students may be familiar with. That is, problems of examination technique would be minimized and also it was felt that students would be more motivated as the questions represented valuable revision for them rather than being seen as extra work.
The actual test questions were developed from ones used for the RADMASTE MAESTRO Programme*.

(The particular questions chosen from this course, as mentioned above, were based on previous matric examination questions.) In this way it was hoped to benefit from questions that had already been trialed and revised a number of times. The validity and reliability of the test had already, to some extent, been established.

* Blieden G S, De Beer W, De Villiers I, Walker S, The Maestro Programme in Physical Science - comprising 75 study units - audio visual. RADMASTE Centre, Johannesburg, First Edition, 2846pp, 1995.

The pre-test was to assess their level of competence and was used to form a comparison with their later performance. Nine revision sessions focussing on the use of the guide were given. These covered the two relevant topics and were conducted by the class teacher and researcher. Half of the students in one class had copies of the RADMASTE Science Concept Guide in English. The other half had the Concept Guide in English and North Sotho. The researcher and teacher discussed the revision sessions and the use of the dictionaries in the classroom. In the tenth session the post-test was administered. This was identical in form to the pre-test but had different questions (i.e. it was a parallel-form test).

The pretest and post-test are included in Appendix 4.

Questionnaires.

These were designed to form a focus for the interviews that followed. The questionnaire is given in Appendix 5.

3.7 Validity and Reliability of Test

Establishing Trustworthiness

I have examined both the quantitative and qualitative aspects of this study with reference to the Naturalistic Inquiry of Lincoln and Guba, (1985) and Preshkin's In search of Subjectivity - One's Own.

Trustworthiness, according to Lincoln and Guba may be summarized as follows:

Table 3.2 Trustworthiness of Research Methods

Quantitative	Qualitative
Internal validity	Truth value
External validity	Applicability
Reliability	Consistency
Objectivity	Neutrality

<u>Quantitative aspects of study</u>

1. **Internal validity** attempts to establish a causal connection between independent and dependent variables. In this case between improvement of test scores and language of Concepts Guide used. The null hypotheses is that the use of a Concept Guide in English and North Sotho will show no improvement in test scores over the use of a Concept Guide in English only.

The internal validity is threatened by the following:

History: specific external events between the first and second measurement. In the case of the pre- and post-tests the time interval was only about three weeks so this is not seen as a confounding factor.

Maturation: changes in the respondents. Again, the shortness of the time interval would preclude this.

Testing: effects of the first test on the second. It is likely that this would have an effect. I tried to minimize this by not returning the pre-test to students nor discussing the answers to questions. Students were also not told that they would be writing another test. The practice effect of already having written a test would, however, be the same for both groups so this would not result in any undue disparity between the two groups that were being compared.

Instrumentation: changes in the observers or scores used. The only change that might have occurred would be a subjective one. This will be discussed shortly.

Differential selection: effects of comparing non-comparable groups. The pre-test did establish that there were some differences in the abilities of each group. Other differences may have been in the attitudes of students or in their linguistic ability. Some students chose not to use the North Sotho Guide even though they were North Sotho first language speakers. This situation would be representative of what would happen if the Guides were available in classrooms generally. So, although I cannot say what these differences are, and have simply grouped students into a North Sotho Group and an ESL Group, such differences do not detract from the research findings.

Experimental mortality: losing some of the subjects during the course of the study. This was of some concern especially as the groups were already so small.

2. **External validity.** This is the extent to which a causal relationship can be generalized. Internal and external validity work against each other and a compromise needs to be established. External validity is threatened by:

Selection effects: constructs that are tested belong to a single group. The two groups of students seem to be representative of ESL students in the area of Mamelodi. According to their teacher and my North Sotho speaking colleagues the North Sotho students appeared to be not as fluent in their mother tongue as students from some other areas. The reason for this could possibly be that they tend to speak a mixture of languages. This could certainly affect their ability to use their North Sotho Guide.

3. Reliability and Objectivity. Problems with reliability in marking are minimized when the test requires short answers or is multiple choice.

Qualitative aspects of the study

1. Credibility: this is the extent to which the study corresponds with reality. That there was a fair correspondence in the conclusions I drew from the interviews with students was confirmed by the students themselves and by their teachers. Later some doubt arose about the students' responses - see Point 3 below). Credibility can be achieved through the use of a variety of methods and this I tried to do by using questionnaires, interviews and classroom observation.

2. Transferability. This refers to the applicability of the research findings. There are two obvious problems here. A small number of students were interviewed and attitudes of students in Gauteng are likely to vary from area to area.

3. Dependability. This refers to the consistency of the situation. Lincoln and Guba point out that reality is not static and so inconsistence must always be borne in mind. I think that some degree of consistency, however, is evident in that the findings of the pilot and main study are very similar. Another consideration here is whether the interview questions did actually elicit the desired knowledge from the students: did they actually respond honestly? There is some doubt in my mind about this on account of the dictates of cultural etiquette. My doubt arose as follows: while asking an entirely different group of teachers during a workshop for their opinion of the lunch arrangements, one teacher responded very enthusiastically that the lunch was super! At this point his colleagues started to laugh and at last told me that this particular teacher had been complaining about the food all the way through the meal! During the ensuing discussion they asked me if I really expected them to reply to such a question honestly? A negative response would apparently be a serious breach of etiquette. Such cultural dictates of behaviour have serious implications for the dependability of qualitative research methods in South Africa.

4. **Confirmability:** This refers to inter-subjective agreement. Having two interviewers increased the confirmability but personal bias certainly played a role. On reflection, one of the main biases I must acknowledge is an enthusiasm in promoting the use of the Guides - rather like an encyclopaedia salesperson! In the everyday context it is unlikely that another teacher would so actively promote the Guide's use.

CHAPTER 4

FIELDWORK

"Mine is a long and sad tale!" said the Mouse, turning to Alice and sighing.

"It is a long tail, certainly," said Alice, ...

Lewis Carroll

4.1 Pilot Study

Rationale

After a number of sections of the Guides had been written and translated and before further work was done, it seemed wise to test the effectiveness of the North Sotho translation and also to receive feedback about the layout. Conducting a pilot study also allowed for the practice and refinement of the interview technique.

The pilot study was conducted at a school in Mamelodi (near Pretoria). (I will call this school the Pilot School.) This school was chosen for practical reasons: willingness of teachers to co-operate; good attendance; time available.

Sample

The group consisted of 38 Std 9 science pupils.
This was a mixed-ability, multilingual group. I divided the group into two classes on the basis of their home language. The one class then consisted of 18 North Sotho speaking students and the other of 20 randomly selected North Sotho speaking students

plus non-North Sotho speaking students.

Implementation

One section of Physics, (vectors) and one section of Chemistry, (the periodic table), were chosen as revision topics in the intervention. This was about one month before their end of year examinations. The students were given the pre-test to assess their level of understanding of the selected concepts. They were then given nine revision lessons on these sections. I took both groups for most of these sessions and was therefore able to ensure that each group received equivalent teaching. I was also able to promote the use of the Guides. For four of the sessions Leslie Lekala, the co-author of the Guide, assisted and was able to discuss problems of language and translation. At the end of each lesson the Guides were handed in. I was concerned that the English Group might start using the North Sotho Guide and thus confuse the results and for this reason the Guides were only issued during class time. Unfortunately this limited students' access to the Guides.

At the end of the revision sessions both groups were given a post-test. The average score of each group was calculated and compared to the average score for the pre-test. I conducted interviews with 25 of the students after they had completed the questionnaire. Since no problems were encountered the tests were not modified for the main field work. The pre-test and post-test were the same as those used in the main study, (see Appendix 4). The Questionnaire used in the Pilot Study is given in Appendix 5. The modification that was needed was in my instructions about writing the test: I took more care in the final version to ensure that students understood the questions.

After seeing the students' responses to the Questionnaire, some modifications of the questions for the main study were needed. For example, Question 4 (b) (in the Pilot) was expanded into 4 (b) and (c) (in the Main Study) for greater clarity. The wording of Question 4 (d) was changed (See Main Study Q 4 (e)). Questions 4 (f), 5 (c), 6 (b) and 7 were added to the main study

I also took more time to explain the purpose of the questionnaire. For example, I suspected that students were trying to please me with their answers and therefore, in the main study I tried to reassure them that it was honesty in their answers that mattered. I emphasised that criticism was helpful and that this was an opportunity for them to say what they thought and felt. I also realized that in the main study I would need to encourage students to give more than one word answers to the questionnaire. By conducting group interviews students opened up more.

4.2 Main Study

A standard 10 mixed-ability science class of 33 students from a different school in Mamelodi was chosen for the study. As in the pilot study, many students were reluctant to admit to being North Sotho speaking. After many reassurances that they would also receive a Concept Guide in English, 16 students came forward for the North Sotho and English Group: 8 boys and 8 girls. In the English group there were 17 students: 11 boys and 6 girls. As the English group showed no interest in the North Sotho Guide, we decided to keep both groups in the one class and also to let the students take the Guides home with them.

We took some care to ensure that students understood the point of the study and the aim of using the guides. I hoped that they would therefore feel more enthusiastic about participating and also feel more inclined to be honest in the interviews. After an introductory talk the students were given the pre-test. (See Appendix 4.) Their class teacher and I worked out lesson plans for the next 9 lessons. During the lessons I observed the class and sometimes assisted with the teaching. During the ninth lesson the students were given the post-test. The following lesson, my colleague Leslie, helped distribute the questionnaires and assisted with student interviews. We found the students extremely reticent so that even with the help of their written answers to the questionnaire they seemed very shy. We therefore tried to group students and initiate a discussion, centring on the interview questions. This was the only way we were able to get any response. There seemed to be no difference between the two groups in their reluctance to speak. It also seemed to make no difference if they were given the opportunity to speak in their vernacular.

After the interviews we summarized briefly the opinions we had received and presented this to the students. They seemed to agree with our perceptions of what they had given us and only at this point appeared more relaxed.

CHAPTER 5

RESULTS and ANALYSIS

"Then you should say what you mean," the March Hare went on.

"I do," Alice hastily replied; "at least - at least I mean what I say - that's the same thing, you know."

Lewis Carroll

5.1 Introduction

This chapter deals with both the quantitative and qualitative results for both pilot and main study. I have attempted to draw links in the analysis of the two sets of data. The quantitative data is first presented as test scores for the two groups giving averages for each group and also showing a division by gender. The pre- and post-test scores are presented again without gender division and are analyzed using Wilcoxon's Test. Although the pre- and post-test design was originally intended to indicate differences in scores before and after the intervention, I have also included some observations and discussion on the type of definitions given by students.

5.2 Pilot Study Results

Pre-test Post-test Results

These showed that the English Group performed slightly better than the English and North Sotho Group. The English and North Sotho Group's scores improved by an average of 14,[illegible]% whereas the English Group's scores improved by an average of 20,03%.
However, these differences were not significant.
The test scores are given in Table 5.1.

Table 5.1 Pilot Study Test Scores

(test results)

English & North Sotho

Student	Pre-test %	Post-test %
NS 1	66	
NS 2	37	50
NS 3	54	71
NS 4	66	71
NS 5	51	76
NS 6	40	
NS 7	60	53
NS 8	29	41
NS 9	49	63
NS 10	37	47
NS 11	31	44
NS 12	31	79
NS 13	37	53
NS 14	74	82
NS 15	60	88
NS 16	34	76
NS 17		24
NS 18	46	65
av	47,18	61,44
T diff.		14,26%

English

Student	Pre-test %	Post-test %
E 1	43	38
E 2	66	80
E 3	29	55
E 4	34	55
E 5	11	24
E 6	34	51
E 7	34	49
E 8	20	44
E 9	60	68
E 10	46	53
E 11	29	65
E 12	31	
E 13	43	71
E 14	57	71
E 15	40	69
E 16	60	85
E 17	20	62
E 18	51	74
E 19	40	
E 20	17	35
av	38,25	58,28
T diff.		20,03%

Conclusions

Conclusions from the quantitative study are tentative as the sample group was small. The English Group's initial average score (for the pre-test) was almost 9% lower than the other group. It may thus have been easier for them to show an improvement. On the other hand, it could be argued that this is the weaker group and thus the improvement was more surprising. It may be that those students in the English Group had more time to concentrate on the English version which is the medium of testing. Over a short time scale this may work to their advantage. One encouraging sign was the improvement shown by both groups. Although both groups had already covered the relevant sections before the pre-test and had supposedly started preparing for the final examination, the marks gained by both groups in the pre-test were very low.

After working with the concept guide, both groups showed greater understanding. This may not, of course, be entirely the result of the use of the Concept Guide! It does however give some indication that it proved helpful.

Interview Results

Students' attitude to the use of language in science varied considerably.

Questions 1 & 2

It may be significant that the English and North Sotho Group spoke an average of only 1,54 other languages per student whereas the English Group spoke 3,37 other languages (in addition to their home language). This may indicate that they are a linguistically advantaged group which may account for the greater improvement in their scores when dealing specifically with concepts.

Question 3

23 out of the 25 students said that they had had problems understanding the words used in science.

Question 4

21 students expressed enthusiasm about the Concept Guide; 3 were indifferent and 1 gave a negative response. The majority of students said that they had found all the words that they had needed and had no difficulty with the lay-out or level of language used. They said that they felt that their understanding had improved.

When asked, most students said that they would like to see diagrams in the text.

Feelings about translation varied. A few were opposed to a vernacular version:

> " I think it will be useful if it is English only and not North Sotho because my home language is North Sotho but I don't speak it clearly."
>
> "I think this thing of North Sotho dictionary won't work because the meaning don't sound at all the same."

Others said:

> "I understand now 'cos it's in two different languages."
> "For the way they had explained now in North Sotho I do understand."

I also noted during the sessions with Leslie that most of the students in the North Sotho Group were very embarrassed to use North Sotho. They also seemed to have great difficulty expressing concepts in North Sotho when asked to do so. This may not be an indication that a translation is inappropriate but may well indicate that it is important to foster cultural identity and pride by developing the scientific register of vernacular languages. Just over half of the students showed an interest in this development.

Question 5

Of the English and North Sotho Group, 9 said that they would prefer to learn science in English only and 5 said that they

would prefer either mixed language or at least having vernacular Concept Guides as well as English Guides. Of the English Group 9 preferred English-only instruction and 6 preferred dual language guides and instruction.
No one opted for vernacular language only.

Question 6

24 of the 25 students said that they would like to study science after school.

Other comments:

> "I think that more dictionaries must be published because they make it easier to study than a text book."
>
> "I'd like to establish science books in other 11 languages to help those who cannot understand English well." (Although the student expressed a preference for English <u>instruction</u> as it is an international language.)
>
> "My suggestion is that you introduce these Guides to school teachers... as many students are having problems w: . terms.."
>
> "I think a carriable book would be better than a file... I would like to use it all the time."

<u>Conclusions</u>

The overall response was very positive and encouraging. There is clearly a need for this type of material. Although those students in favour of material in the vernacular were a minority their preference cannot be ignored and is supported by Khekheti Makhudu (ANC Language Commission Co-ordinator):

> "Every patriotic South African must assist therefore in making society multilingual... because speaking freely in any of the official languages is the very essence of one's civic consciousness, demonstrated by the exercise of one's democratic right."

(The Star. Nov.29,1994)

5.3 Main Study Results

In tables 5.2, 5.3 the test scores of the English Group and the English & North Sotho Group are given showing a subdivision according to gender and include the scores of all students. Table 5.4 summarizes these last two tables omitting differences of gender.

Initial scores were very low. This gives an indication that although these students had passed Std 9 their knowledge of these two topics (The Periodic Table and Vectors), was very poor. For the English & North Sotho Group the average pre-test score was 20,75%. There was very little difference between the boys and girls. The average pre-test score for the English Group was 24,33%. The male average was 30,44% and the female 15,17%. Although this is a small sample of students, the gender difference appears marked. This was also borne out later in the classroom observation where the girls did not participate in discussions.

In spite of the low scores, both groups scored considerably higher in the post-test. The increase in marks was 6,25% for the English & North Sotho Group and 7,67% for the English Group. In addition, the overall pre-test average for the English group was higher than that of the English & North Sotho Group. This may be an indication that those students who are more in favour of learning through English and having English texts in the classroom have been benefiting more from the current system than those students who show an interest in learning also through their ernacular. (This difference in language preference is discussed after the table on interview results: Table 5.4.) It is evident in this table that the English group claims competence in more languages and this may have led to more advanced cognitive development.

Although the difference in the average pre-test scores of the groups appears marked, statistically no significant difference could be found as the groups were too small.

Table 5.2

Initial Data Analysis: Males

English & North Sotho

MALES

Student number	Pre-test %	Post-test %
1 NS	11	12
2 NS	20	29
3 NS	37	41
4 NS	23	32
5 NS	11	--
6 NS	14	12
7 NS	11	11
8 NS	37	47
male ave.	20,5%	26,3%
Δ	5,8%	

English

MALES

Student number	Pre-test %	Post-test %
1 E	20	18
2 E	29	38
3 E	49	32
4 E	14	38
5 E	34	69
6 E	17	--
7 E	17	24
8 E	43	41
9 E	51	38
male ave.	30,44%	37,25%
Δ	6,81%	

Table 5.3

Initial Data Analysis: Females

English & North Sotho

FEMALES

Student number	Pre-test %	Post-test %
9 NS	34	--
10 NS	14	21
11 NS	14	15
12 NS	14	24
13 NS	49	44
14 NS	11	29
15 NS	6	--
16 NS	26	34
fem. ave.	21%	27,8%
Δ	6,8%	

English

FEMALES

Student number	Pre-test %	Post-test %
10 E	14	12
11 E	11	24
12 E	20	32
13 E	20	--
14 E	23	35
15 E	3	15
fem. ave.	15,17%	23,6%
Δ		8,43%

Table 5.4

Combined Male & Females Scores

English & North Sotho Total Female & Male Ave.	
Pre-test	Post-test
20,75%	27%
Total diff.	6,25%

Total English Female & Male Ave.	
Pre-test	Post-test
24,33%	32%
Total diff.	7,67%

As the groups were very small it was decided that a more meaningful analysis would be obtained by combining the male and female scores into a single group. The data were therefore regrouped into matched pairs omitting those students who completed only one test. The pairs consisted of each student's pre-test score and post-test score. See Tables 5.5 and 5.6. Scores were then analyzed according to Wilcoxon's test for matched pairs.

Wilcoxon's Test

This is a non-parametric or distribution-free test especially developed for small samples. It was decided to use the sign-rank test of difference to test for significance in the correlated data of the pre- and post-test scores. Although this test is less powerful than a parametric test, it does indicate a degree of significance in the final analysis that other tests were unable to do.

This test assumes that there is a mutual independence of the differences in the scores. The difference, D, between the pre- and post-test score for each pair is calculated. Then, ignoring the algebraic signs, the differences are ranked according to size only. As there are two D values of 1, we cannot say which is first and which is second, so each is assigned the value of 1,5. The next smallest difference is 2 and is ranked 3. in this way all the values R | D | are obtained. Next, the signs of the differences are considered. The negative signs are in the minority and they are singled out. There are only two negative signs. The sum of this column is given the statistic *T*.

The hypothesis tested is that the differences are symmetrically distributed about a mean difference of zero. This would coincide with the sums of randomly selected ranks *T*, which is also half the sum of *N* successive ranks and which would be given by the formula: (mean of sum of ranks):

$$T = \frac{N\ (N + 1)}{4}$$

The deviation obtained is $T - \overline{T}$. Wilcox's Table of T Values was used to obtain the T values significant at the .05, level.

<u>The null hypothesis</u>

A null hypothesis was formulated as follows:

H_o: There is no difference in the increases/decreases in the scores of the English & North Sotho Group and the English Group on the pre- and post-tests.

Table 5.5

Data and Calculation of rank and difference

English and North Sotho Group

Student	pre-test %	post-test %	Diff. D	Rank R|D|	R(+)	R(-)
1.	11	12	+1	1,5	1,5	
2.	20	29	+9	8,5	8,5	
3.	37	41	+4	4	4	
4.	23	32	+9	8,5	8,5	
5.	14	12	-2	3		3
6.	11	11	0	–	–	
7.	37	47	+10	10,5	10,5	
8.	14	21	+7	6	6	
9.	14	15	+1	1,5	1,5	
10.	14	24	+10	10,5	10,5	
11.	49	44	-5	5		5
12.	11	29	+18	12	12	
13.	26	34	+5	7	7	
average	21,6%	27,0%			ΣR(+) 70	ΣR(-) 8

English and North Sotho Group

There are 13 pairs in this group. One pair of observations has a zero change so cannot be included as either positive or negative and is therefore discarded. This leaves 12 changes for the test. The hypothesis calls for 6 positive changes whereas we obtained 10.

The Wilcoxon's test for matched pairs and signed ranks (data on an interval scale) showed that for 12 pairs $T \leq 14$ is sufficient to reject the null hypothesis at a significant level of 5%. For the above data $T = 8$. We can therefore say that there is a **significant difference ($p < 0,05$)** between the scores on the pre-test and the post-test. The null hypothesis for the English & North Sotho Group can be rejected. On the basis of this test we can concluded that there *is* a significant improvement in the scores of students who had access to the North Sotho & English Concept Guide.

Limitations: The average scores are extremely low.

English Group

See Table 5.6.
For 13 pairs $T \leq 17$ is sufficient to reject the null hypothesis at a significant level of 5%. The data of the English Group yields a T value of = 26,5. There is **not** a significant difference between the scores on the pre-test and the post-test. The null hypothesis cannot be rejected.

Table 5.6

Data and Calculation of rank and difference

English Group

Student	pre-test %	post-test %	Diff. D	Rank R|D|	R(+)	R(-)
1.	20	18	-2	2		2
2.	29	38	+9	5	5	
3.	49	32	-17	11		11
4.	14	38	+24	12	12	
5.	34	69	+35	13	13	
6.	17	24	+7	4	4	
7.	43	41	-2	2		2
8.	51	38	-13	9,5		9,5
9.	14	12	-2	2		2
10.	11	24	+13	9,5	9,5	
11.	20	32	+12	7	7	
12.	23	35	+12	7	7	
13.	3	15	+12	7	7	
average	25,2%	32,0%			ΣR(+) 64,5	ΣR(-) 26,5

Some observations regarding the Pre- and Post-tests

Introduction

Although the pre- and post-test were designed to provide statistical data, the nature or quality of the answers obtained provided some interesting observations.

Because the test scores provide limited insight into the degree of confusion or understanding of a student, I have included some of the typical definitions students gave in the pre- and post-tests. I have not included all definitions but have selected some that are representative of a general trend.

Pre-test

The immediate impression from the definitions that students gave in the pre-test was that they had attempted to rote learn sentences that were incomprehensible to them. Also many students left out definitions altogether: on average 1,3 definitions were left out in the pre-test compared with 0,6 left out in the post-test.

Examples of definitions in pre-test:

Speed is a scalar quantity which accelerates when two forces act together.

The speed which travel faster is the measure of an object moving all round without direction.

Distance is the time between two objects.

Distance is the magnitude and direction of proportional point.

Velocity is the speed for measuring temperature.

Post-test

Almost all students at least attempted the definitions in the post-test and although the definitions were not all completely accurate there was a definite improvement in the logic and understanding as is evident in these examples of definitions:

Velocity is the change of rate of displacement.

Velocity is a vector quantity.

Weight is the mass of an object by gravitational force.

Weight is a vertical force which act on an object.

Weight is a gravitational force which pulls a body downwards.

Speed is the length travelled over a period of time.

Speed is the movement of the body without direction

Speed is the rate of change of distance.

Force is a pushing or pulling on an object.

Force has magnitude and direction.

5.4 Qualitative Study

Observations:

After observing the nine science revision lessons, one of the most striking classroom observations was that during the entire time that I was in the classroom for observation, not once did a girl ask a question or volunteer an answer. They were all merely observers. Their teacher seemed unaware of this and interacted only with the boys. Students did appear to be motivated and also made frequent use of the Guides. As in the pilot study, students would talk socially in vernacular but could not answer any science questions in North Sotho. Some of them did try when asked to do so but there was generally a lot of laughter and embarrassment.

Questionnaires:

All students were asked to fill out the questionnaire (Appendix 6), so that they would have some time to consider the questions which I went through again in the interviews. The questionnaire served as a pre-interview prompt and these were analyzed in conjunction with the interviews.

Interview results:

Because the students were so shy they were interviewed in groups of three or four. 30 students were interviewed after they had filled in the questionnaires. In the North Sotho Group 14 students were interviewed, 13 of whom had North Sotho as a home language, (the 14th considered himself fluent in North Sotho). In the English Group 16 students were interviewed. 8 had Zulu as a home language, 2 had North Sotho and 6 had some other language.

Only some of the questions allowed comparisons between groups. In Question 4, (given below), the answers were similar and positive (i.e. indicated an appreciation for the Guide saying it contained the words needed and these were easy to find). There was one response which was an exception: one boy in the English group said that the Guide was not helpful. All his comments were negative: the Guide was "too simple and not academic". He was strongly in favour of learning through English.)

The general answer for Question 4:
(with the exception noted above)
All students appreciated the Concept Guide (in English, at least) and said that the language of the Concept Guide was accessible. No one had difficulty finding the words he or she needed.

All students thought that they understood the concepts better having used the guide.

4 (a). How did you like the science dictionary?
   (b). Could you find all the words and ideas that you wanted?
   (c). Have you any other comments about it?
   (d). Can you tell me any words that you didn't understand?
   (e). Do you think that the dictionary helped you understand the concepts better?

Interview results

By grouping the questions (from the questionnaire) and labelling the responses as in Table 5.7, I hope to highlight any trends that may be present.

I have summarized the questions in the first column of Table 5.7. The following is an explanation of the first column:
Home lang. refers to Question 1. "What is your home language?"
Range of lang. refers to Question 2. **"Which other languages do you speak?"** Here I have given the range of other languages (apart from English), spoken in the group.
Ave no. of other lang. refers also to Question 2. (Here I have only given the **number** of other languages spoken.)
(Question 4 is not on the table - it has been discussed.)
Preferred medium of study refers to Question 5 (a) and (b)
Dictionary pref. refers to Question 5 (c)

Science Career refers to Question 6 (a) and

Career to Question 6 (b)

No comments refers to Question 7 when students didn't respond

Difficulty with science terms refers to Question 3

The other results are summarized in the following table:

Table 5.7 Interview results

	English girls	English boys	Eng & NS girls	Eng & NS boys
Total	5	11	6	8
Home lang.	5. other	2: NS 9: other	6: NS	7: NS 1: other
Range of lang.	2 - 4	2 - 8	1 - 3	1 - 4
Ave. no. of other lang.	3,4	3,8	3,0	3,37
Preferred medium of study	3: E 2: Z & E	6: E 1: Z & E 1: NS &E 1: Z	1: E 5: NS &E	1: E 6: NS &E
Dictionary pref.	3: E 2: Z & E	7: E 2: Z	1: E 5: NS &E	1: E 6: NS &E
Science career	all	all	all	all
Career	4 degrees 1 nursing	10 degrees 1 teacher	5 degrees 1 beauty therapy	8 degrees
No comments	1	3	3	5
Difficulty with science terms	4: yes 1: no	7: yes 3: some 2: no	3: yes 2: some 2: no	3: yes 2: some 2: no

Abbreviations in Table 5.7
NS - North Sotho
pref. - preference
lang. - language
E - English
Z - Zulu

Trends in the table

(You will notice that the totals for the various questions differ as not all the students responded to all questions.)

The English group spoke more languages and showed a greater range in the number of languages spoken than the North Sotho Group. They were also more in favour of learning through English: 9/16 as opposed to 2/14 of the North Sotho Group.
It may be that this group had some academic advantage and more confidence on account of their linguistic skill.
10/14 of the English Group preferred an English dictionary (Concept Guide) compared with 2/13 for the North Sotho Group. This is consistent with the answers to the previous question. It may be worth noting that these responses show that most of the students in each group had the Guide in the language of their choice. The Hawthorne effect may therefore be seen to be similar for both groups. Of each sub-group this applies least to the English Girls Group. It is interesting to note then that this group had the largest average improvement in their post-test scores, (8,43%).

By including Question 6 about career choice I hoped to gain some impression of their motivation to understand the concepts and the following question really confirms the students' answers they had just given. It is worth noting that although the students were having difficulty with science, (only 2 scored above 40% in the pre-test and 19 did not score above 20%), they all said that they wanted to study science after school. (Of course they might have been trying to give an answer that they thought I wanted but I can see little motive for their doing this.)

Question 7 is summarized in the table in terms of the number of students who made no comment. Here it is interesting to note that although the English Girls Group was very reticent in class only 1/5 had "no comment" whereas 5/8 of the English & North Sotho Boys Group had "no comment". Obviously these girls did have something to say and the reasons for their reluctance to speak in class could be an area for further investigation.

It is also interesting that this Group had the greatest majority admitting to having difficulty with science terms. Looking at the English Group as a whole (boys and girls) compared with the North Sotho & English Group, 11/16 of the English Group said they had difficulty with terms as opposed to 6/14 of the North Sotho & English Group. Considering the North Sotho & English students' poor performance in the pre-test and the difficulties that they had defining terms it seems that their positive answers to this question are more of an indication of their lack of awareness of their confusion or show a reluctance to admit that language is a problem.

Some Comments: (Question 7)

<u>English: Girls' Group</u>:

I suggest you translate the dictionary to Zulu or Xhosa...

The science dictionary should be also in Tswana...

<u>English: Boys' Group</u>:

I wish if it is not translated into other languages because it will result a bad knowledge of science to black society.

Give us detailed explanations in Zulu it will be splendid by the way.

I wish you include Venda.

I suggest the dictionary should be published. (I)

North Sotho & English: Girls' Group:

I suggest that you also give us the Tswana science dictionary... (The dictionary) explain more simple than the words in the text book.

I think better to find two languages because I can use both, if I have a problem with other one.

North Sotho & English: Boys' Group:

I suggest that this dictionary must be printed in other languages for students who can't read NS I think it can help them the way it help us.

That dictionary must be put into more simple words of NS so that it can be more simple.

General: 7 students said that they needed more help in chemistry.

5.5 Conclusion

Although the sample was small, the results of the quantitative study add to the findings of the classroom observation and the interview results. Students used the Concept Guide in class and expressed appreciation for it. Their understanding of concepts generally improved. Only through statistical analysis were the differences in the performance of the two groups evident. The data obtained provides some answers to the research questions. These will be discussed in Chapter 6.

CHAPTER 6

DISCUSSION and CONCLUSION

" Not the same thing a bit!" Said the Hatter.

"Why, you might just as well say that 'I see what I eat' is the same thing as 'I eat what I see'!"

"You might just as well say," added the March Hare, "that 'I like what I get' is the same thing as 'I get what I like'!"

Lewis Carroll

6.1 Answering the Research Questions

1. Do North Sotho-speaking high school students show a greater understanding of specific physics and chemistry concepts after having had access to the English version of the RADMASTE Science Concept Guide or after using the English plus North Sotho Guide?

It was encouraging to note the improvement in the scores of all students. Classroom observation and interview results showed that students were keen to use the Guides. Statistical analysis showed that in fact using the RADMASTE Concept Guide in North Sotho and English produced a significant improvement in the student's test scores whereas the improvement in the group using the English Concept Guide was not significant. The reasons for the significant difference in scores between the two groups is largely speculation but does, I believe, give some indication that the North Sotho Guide is useful to students. The fact that the North Sotho and English Group showed a greater improvement in their test scores than the English Group may indeed be because their understanding of the concepts was improved by having access to definitions in their mother tongue. Having material in North Sotho may also have had a positive effect on their confidence, attitude and motivation. The whole intervention may also have made them more aware of the role of language in science and this may have led to an improvement in scores. This latter point would, however, apply to both groups. The Hawthorn effect may certainly have played a role and this would probably have been more marked for the North Sotho & English Group.

Any generalizations need to be made with caution in view of the small samples and also the limited time of the intervention. There is however a clear indication, taking the interview results into consideration, that the Guide proved useful to almost all students and that further research into the use and provision of material in the vernacular in warranted.

Comments on the post-test

The definitions given by the students highlight the intricacies and difficulties of scientific language: one student, for example defined velocity as: " the change of rate of displacement". This statement may be used to define acceleration. With just a word order switch, a correct definition for velocity could have been: "the rate of change of displacement"! It was encouraging to see that even where definitions were incorrect, students had tried to formulate their our definitions (i.e. they were not rote learnt). It appears to me that these definitions showed improved understanding, (if it is possible to make such a claim where definitions were still confused!)

2. What opinions do students have about the use of vernacular and \ or English in the science classroom?

It was fortunate for the research design that as it happened students were more or less equally divided in their opinions about the use of vernacular in science. (This made it possible for students to choose their own group.) It is interesting to note that although many students were shy to speak in class and also extremely reticent in the interviews they were not afraid to have different opinions from their friends regarding the use of language. 15 students out of 27 were in favour of a dual medium of instruction in science and a vernacular Concept Guide (or vernacular and English). In terms of the purpose of the research this again confirms the need to pursue the development of science material in vernacular languages.

3. What are the participants' experiences and criticisms of the RADMASTE Science Concept Guide?

As has been discussed the overall responses were very positive. The level of language used was accessible to the students. In order to gain more criticism of the content feedback from teachers, lecturers and writers would be useful.

4. Does data obtained show any differentiation according to gender?

The overall female test scores were lower than those of the males. The female average increased from 19,9% in the pre-test to 25,9% in the post-test, (an increase of 6%).
The overall male average for the pre-test increased by 6,37% from 25,76% in the pre-test to 32,13% in the post-test. Taking into account the girls' passive role in class it is likely that this had a considerable effect on their performance. It does not seem to be a result of lack of interest or motivation as all the girls are interested in pursuing a science career and most had comments to contribute during the interviews. It also seems

unlikely that there is a significant difference in their ability as the girls were able to show an improvement comparable to the boys in the same amount of time (even though they received less attention in class).

6.2 Limitations of Research

One of the difficulties was the nature of the material that I wished to assess: a dictionary as an aid to improved understanding of concepts. It is not easy to gauge the effectiveness of a Concept Guide in the classroom. The amount of time was also short for such an assessment.

In the quantitative study the group sizes were very small. The questionnaire could not have been used on its own as students tended to leave out questions or simply wrote one word answers. They needed to be encouraged through discussion with colleagues. The questionnaire allowed them to consider the aspects individually before the interview. The educational culture of reticence made it difficult for most students to express their opinions.

6.3 Conclusions

The greater improvement of scores for the North Sotho & English Group (compared to the English Group) confirms the findings of the interviews: 11 of the 13 students in this group were in favour of a multilingual Concept Guide (and a mixed-language medium of instruction). This group claimed that having concepts defined in North Sotho increased their understanding. Although some students thought that learning in English only was most beneficial, a total of 15 students from both groups expressed enthusiasm for a Guide in their mother tongue. I think therefore that the research findings provide enough support to justify the development of such material for education.

6.4 Directions for Further Research

<u>The usefulness of the Guide for other groups such as teachers, writers, tertiary educators and students from other areas.</u>

The population and sample was limited. The potential users of the Guides may come from any of the above groups. It would be interesting to receive evaluation for this material from other interested groups.

<u>Longer term evaluation</u>

In this study, the novelty aspect of the Guides may have increased the students interest in them. It would be useful to know whether this interest would be sustained throughout the year on an ongoing basis.

Appendix 1

Back Translations (North Sotho to English)

EXTRACTS FROM ACPSE ASSIGNMENTS

Weight is a scalar.

Weight has no specific direction. It differs according to ..atmospheres.

Resultant is a strong force that can stand against two or more forces.

Force is an efford.

Weight is a quantity movement and direction.

It is not always true that an unbalanced force can cause acceleration.

Power is the product of different that will be there with electricity inside the conductor.

EMF is the force.....
is the rate of energy that....
is the rate of force of electricity...

The unbalancing of a force can combine to give individual force which is called the resultant.

The resultant of this force can be measured to what we call equilibrant.

Vector: line conceived to have fixed length/ direction but no fixed position.

Force can be equal the way momentum is changed.

From the force which is attracted to each other force from the body is formed by something else that they force the force from the first line with the same mass from different directions. Those masses are called action- reaction pair of forces.

Appendix 2

Fog Index

One Way of measuring readability:

1. Calculate the number of average words per sentence in a passage.
2. Add on the percentage of words with three or more syllables.
3. Multiply by 0,4.

If the result - the **Fog Index** - is more than 12, the text could be too difficult for most readers.

Appendix 3

"Speak English!" *said the Eaglet.*

"I don't know the meaning of half those long words, and, what's more, I don't think you do either!"

Lewis Carroll

PHYSICAL SCIENCE PRETEST

Std. 9

Chemistry: The Periodic Table

Question 1

Multiple choice:

(1) In the periodic table the elements are arranged according to their:

(A) number of electrons
(B) number of neutrons
(C) number of protons
(D) number of protons and neutrons

(2) Which one of the following statements about the electrons in a sodium atom is correct? (Atomic number for sodium is 11)

(A) Sodium has 1 valence electron.
(B) Sodium has 11 valence electrons.
(C) Sodium has 3 valence electrons.

(3) The atomic numbers of certain elements are given below. Which of them represents an element with chemical properties similar to sodium?

(A) 7 (C) 10
(B) 8 (D) 19

(4) The element in the third period with 1 "s" electron only is:

(A) Al (C) Na
(B) Ga (D) H

, In the periodic table, metallic characteristics decrease:

(A) from right to left and bottom to top
(B) from left to right and top to bottom
(C) from top to bottom
(D) From left to right and bottom to top

(5)

Question 2:

(1.) On the periodic table below:

(a) Draw a diagonal line to separate metals and nonmetals. (2)

(b) Indicate by using arrows in which direction ionization energy will increase across the periods and along the groups. (4)

(c) Indicate where the transition metals are. (1)

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

(2.) Explain why the melting point increases in period two up to carbon and then drops drastically at nitrogen. (3)

Physics: Vectors

Question 1.

1. Which of the following is a scalar quantity?

    (A) displacement (C) distance
    (B) velocity (D) weight

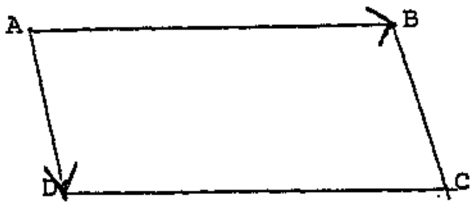
2. The resultant of a number of vectors is

    (A) the single vector from the last to the first vector.
    (B) the same as the equilibrant.
    (C) the vector which has the same effect as the other vectors acting together.
    (D) of the same magnitude as the magnitudes of the separate vectors added together.

3. Two forces acting on a point will be in equilibrium when they:

    (A) act in the same direction.
    (B) are equal.
    (C) are equal but act in opposite directions.
    (D) act at an angle of 90° to each other.

4. In the diagram AB and AD represent the magnitude and direction of two forces. The point C completes the parallelogram.



The magnitude of the resultant force will be represented by:

(A) BC (B) AB (C) AC (D) AB + BC

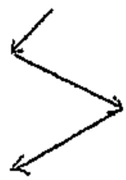
(4)

Question 2.

Sketch in the approximate magnitude and direction of the resultant for each of the following sets of displacements.

(A) 

(B) 

(C) 

(6)

PHYSICAL SCIENCE POST-TEST

Std. 9

Chemistry: The Periodic Table

Question 1

Multiple choice:

(1) Scientists today use atomic numbers for the sequencing of the elements in the Periodic Table, because:

(A) the masses of the atoms are connected to their chemical behaviour.
(B) the chemical behaviour of an atom is connected to the number of charged particles in the atom.

(C) elements with similar properties are placed in horizontal rows.

(2) Which statement is correct?

(A) The ionization energy of an atom is the energy released when it loses an electron.

(B) The radius of the atom is defined by the radius of its outermost shell.

(C) As the ionization energies of atoms increase, their radii decrease.

(D) The radius of an atom increases with increasing atomic number.

(3) Which one of the following statements is correct? (Atomic number for carbon is 6)

(A) Carbon has 4 valence electrons.
(B) Carbon has 2 valence electrons.
(C) Carbon has 6 valence electrons.

(4) The element in the second period with 2 "s" electrons only is:

(A) Be
(B) Mg
(C) Al
(D) P

(5) The atomic numbers of certain elements are given below. Which of them represents an element with chemical properties similar to helium?

(A) 7 (C) 10
(B) 8 (D) 19

(5)

Question 2

1. Circle the elements that are liquids at room temperature. (2)

2. Shade in all the elements that exist as diatomic gases. (5)

3. Indicate by using arrows in which direction atomic radius will increase across the periods and along the groups. (4)

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn

Physics: Vectors

Question 1.

(1) Which of the following, is a vector quantity?

(A) time (B) speed (C) distance (D) weight

(2) Which word best completes the following sentence?

The ____________ of a number of vectors has the same magnitude as the resultant but the opposite direction.

(A) equilibrium
(B) equal
(C) balance
(D) equilibrant

(3) The resultant of two forces acting at the same point on a body:

(A) keeps the body in equilibrium.
(B) has exactly the same effect as the two forces together.
(C) has the opposite effect to the two forces together.

(4) The minimum resultant of two forces of 2,5N and 7,5N is

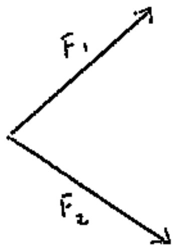
(A) 10N
(B) 5N
(C) 2,5N
(D) 0N

(4)

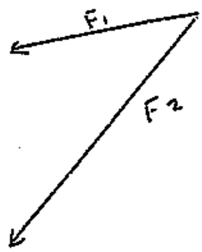
<u>Question 2.</u>

Sketch the magnitude and direction of the resultant for each of the following pairs of forces.

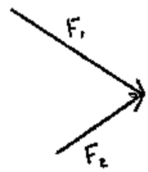
(A)



(B)



(C)



(6)

Question 3.

Explain the meaning of the following terms so that it is clear what the difference is between them.

1. (a) **speed**

   (b) **velocity**

2. (a) **force**

   (b) **weight**

(8)

Appendix 4

"... I wonder what Latitude or Longitude I've got to?"

(Alice had no idea what Latitude was, or Longitude either, but thought they were nice grand words to say.)

Lewis Carroll

Questionnaires - Interview Questions - Pilot Study

1. What is your home language?
2. Which other languages do you speak?
3. Have you had problems understanding the words used in your science textbook or in your science class?
4 (a). How did you like the science dictionary?
   (b). Could you find all the words and ideas that you wanted?
   (c). Have you any other comments about it?
   (d). Can you tell me any words that you didn't understand?
   (e). Do you think that the dictionary helped you understand the concepts better?
5 (a). How do you feel about learning science through English?
   (b). Would you like to study science in English/ English and North Sotho/ North Sotho (or your own Mother Tongue)?
6. Would you like to study science when you have finished school? (Please elaborate.)

Appendix 5

Questionnaires - Interview Questions - Main Study

1. What is your home language?
2. Which other languages do you speak?
3. Have you had problems understanding the words used in your science textbook or in your science class?

4 (a). How did you like the science dictionary?
(b). Did it contain all the words and ideas that you wanted?
(c). Did you have any difficulty finding the words?
(d). Have you any other comments about it?
(e). Were there any words that you didn't understand after reading the explanations?
(f). Was the language of the dictionary too difficult, or could you understand it?
(g). Do you think that the dictionary helped you understand the concepts better?

5 (a). How do you feel about learning science through English?
(b). Would you like to study science in English/ English and North Sotho/ North Sotho (or your own Mother Tongue)?
(c). Would you like to use a Concept Guide in your Mother Tongue.

6 (a). Would you like to study science when you have finished school?
(b). What do you hope to study?

7. Have you any other comments or suggestions?

Appendix 5

Questionnaires - Interview Questions - Pilot Study

1. What is your home language?
2. Which other languages do you speak?
3. Have you had problems understanding the words used in your science textbook or in your science class?
4 (a). How did you like the science dictionary?
   (b). Could you find all the words and ideas that you wanted?
   (c). Have you any other comments about it?
   (d). Can you tell me any words that you didn't understand?
   (e). Do you think that the dictionary helped you understand the concepts better?
5 (a). How do you feel about learning science through English?
   (b). Would you like to study science in English/ English and North Sotho/ North Sotho (or your own Mother Tongue)?
6. Would you like to study science when you have finished school? (Please elaborate.)

REFERENCES:

ANC Education Department: Draft Discussion document for Education Policy, C..ntre for Education Policy Development, January 1994.

Bamgbose, A. (1984), Mother tongue medium and scholastic attainment in Nigeria. Prospects, Vol.X1V,1.

Barba, R.H. (1993), A Study of Culturally Syntonic Variables in the Bilingual/ Bicultural Science Classroom. Journal of Research in Science Teaching, Vol.30, 9 (1053 - 1071).

Blieden G S, De Beer W, De Villiers I, Walker S, The Maestro Programme in Physical Science - comprising 75 study units - audio visual. RADMASTE Centre, Johannesburg, First Edition, 2846pp, 1995.

Bulman, L. (1986), Teaching Language and Study Skills in Secondary Science. Heineman Educational, London.

Carrol, L. (1865), Alice's Adventures in Wonderland. Macmillan and Co. London.

Case, S.M. (1968), The Language Barrier in Science Teaching. Teacher Education in New Countries, Vol.9, 1 (15 - 26).

Cassels, J.R.T. and Johnstone, A.H. (1979), Underst...ng of Non-Technical Words in Science. London, The Chem Society, Educatio. Division.

Cassels, J.R.T. and Johnston, A.H. (1984), The effect of language on student performance on multiple choice tests in chemistry. Journal of Chemical Education. Vol. 6, 7, (613-615).

Chomsky, N. (1975), Reflections on Language. Pantheon Books, New York.

Collison, G. Omani. (1974), Concept Formaticn in a Second Language: A Study of Ghanian School Children. Harvard Educational Review, Vol.44, 3, (441-457).

Cummins, J. (1977), Cognitive Factors associated with the attainment of Intermediate levels of bilingual skills. The Modern Language Journal, Vol.61, (135-146).

Cummins, J. (1980), The cross-lingual dimensions of language proficiency: implications for bilingual education and the optimal age issue. TESOL Quarterly, Vol.14, (175-187).

Curtis, S. and Millar, R. (1988), Language and Conceptual Understanding in Science: a comparison of English and Asian language speaking children. Research in Science & Technological Education, Vol.6, 1, (61-77).

DBSA (1994), South Africa.s nine provinces: A human development profile. Development Bank of South Africa.

DNE, (1994), Curriculum Model for Fouth Africa Policy document. Pretoria, UNISA Press.

EDUSOURCE,(1993), The National Teacher Education Audit. Ed source Data News, July.

Fafunwa, Babs A. (1975), Education in the Mother -Tongue: A Nigerian Experiment - The Six-Tear (Yoruba Medium) Primary Education Project at the University of Ife, Nigeria. West African Journal of Education, Vol.X1X, 2, (213-227).

Fishman, J.A. (1984), Minority Mother Tongues in Education. Prospects, Vol.X1V, 1, (37-49).

Gilbert, John, K. and Osborne, R.J. (1980), Some Problems of learning Science. School Science Review, Vol.61, 217, (664-674).

Guilford, J.P. and Fruchter, B. (1981), Fundamental Statistics in Psychology and Education. McGraw-Hill, Tokyo.

Gonzales, P.C. (1981), Teaching Science to ESL Students. Science Teacher, Vol.48, 1, (19-21).

Halliday, M.A.K. (1976), Systems and Function in Language, Oxford.

Hawkins, J. and Pea, R.D. (1987), Tools for Bridging the Cultures of Everyday and Scientific thinking. Journal of Research in Science Teaching, Vol.24, 4, (291 - 307).

Haywood, J.W. and Varela, F.J. (1992), Gentle Bridges. Shambhala, London.

Heine, B. (1992). Language Policies in Africa, In: Herbert, R.K. ed. Language and Society in Africa.

Herbert, R.K. (ed). (1992), Language and Society in Africa. The theory and Practice of Sociolinguistics. Witwatersrand University Press.

Ho, K.K. (1982), Effects of Language of Instruction on Physics Achievement. Journal of Research in Science Teaching, Vol.19, 9, (761-767).

Isa, A.M. and Maskell, R. (1982), A Comparison of Science Word Meaning in the Classrooms of two different countries: Scottish Integrated Science in Scotland and in Malaysia. British Journal of Educational Psychology, Vol.52, (188-198).

Johnstone, A. and Cassels, J. (1978), What's in a word?, New Scientist, Vol.78, 103, (43?-434).

Jordaan, A.S. and Nangu N.S. (1995), The influence of Written Text on Std. 6 Pupils' Understanding of Elements and Compounds.FRD.

Kahn, M. and Rollnick, M. (1993), Science Education in the New South Africa: reflections and visions. Int. J. of Sci. Educ. Vol. 15, 3:261.

Kallaway, P. (ed) (1991), Apartheid and Education. The Education of Black South Africans. Ravan Press, Johannesburg.

Kane-Berman, J. (1996), South African Survey, 1995/96. South African Institute of Race Relations, Galvin & Sales, Cape Town.

Krashen, S. Butler, J. Birnbaum, R. and Robertson, J. (1978), Two Studies in Language Aquisition and Language Learning. ITL: Review of Applied Linguistics. 39-40: (73-92).

Krashen, S. and Scarcella, R. (1978), On routines and patterns in language aquisition and performance. Language Learning, 28, (283-300).

Krashen, S.D. and Terrell, T.D. (1984), The Natural Method: Language Acquisition in the Classroom. Oxford. Pergamon Press.

Laing, M. (1990), A Book Should have a Soul and not be called "9 New Syllabus". Chemistry Department, University of Natal, Durban.

Lemke, J.L. (1982), Talking Physics. Physics Education, 17 (263-267).

Levy, S. et.al. (1992), National Education Policy Initiative: Science Curriculum Group Report. EduNet, Johannesburg.

Lincoln, T.S. and Guba, E.G. (1985), Establishing Trustworthiness: Naturalistic Inquiry. Sage Publications, Beverly Hills, C.A.

Liptrot, G.F. (1971), Modern Inorganic Chemistry. Mills and Boon Ltd. London.

Littlewood, W. (1981), Communicative Language Teaching. From: "Discussions that Work." Cambridge University Press.

Littlewood, W. (1984), Foreign and Second Language Learning. Cambridge University Press.

Littlewood, W. (1985), Foreign and Second Language Learning. CUP. "The Effects of Instruction in the Weaker Language". Journal of Social Issues, Vol.23, 2, ..21-135).

Livingston, R.B. (1992), Development of the Human Brain. In Haywood, J.W. and Varela, F.J. (ed), Gentle Bridges, Shambala, London.

Lynch, P.P. et al. (1985), The Language of Science and High School Student: The Recognition of Concept Definitions: A Comparison Between Hindi Speaking Student in India and English Speaking Students in Australia. Journal of Research in Science Teaching, Vol.22, 7, (675 - 686).

Maley, A. (1989), Divided Worlds: Divided Minds. In Bickley, V. (ed), Language Teaching and Learning Styles within and Across Cultures. Institute of Language in Education, Hong Kong.

McNaught, C. (1991), Learning Science at the Interface Between Zulu and English: A Brief Overview of Research Issues in this area. Paper delivered at the Conference: "Language, Thought and Culture", Johannesburg.

Mokuku, T.T. (1993), Biology and Language: Evaluating the validity of multiple-choice tests for use with Std. 8 English Second Language Ecology students. Thesis (M.Sc.) University of the Witwatersrand, Johannesburg.

NEPI: National Policy Initiative: See Levy.

Ndunda, M. and Munby, H. (1991), "Because I'm a Woman": A Study of Culture, School and Futures in Science. Science Education. Vol 75, 6, (683-699).

Nhlapo, M.V.J. (1993), Problems Encountered by EFL and ESL Pupils with Techuical and Non-technical Terms used in Ecology. Unpublished MSc. Thesis, University of the Witwatersrand, Johannesburg.

Nkopodi, N. (1989), Recognition of some science concept definitions in English and North Sotho for High School pupils in Lebowa. Unpublished MSc. Thesis, University of the Witwatersrand, Johaannesburg.

Ogunnini, M.B.(1088), Adapting Western Science to Traditional African Culture. Int. J. of Sci. Ed. Vol.10, 1, (1-9).

Peatman, J.G. (1963), Introduction to Applied Statistics. Harper and Row. New York.

Piaget, J. (1954), Language and Thought from a genetic point of view. In Adams, P. (Ed.), 1972, "Language in thinking" R. Clay. London, Chaucer Press Ltd.

Pinker, S. (1994), An Instinct for Language. New Scientist, No.1931, (28-31).

Popov, (1994), Problems and change in science education in Mozambique. paper presented at the Conference of the Southern African Association for Research in Science and Mathematics Education. Grahamstown, S.A.

Prah, Kwesi, (1993), Mother Tongue For Scientific and Technological Development in Africa. German Foundation for International Development.

Preshkin, A. (1988), In search of subjectivity - one's own. Educational Researcher. Vol.17, 7 (17-21).

Rathbone, A. (1995), Windows 3.11 for Dummies. IDG Books. Foster City, USA.

RIEP (See Strauss et al.)

Rogers, J. (1982), The World for Sick Proper. ELT Journal. Vol.36, 3, (144-151).

Rollnick M. and Rutherford, M. (1993), The use of a conceptual change model and mixed language strategy for remediating misconceptions on air pressure. Int. J. of Sci. Educ. Vol.15, 4, (363-381).

Rutherford, M. and Nkopodi, N. (1990), A Comparison of the recognition of some science concept definitions in English and North Sotho for second language English speakers. Int. J. of Sci. Educ. Vol.12, 4, (443-456).

Ryan, T.N. (1985), The Language Gap: Common Words with Technical Meanings, Journal of Chemical Education. (1098 - 1099).

SAIRR: See Kane-Berman.

Schmied, J. (1991), English in Africa: An Introduction. Longman, Singapore.

Seddon, G.M. and Waweru, G. (1987), The Transferability of Scientific Concepts between different languages for Kenyan students. Br. J. Educ. Psychol., Vol.57, (244-248).

Sigabi, M. (1993), Receiving mathematics tuition in a second language: metacognitive implications for mathematical problem solving. Unpublished MSc.Thesis, University of the Witwatersrand, Johannesburg.

South African Institute of Race Relations. (See Kane-Berman.)

Stoll, (1994), Science Education in Developing Countries. What's the point? Science Education international. March.

Strauss, J.P. Plekker, S.J. Strauss J.W.W. van der Linde, H.J. (1994), Education and Manpower Development. Research Institute for Education Planning. No.15. Bloemfontein.

Strevens, P. (1976), Problems of Learning and Teaching Science through a Foreign Language. Studies in Science Education, Vol.3. (55-68).

Strevens, P. (1980), Teaching English as an International Language: From Practice to Principle, Pergammon Press. Oxford.

Sutton, C.R. (1980), The learners' prior knowledge: a critical review of techniques for probing its organization. European Journal of Sci. Ed. Vol.2, (107-120).

Sutton, C. (1981), Metaphorical Imagery: A means of coping with complex and unfamiliar information in science. Durham and Newcastle Research Review, Vol.1X, 46, (216-222).

Sutton, C. (1982), Science, Language and Meaning. School Science Review, Vol.62, 218, (47-56).

Sutton, C. (1992), Words, science and learning. O.U.P. Buckin gham, UK.

Swain, M. (1979), Home School language Switching. In "Understanding Second and Foreign Language Learning: Issues and Approaches." Richards, J.C. (ed.). Newbury House Publishers.

Swain, M. and Cummins, J. (1979), Survey Article: Bilingualism, Cognitive Fubctioning and Education. Linguistic Abstracts, Vol.12, 1, (4-18). Cambridge University Press.

Volbrecht, T. (1992), At Play in the Fields of the Flawed. SAAAD Conference Proceedings, P.E. Technikon, (258-275).

Vygotsky, L.S. (1962), Thought and Language. MIT Press, Massachusets.

Wandersee, J.H. (1985), Are there too many terms to learn in Biology?. American Biology teacher. Vol.47, 6, (346-347).

Weiten, W. (1995), Psychology: Themes and Variations. 3rd ed. International Thomson Publishing Company, USA.

White, J. (1988), The Language of Science. Department of Education and Science, London.

Wilkinson, A. (1982), Language and Education. Oxford University Press.

Whorf, B.L. (1978), Language Thought and Reality. MIT Press.

Wright, E. (1982), Language Problem or Study Problem - Confusion Area. Teacher Education.

Yarroch, W.L. (1991), The implications of the content versus item validity on science tests. Journal of Research in Science Teaching. Vol. 28, 7, (619-625).

Concept Guide

Topics

Introduction

Chemistry

1. Substance
    - Atomic Structure / Particle Nature of Matter
    - Periodic Table
    - Bonding
    - Phases of Matter

2. Change of Substance
    - Reactions
    - Type of Reactions
    - Redox
    - Electrochemistry
    - Acids and Bases
    - Solubility
    - Rates of Reaction
    - Equilibrium

3. Organic

Physics

4. Energy

5. Electricity
   - Current
   - Static
   - Electromagnetism

6. Thermodynamics
   - Heating
   - Working

7. Waves

8. Light / Geometric Optics

9. Sound

10. Radioactivity

Units

Mass

Charge

SECTIONS

AND

LISTS OF CONCEPTS

CHEMISTRY

1. SUBSTANCE

ATOMIC STRUCTURE

	ion
anion	isotope
atom	matter
atomic mass	mole
atomic orbital	molecule
Avogadro's number	mixture
cation	neutron
compound	orbital
diatomic molecule	particle
electron	proton
element	pure substance
elementary particle	sub-atomic particle
heterogeneous	relative atomic mass
homogeneous	substance
impure substance	valence electron

PERIODIC TABLE

actinoids	non-metal
halide	periodic function
hydride	periodic law
inert	periodic table
lanthanoids	semimetal/ metalliod
metal	transition elements

BONDING

bond	lattice
bond energy	lone pair
coordinate bond	London force
covalent bond	metallic bond
electron affinity	orbital
electronegativity	polar-covalent bond
hydrogen bond	polar molecule
intermolecular force	salt
intramolecular force	valency
ionic bond	v.d.Waals force
ionization	
ionization energy	

PHASES OF MATTER

boil / boiling point	phase
closed system	phase change
condense	phase equilibrium
critical temperature	solid
dynamic equilibrium	sublime
evapouration	triple point
fluid	vapour/ vapourize
freeze	vapour pressure
gas	volatile
liquid	volume
melt / melting point	

2. CHANGE OF SUBSTANCE

TYPES OF REACTIONS

acid / base	hydrolysis
addition	irreversible
combination	reaction
chemical equation	reactivity
decomposition	redox
displacement	reversible
endothermic	spontaneous
exothermic	substitution

REDOX

combustion	oxidising agent
half reaction	redox
oxidation	reducing agent
oxidation number	reduction

ELECTROCHEMISTRY

activity series	electrolysis
anode	electrolyte
battery	electrolytic cell
cathode	emf
charge carriers	half cell
Daniel cell	reference electrode
electrochemical cell	salt bridge
electrochemical series	standard electrode potential
electrode	Voltaic cell
electrode potential	

ACIDS AND BASES

acid	neutral
alkali	neatralize
amphoteric / ampholyte	pH
base	protolysis
concentration	standard solution
conjugate pair	strong acid
dilute	strong base
dissociation	titration
indicator	volumetric analysis

SOLUBILITY

aqueous solution	solute
dissolve	solution
precipitate	solvent
saturated	suspension
solubility	vapour pressure
soluble	

RATES OF REACTION

activation energy	forward reaction
catalyst	rate of reaction
energy of reaction	reverse reaction

EQUILIBRIUM

closed system	Law of Mass Action
equilibrium	Le Chatelier's Principle
equilibrium constant	shift in equilibrium

5. ORGANIC CHEMISTRY

ORGANIC

alcohol	hydrocarbon
aldehyde	isomer
aliphatic compound	molecular formula
aromatic compound	organic
carboxylic acid	saturated
empirical formula	semi-structural formula
ester	structural formula
functional group	unsaturated
homologous series	

PHYSICS

WAVES

amplitude	medium
antinode	node
constructive interference	period
destructive interference	pulse
electromagnetic spectrum	spectrum
frequency	transverse
interference	wave
longitudinal wave	wavelength

SOUND

echo	pure note
frequency	harmonic
fundamental frequency	noise
sound	resonance
pitch	speed of sound

LIGHT

light	spectrum
opaque	translucent
photon	ultra-violet
radiation	wavelength

PERIODIC TABLE

Table of Contents

THE PERIODIC TABLE

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
H																	He	1
Li	Be				Transition Elements							B	C	N	O	F	Ne	2
Na	Mg											Al	Si	P	S	Cl	Ar	3
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	K	4
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	5
Cs	Ba	*	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	6
Fr	Ra	**																7

Inner Transition Elements

*	La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	6 Lanthanoids
**	Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr	7 Actinoids

PERIODIC LAW

1. The properties of the atoms of the elements are a periodic function of their atomic numbers.

2. A consequence of the law is that the properties of the elements can be predicted from their position in the periodic table.

PERIODIC FUNCTION

1. This refers to the regular recurrence of similar properties of elements within the groups of the periodic table.

The properties of elements repeat at regular intervals with increasing atomic number.

METALS

1. Elements that are classified as metals have the following macroscopic characteristics
   - good conductors of heat
   - good conductors of electricity
   - shiny
   - malleable (can be bent and beaten into sheets)
   - ductile (can be drawn into wires)
   - their oxides are usually basic

The microscopic characteristics of metals include:
large atoms
atoms with low **ionization energy**
atoms which are "electron deficient"
(i.e. have lots of vacant atomic orbitals).

2. About 75% of the elements are metals.

3. Me..l elements are found on the left-hand side of the periodic table.

4. Some mixtures can also be classed as metals e.g. alloys such as brass or steel.
Relativley few compounds are metals.

NON-METALS

1. Elements that have the following macroscopic characteristics are generally classed as non-metals:
poor conductors of heat
poor conductors of electricity
not malleable or ductile
The microscopic characteristics of non-metals include:
atoms have high ionization energy
atoms are usually electronegative
their oxides are either neutral of acidic
atoms are relatively small

2. Non-metal elements are found on the right hand side of the periodic table.

3. Most compounds are non-metals.

SEMI-METALS / METALLOIDS

1. These are elements that have properties in between those of metal and non-metal elements.

2. They are electrical semi-conductors.

3. Their oxides may be acidic or basic (**amphoteric**).

4. They are found between the metals and non-metals on the periodic table.

HYDRIDES

Compounds that contain hydrogen atoms plus atoms that are less **electronegative** than the hydrogen atoms.

HALIDES

Compounds that contain halogen atoms (atoms of a group VII element) and atoms that are less **electronegative.**

INERT / NOBLE

1. Inert means unreactive. Elements in group VIII (‹ ›metimes called Group 0) are called inert or noble gases.

2. Atoms of the noble gases do not form chemical bonds except in a few rare cases.

TRANSITION ELEMENTS

1. These are all metals whose atoms exhibit multiple **valency** and form coloured compounds, e.g. copper; cobalt.

2. They are found between Group II and Group III (i.e. Groups 3-12) in the periodic table.

LANTHANOIDS (or lanthanides)

These elements (plus Sc and Y) are also called **rare-earth metals.**
These are the elements from cerium to lutetium. Their atoms all have valence electrons in the 4f atomic orbitals.

ACTINOIDS

These elements are the 15 elements from thorium to lawrencium.
Their atoms all have valence electrons in the 5 f atomic orbital and are radioactive.
Those with $Z \geq 93$ are artificially made.

ACTINOIDS

These elements are the 15 elements from thorium to lawrencium.
Their atoms all have valence electrons in the 5 f atomic orbital and are radioactive.
Those with $Z \geq 93$ are artificially made.

Section 2 : Mechanics

Table of contents

Force

What a force IS

1. A force is a **push or pull** on an object.
2. A force may be in contact with the object (touching) or may act with no contact (not touching).
3. Force is not something one can see. A force is recognised by its effects on an object. The effects of force on an object may be a change in **speed, direction, shape,** or **position** of the object.
4. A force on an object causing a change in speed, direction, or both is said to be an **unbalanced force.** Any unbalanced force on an object will accelerate the object.
5. There may be more than one unbalanced forces on an object. A single force having the same effect as all the unbalanced forces acting on the object combined is called **resultant.** The resultant force may be balanced by another force. This force is called the **equilibrant.**
6. An equilibrant is a force whose magnitude (size) is equal to that of the resultant but which acts in the opposite direction to the resultant.
7. The resultant and the equilibrant form a **pair of balanced forces.**
8. A force on an object produces a change in momentum.
9. The force is directly proportional to the rate of change of momentum produced.
10. For contact forces, a force on an object is produced by another object. The first object exerts a force on the second object; and the second object exerts a force of equal magnitude, but opposite direction on the first object at the same time.
11. A force of attraction due to the Earth on the object is called the **weight** of the object. Weight is the force caused by the gravitational attraction between the Earth and the object.
12. Gravitational force always acts towards the centre of the

Earth.

13. Weight is a vector.

Other meanings of force.

The everyday usage of the word force has a different meaning to the scientific definition of a force. The following statements show examples of what a force is NOT as defined in science.

1. Force is does not mean strength.
2. Force does not mean army.
3. Force does not mean to compel.

Speed, velocity, acceleration.

The terms speed, velocity and acceleration are defined in the statements below. The definitions start from the simplest to the more general definitions.

Speed

1. **Speed** of an object tells us how fast an object travels in a given time.
2. Speed of an object is the distance the object travelled in unit time.
3. Average speed is define as: **average speed = (distance travelled)/(time taken)**
4. **Distance** is the total path length travelled by an object relative to some reference point. It is a scalar quantity.
5. The instantaneous speed is the speed of an object at a given instant of time.
6. When the object covers the same distance in each unit of time it is said to have a constant speed. We say the object moves with a constant speed.
7. Speed is a scalar quantity.
8. A scalar quantity is any physical quantity which has only

magnitude (size).

9. When referring to the speed, the direction in which the object travels, though important, is not needed to specify the speed.

Velocity

1. **Velocity** of an object tells us how far an object travels in a given time, in a given direction. Thus velocity tells us how fast an object is moving and the direction in which it is moving.
2. Average velocity is the rate of change of displacement.
3. Displacement is defined as the change in position of an object.
4. **Instantaneous velocity** is the velocity at any instant of time. Alternatively, the instantaneous velocity is defined as the velocity over an indefinitely short time interval.
5. Velocity is a vector quantity.
6. **A vector quantity** is any physical quantity which is completely specified by both magnitude (size) and direction. In physics we also need units.
7. **Displacement** is defined as the change in position of an object. In the strict mathematical sense, the displacement between any two points is the shortest distance between the points in a given direction.
8. Velocity can be positive or negative. Speed is never negative.
9. In everyday language speed and velocity are used interchangeably. In physics we make a distinction between them. For a rectilinear(i.e. movement in a straight line) the magnitudes of speed and velocity are equal. This is what is normally referred to in everyday experiences.

Acceleration

1. Acceleration may be a change in speed, a change in direction, or a change in both speed and direction.

2. When the velocity of an object changes the object is said to be **accelerating**. This may be positive or negative.
3. A constant resultant force produces a constant acceleration of an object.
4. If the velocity of an object changes in equal amount in equal times, the acceleration is said to be uniform.
5. Acceleration is related to change in velocity as follows:

$$a=\frac{\Delta V}{\Delta t}$$

6. A force on an object of mass m, produces an acceleration a, which is proportional to the magnitude of that force.

F= m.a

7. An acceleration caused by gravity is called **gravitational acceleration** and is designated by the letter g.

Momentum

The concept of momentum is very important in the description of moving objects. It provides a link between force and acceleration, leading to a more general definition of force. This section deals with linear momentum only, that is the momentum of an object moving in a straight line.

1. The **momentum** of a moving object is defined as a product of its mass and velocity.

i.e. momentum = mass x velocity

2. Momentum is a vector. The direction of the momentum is the direction of velocity.
3. Momentum is a measure of the "amount" of motion. e.g the fast moving object has more momentum than the slow moving of the same mass.
4. The more momentum an object has the harder it is to stop it. That is the momentum relates to how easy it is to stop a moving object.
5. An unbalanced force produces a change in the momentum of an object.
6. The magnitude of an unbalanced force on an object is

directly proportional to the rate of change of momentum of that object.

$$F=\frac{\Delta p}{\Delta t}$$

7. When moving objects collide their total momentum before collision is equal to the their total momentum after collision. This is called the **principle of conservation of linear momentum.**
8. The principle of conservation of momentum can be restated as follows: 'The total momentum of an isolated system of bodies remains constant.'
9. The product **force x time** equals the momentum change. We call this product the **impulse**. The time here is the time over which the forces acts.
10. Impulse is defined as the total change in momentum.

Work, Energy, Power

The concepts of work, energy and power are usually problematic to students because they have different meanings in science to their everyday meanings. The concept of energy, which is discussed in detail in section 1, is the most problematic one because it is a most abstract.

Work

1. The term work is associated with the movement of an object.
2. Work is done on an object whenever that object moves.
3. Working means transferring energy. i.e. work is a measure of energy transferred by the action of a force.
4. The amount of work done is therefore equal to the amount of energy transferred.
5. We define work mathematically as: work = force x distance. The distance moved is the distance in the direction of the force causing the movement. e.g. If the force is gravity, we count only the vertical distance moved.

6. Work can be defined as the energy transferred when a force moves an object through a given distance.
7. The object doing work loses energy; and the object on which work is done gains an equal quantity of energy.
8. The work done is equal to the energy transferred.

Power

1. Different objects can do the same amount of work at different times. The rate at which work is done is called power. Power is therefore defined as the ratio of work done (or energy transferred) in a unit time.
2. Power is a measure of how quickly the work is done or energy is transferred.

Other meanings of power

The word power has different scientific meaning than the everyday meaning; or its meaning mathematics. The followi g statements shows the different meanings.

1. In mathematics the word power is used to mean an exponent.
2. In politics power means the right of ruling or commanding.
3. In everyday language the word power is used to mean the *means of doing.*

Newton's Laws

The laws describing the motion of objects are called Newton's laws. Newton was the first person to produce a systematic work on the subject. There are three laws of motion known as Newton's first law, Newton's second law, and Newton's third law.

1. Newton's first law: When an object is at rest it remains at rest unless it is disturbed by something (some external force). Also when an object is moving it will continue

moving in exactly the same direction and speed unless it is disturbed by something (external force). The two statements are together called Newton's first law. It is sometimes called the law of **inertia**. Inertia is the property of an object to resist change.

2. **Newton's second law:** A moving object possess momentum. Newton's second law relates the change in momentum of an object to the force that causes the motion. This law states that the change in momentum in a unit time is equal to the force that produces the motion. In mathematical form it means.

$$F=\frac{\Delta m.v}{\Delta t}$$

or **F = m.a**

The symbol **m** is mass of the object, **a** is acceleration, **v** is velocity and **F** is the force.

3. **Newton's third law:** When two objects are in contact with each other, each object exerts a force on the other. The magnitude of the forces are equal, but their directions are opposite to one other. However, the two forces are acting on different objects. Hence the resultant force on either object is not necessarily zero. The two forces form what we call **action-reaction pair.** Thus Newton's third law is sometimes stated as follows: "For every action there is an equal and opposite reaction".